BALTIC SEA ENVIRONMENT PROCEEDINGS

No. 14

SEMINAR ON REVIEW OF PROGRESS MADE IN WATER PROTECTION MEASURES

17-21 October 1983
Espoo, Finland

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PREFACE

The Seminar on Progess in Water Protection Measures was convened by the Government of Finland at Hanasaari Cultural Centre, Espoo in October 1983 to review the available technology for protecting the Baltic Sea from pollution originating from land-based sources.

This seminar was the seventh in the series of seminars convened by the States parties to the Convention on the Protection of the Marine Environment of the Baltic Sea Area – the Helsinki Convention – to discuss in detail water pollution control technology and thus to contribute to the work of the Helsinki Commission.

The first of these seminars was held in 1976 in Finland. Denmark, Sweden, the Federal Republic of Germany, the Union of Soviet Socialist Republics and Poland orqanized in 1978, 1979, 1980 and 1982 seminars to elucidate various aspects of water protection measures.

The aim of this seventh seminar was to review the progress in water protection technology since the signing of the Helsinki Convention in 1974, to analyze the present state, and to give views of the future prospects.

Representatives of all the seven Contracting Parties to the Helsinki Convention attended the seminar, i.e. Denmark, Finland, the German Democratic Republic, the Federal Republic of Germany, Poland, Sweden and the Union of Soviet Socialist Republics.

The seminar provided a forum for dissemination of technical knowledge and open discussion on relevant problems. The national reports, technical papers, and written statements presented are compiled in this publication. These valuable documents and the expert knowledge of the participants contributed to the success of the seminar.

The conclusions drawn by the seminar (cf. page 2) were immediately presented to the Scientific-Technological Committee of the Helsinki Commission. The Committee noted the high value of the deliberations and resolved to take them into account in the planning of future activities aimed at protecting the Baltic Sea from pollution from land-based sources.

The deliberations of the seminar were further submitted by the Committee to the Helsinki Commission, which at its fifth meeting, held in March 1984 at ministerial level to commemorate the tenth anniversary of the signing of the Helsinki Convention, took note of the deliberations and stressed the importance of these seminars for the future work of the Commission in the field of science and technology.

The Helsinki Commission further decided to publish the proceedings of the seminar in the Baltic Sea Environment Proceedings series, the volume being jointly sponsored by the Commission and the Government of Finland.

The Advisory Board for the Marine Environment of Finland was responsible for the organization of the seminar. An executive committee was nominated by the Board for the purpose with Mr. Seppo Ruonala as chairman, Mr. Aaro Haverinen, Mr. Risto Kuusisto and Mr. Antti Soikkeli as members, Mr. Aarno Kavonius as adviser and Mr. Juhani Puolanne as secretary.

Mr. Juhani Puolanne and Ms. Mikaela Forsskåhl were responsible for the practical arrangements of the seminar and the technical editing of this publication.

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REPORT OF THE SEMINAR ON PROGRESS IN WATER PROTECTION MEASURES

The Seminar on Progress in Water Protection Measures was held in Finland at the Hanasaari Cultural Centre, Espoo, from 17 to 21 October 1983. The Seminar was the seventh in order in the series of seminars arranged by the Baltic Sea States in the framework of the Scientific-Technological cooperation under the Helsinki Commission. The aim of the Seminar was to

- review the progress in the field of water protection technology and measures in the Baltic Sea States after the signing of the Helsinki Convention and

- analyze the present state of water protection technology and its future development in order to advance the implementation of the Helsinki Convention.

Experts from Denmark, Finland, the German Democratic Republic, the Federal Republic of Germany, the Polish People's Republic, Sweden and the Union of Soviet Socialist Republics attended the Seminar.

The Seminar was opened by Mr. Holger Rotkirch, Assistant Director, Chairman of the Finnish Advisory Board for the Marine Environment. Mr. Lauri Tarasti, Secretary General of the Ministry of the Environment, presented an address of welcome. Professor Aarno Voipio, Executive Secretary of the Helsinki Commission, addressed the participants on behalf of the Commission.

Seven National Reports, eighteen technical papers and three back-ground papers were presented. The latest achievements in water protection technology were comprehensively reviewed. In addition to control strategies, evaluation of purification requirements, experience gained in wastewater treatment and new technology, also specific pollutants as well as airborne pollution were discussed.

The Seminar arrived at the following conclusions:

C o n c l u s i o n s

The years after the signing of the Helsinki Convention (1974) can be characterized as a period of increasing consciousness on water pollution problems. Legislation, administration and technology regarding water protection have been developed in many ways taking into account the Helsinki Convention and also other relevant international agreements. There has also been a clear progress towards more stringent water pollution control requirements. The requirements are continuously reviewed in order to meet the information offered by experts.

Considerable sums have been invested in water protection measures – an indication of growing effort towards the protection of the Baltic Sea. The measures already carried out have considerably reduced the discharges of pollutants despite the increase in population served by sewer systems and the growth in industrial production.

In municipal waste water treatment, biological or other treatment of equal efficiency, is applied generally. Phosphorus removal is widely practiced in several countries, while removal of nitrogen compounds has so far only a few full scale applications. Internal and external water pollution control measures have decreased the pollution load from the industry. This is true especially of some harmful substances, such as e.g. mercury, which has been succesfully diminished in discharges. The measures already carried out are encouraging and in the right direction, but not always sufficient.

The following trends further influencing water protection technology and measures as well as the pollution load introduced into the Baltic Sea can be observed:

- continuing urbanization in some Baltic Sea States

- rationalization and intensification of agriculture and forestry

- changing structure of industry.

Attention should be paid to municipal wastewater treatment with special emphasis on elimination of nutrients, to reductions in water use and to internal process modifications in industry that make external wastewater treatment feasible. As regards such external measures anaerobic treatment is of current interest for some industries. Pulp bleaching as a source of pollution requires high priority attention and the question was raised as to the necessity of bleaching to the present extent. Also the coordination of research resources should be focused upon.

More knowledge and research are required e.g. concerning

- stormwater equalization and treatment,

- input of nutrients from diffuse sources i.a. agriculture and forestry,

- pathways and environmental effects of harmful substances including persistant contaminants,

- importance of nitrogen compounds elimination.

The Seminar provided an important forum for dissemination of technical knowledge and open discussion on relevant problems, the acknowledgement of which is likely to provoke new research. The necessity of continuing the series of seminars on water protection technology in the framework of the Helsinki Convention was stressed upon. It was generally felt that in future work sectorial or branchwise approach should be considered.

OPENING OF THE SEMINAR

Holger Rotkirch
Assisstant Director, Chairman of the Advisory Board for the Marine Environment
Finland

Water is an absolute prerequisite for life. Freshwater, the basic necessity of human life, forms only 0.8 per cent of the total water reasources in the world. An unknown part of this freshwater supply is polluted. Contaminated water together with insanitary living conditions constitute the main cause for diseases in the Third World. In 1981 the United Nations General Assembly declared the following ten-year period the International Drinking Water Supply and Sanitation Decade. One of its basic goals is to ensure safe drinking water and sanitation for all people by the year 1990.

Contamination of freshwater is, however, not only a problem for developing countries. Recently growing concern on the quality of freshwater has also arisen in Europe. The reason is the increasing threat of contamination of groundwater.

The task of this seminar on Progress in Water Protection Measures is not to secure the supply of safe freshwater but to review available technology in protecting the Baltic Sea from pollution originating from land-based sources. However, also in this context we should keep in mind the necessity of water protection in a comprehensive manner for the well-being of the peoples in the Baltic Sea States. I would like to emphasize the importance of the work carried out by each of you who participate in this Seminar – in protecting the perhaps most basic need of man, water.

The common concern of all the States bordering the Baltic Sea for the health of 'our' sea led to the Convention on the Protection of the Marine Environment of the Baltic Sea Area – the Helsinki Convention. All the seven Baltic Sea States are Parties to the Convention. According to the Convention the Baltic Sea States shall individually or jointly take all appropriate measures in order to prevent and abate pollution and to protect and enhance the marine environment of the Baltic Sea Area.

The convention entered into force in May 1980. The Helsinki Commission, established by the Convention, was immediately convened to its first meeting which was held at a ministerial level. The Commission was preceded by the Interim Commission which was constituted in 1974. To commemorate the tenth anniversary of the signing of the Helsinki Convention the forthcoming 5th Meeting of the Helsinki Commission in March 1984 will again be held at a ministerial level.

To advance the work done within the Helsinki Commission and its predecessor, the Interim Commission, each of the seven Baltic Sea States has since 1976 organized seminars, workshops and symposia on matters pertinent to the Convention and its implementation.

The aim of the series of seminars on water protection technology has been to gather information and material on measures aimed at diminishing discharges into the Baltic Sea. These seminars provide valuable background information for the Helsinki Commission in preparing recommendations for the limitation of discharges of various harmful substances from land-based sources. These recommendations are prepared within the Scientific-Technological Committee of the Helsinki Commission as well as within a special group of experts. Information on discharges and the occurrence in the marine environment of various harmful substances has been collected on a lead country basis. This information is further evaluated and processed in order to find common criteria for reducing discharges of these substances and their occurrence in the marine environment.

The seminars on water protection measures form a forum for exchanging basic information on the present state of water protection technology, the possibilities for its development and its effect on the reduction of the pollution load on the Baltic Sea. It is also important to review legislation, administration models and water protection requirements in the different Baltic Sea States. Valuable ideas might thus emerge for the development of water protection policy on the national level as well as within the Helsinki Commission.

The seminars are further necessary as a means of acquainting the participating experts with the development of technological methods. The seminars also provide a possibility for informal discussions and the exchange of ideas.

A water protection seminar similar to this one was arranged in Finland in 1976. The date of that seminar held seven years ago in these same premises coincides precisely with that of the present seminar. This might be seen as a good omen. That seminar was the first of the series of seminars on water protection technology arranged within the framework of the Helsinki Convention and it discussed the development of water protection technology in the Baltic Sea Area until 1976.

When Finland in 1981 presented the idea for arranging this 'review seminar' on water protection the goals of the seminar had already been defined. Taking also into account the forthcoming tenth anniversary meeting of the Helsinki Commission in 1984, the aim of the present seminar is

- on the one hand to review the progress in the field of water protection technology during 1974-1983 since the first seminar and the resulting reduction of the pollution load, and

- on the other hand to analyze the present state of water protection technology and its future development in order to reduce the pollution load of the Baltic Sea.

We can thus hope that the seminar will review the achievements so far, as well as give impulses and open new prospects in the field of water protection technology for the next decade of the Helsinki Commission. The goals of the seminar have therefore been set rather high. We hope that this seminar will produce summaries of the present development of water protection technology and the resources provided for water protection, which can be of use for the Commission's tenth anniversary meeting.

The other task of the seminar – to analyze the present state of water protection technology and its future development – will hopefully produce knowledge which can form the basis for defining the goals and possibilities of water protection in the Baltic Sea Area.

The organizer of this seminar, the Finnish Advisory Board for the Marine Environment, highly values the work to be undertaken this week by experts of the

Baltic Sea States. Therefore representatives of the Finnish administration and industry have been invited to follow the seminar. This explains the somewhat more numerous participation than usual.

I would like to conclude by wishing the distinguished experts of the other Baltic Sea States a most pleasant stay in Finland and all the participating experts every success in your valuable efforts for the protection of the Baltic Sea. With these words, I bid all of you most heartily welcome and declare the seminar opened.

ADDRESS OF WELCOME

Lauri Tarasti
Secretary General at the Ministry of the Environment
Finland

Ladies and Gentlemen,

Soon a decade has passed since the signing of the Helsinki Convention. Those ten years have been a period of upheaval and transformation in many respects. The world has been aroused to awareness of the fact that the natural resources on which our prosperity is based are not inexhaustible – and in some cases very limited indeed. This observation has affected each and every one of us and impelled measures to use alternative forms of energy. More attention has been focused on renewable sources of energy, energy savings and recycling of wastes.

Environmental protection has also undergone a complete transformation in the past decade. It has become a key factor in all activities that influence the delicate balance between Man and Nature.

Water pollution control is a good example of the development that has occurred in environmental protection in Finland. At the beginning of the 1970s, a building programme for municipal sewage treatment plants was well under way. As more information about the eutrophying effects of nutrients on our shallow and ecologically vulnerable water bodies became available, phosphorus reduction was also included in water pollution control measures. Today, we have arrived at a point where we have to turn our attention also to toxic and other harmful substances. And we do not even know yet all the effects of these substances. As soon as we have managed to limit the detrimental effects of one substance by prohibiting its use, it is replaced by several substitutes which may in turn prove to be toxic themselves.

Environmental protection knows no national frontiers, as the substances that pollute the water and the air travel freely over geographical boundaries. Thus international co-operation is a natural starting point in developing environmental protection. International co-operation, and joint international research in particular, can help to speed up the development of environmental protection measures. It can also help to standardize environmental protection measures in such a way that the benefit gained accrues to all parties concerned at moderate cost. Indeed, international co-operation in this field is based on the common interests of those involved. As in the case of the Helsinki Convention, it also often covers a particular geographical region. The Convention is based both on common environmental protection problems and on a defined geographical region. Thus the prospects for successful co-operation are exceptionally good.

All of the countries bordering the Baltic Sea have always depended on the sea as a means of transport. It has also provided a recreational amenity and a source of food. Thus the interests of these countries fully coincide. Joint measures have been taken by these countries, in the frame of the Helsinki Convention, to counter the many forms of pollution that are affecting the Baltic Sea, perhaps irreversably.

The past ten years have been important *from* the viewpoint of the Baltic Sea. That period may form only a moment in the lifetime of the sea. It is an important moment nevertheless, because the decisions taken and still to be taken will have a decisive effect on the health of the Baltic Sea for many decades ahead. After the signing of the Helsinki Convention, the countries around the sea have consolidated their efforts to protect it. This consolidation phase does not represent a pause, but rather a new basis for future efforts for the protection of the Baltic Sea.

You have gathered here at Hanasaari as representatives and experts of the States Parties to the Helsinki Convention to assess the development of water pollution control technology and to discuss relevant measures in reducing the pollution load on the Baltic Sea. Another aim is to consider the opportunities that exist for further developing water pollution control technology and applying it in practice. Everything indicates that our joint efforts have yielded good results, but that a lot still remains to be done in the decades ahead.

On behalf of Finland's newly-established Ministry of the Environment, I wish to emphasize our firm commitment to develop protection of the Baltic marine environment in every possible way. I would like to welcome you, on behalf of the Government of Finland, to this seminar and to wish you every success in *your* work and a pleasant stay in our country.

ADDRESS

Aarno Voipio
Executive Secretary of the Helsinki Commission

Mr. Chairman, Ladies and Gentlemen,

This seminar on progress in water protection measures will to my understanding not only summarize and review the progress made in this field since the signing of the Convention but is also an outset for the new phase in the work of the Helsinki Commission.

The earlier phases which are the preparative phase before the signing of the Commission, the Interim Commission period and the commencing of the regular work of the Helsinki Commission, have more or less been concluded. We must now look at the future, focus our attention to the evidently lengthy discussions on how fast the goals of the Convention regarding the land-based pollution can be implemented taking into account the practical possibilities within the seven Contracting Parties.

Naturally it is also necessary to summarize the past achievements in order to find out which lessons have been learned.

Personally, I have no competence to deal with the lessons learned about water protection technology. I am, therefore, looking forward to the results of this seminar: what is feasible to do using the present know-how and how the research and development work should be designed to improve the fulfilment of the goals of the Convention.

Having a marine scientific background I, however, would like to pinpoint the outcome of the Assessment of the Effects of Pollution on the Natural Resources of the Baltic Sea, 1980, as well as the subsequent scientific results.

In a nutshell, the contents of hazardous substances in the various compartments of the Baltic Sea show delighting negative - or should I say-positive - trends, anyhow decreasing trends thus encouraging the continuation of the efforts of the Contracting Parties.

At the same time no clear improvement in the contents of noxious substances listed in Annex II of the Helsinki Convention has been recorded excluding perhaps mercury. On the contrary, the only so far proved trend has been an increase of phosphorus compounds in the surface waters of the open Baltic Sea.

Remembering again my background as scientist I have also to remind that no generally agreed opinion regarding the reasons to the trend mentioned has been found. We are still asking to what extent the increase in the phosphorus contents is caused by the activities of man and which is the role of natural changes.

However, we all have to admit one fact: The Commission has not yet seriously discussed the joint guidelines on how to reduce the nutrient discharges into the Baltic Sea in spite of the fact that some countries have carried out very effective measures to that end or are in process to construct efficient purification plants.

The present joint activities regarding the implementation of Article 6 and Annex II of the Convention comprise the elaboration of guidelines for the discharge reduction of some substances to which high priority is given. They are mercury, cadmium, lead, copper, zinc and oil. As most of you will know, some concrete proposals, that is, draft HELCOM Recommendations, will be considered already next week by the Scientific-Techological Committee.

The progress with these high-priority substances has after all been rather slow. As far as I understand, it is not caused only by the limited knowledge on dose/effect relations but also by the demand of additional technological know-how, at least on economically feasible measures to reduce the input of high priority substances into the Baltic Sea Area.

The Commission instructed the Executive Secretary to draft a Medium-Term Plan for the Commission to be considered at the Review Meeting of the Commission next year. In my proposal I have made a suggestion which, to my mind, is an important step forward if the Commission is ready to accept it. Again in a nutshell, the high priority status within the Annex II substances should also be given to nutrients and oxygen consuming substances, that is, to the domestic sewage and waste waters from pulp and paper industry. I know that there are quite many persons who would be ready to go still further and are expecting a concrete schedule for measures. However, I personally feel that further steps can be planned only after reaching a concensus in this important principle.

In any case, I can foresee that the implementation of this potential decision will need much technological expertise to design the quidelines for reduction of the input of substance groups mentioned. I hope that this seminar could, among others, contribute also to this end.

Mr. Chairman, let me once more thank you and through you the organizers for the kind invitation to give an address at this important meeting and let me wish every success for the Seminar on Progress in Water Protection Measures.

Thank you, Mr. Chairman.

THE CO-OPERATION WITHIN THE HELSINKI CONVENTION FROM THE STANDPOINT OF THE SCIENTIFIC-TECHNOLOGICAL COMMITTEE

Lars G. Thorell
National Environment Protection Board
Sweden

Already at the beginning of the Convention on the Protection of the Marine Environment of the Baltic Sea Area the importance of scientific and technological co-operation in the protection and enhancement of the marine environment of the Baltic Sea Area is noted, particularly between the Contracting Parties.

The Contracting Parties shall take all appropriate measures to control and as far as possible limit land-based pollution of the Baltic Sea Area.

The Contracting Parties undertake directly, or when appropriate through competent regional or other organizations to co-operate in the field of science, technology and other research and to exchange data as well as other scientific information.

The Scientific-Technological Committee (STC) is advisory to the Commission and its terms of reference are shortly to advise the commission to

- collect and review scientific and technological data and knowledge and to promote the exchange of information

- elaborate and periodically review co-operative monitoring programmes

- elaborate methods, models and techniques, taking into account the need for intercalibration and standardization

- elaborate criteria and standards for the abatement of land-based pollution.

The STC (earlier STWG) has in different ways tried to fulfil1 its duties. Within the framework of the activity of the STC these has e.g been arranged and carried out

- seminars
- monitoring programmes
- assessment of the pollution effects
- compilation of pollution discharges
- intercalibrations
- bibliographies

The seminars have mainly concentrated on fields of special importance to the protection of the Baltic Sea Area. The exchange of information has enhanced the general knowledge within the fields discussed, but above all a better understanding of the water protection problems and water protection policies of the participating countries have been achieved. The information spread at the seminars has generally not been purposefully utilized in the work of the STC.

The work on the monitoring-programme for the Baltic Sea is in its first stage. The participating countries have co-ordinated their efforts and divided the sampling work between the countries concerned. The Baltic Sea States also agree on which parameters to measure and which methods to use. In this work there has been a comprehensive co-operation mainly with the International Council for the Exploration of the Sea (ICES), the Baltic

Marine Biologists (BMB) and the Baltic Oceanographers (CBO). Evidently a great deal of the work has been done within the framework of the Convention, such as intercalibration exercises and the preparation of the monitoring programme.

The co-operation on the programme now works excellently. The main goal of the first stage is therefore fulfilled, that is to co-ordinate the sampling of the participating countries, and to agree on suitable research and analytical methods.

However, it is now essential to realize that it will take long time before the programme shows any evident trends in the pollution status of the Baltic Sea. And it will take even longer time before the results from the monitoring programme will give indication on measures to take to improve the marine environment of the Baltic Sea.

The STC has at present two working groups:

- an ad hoc Working Group on Criteria and Standards for Discharges of Harmful Substances into the Baltic Sea (WGS).

- an ad hoc group of Experts on Assessment of the State of the Marine Environment of the Baltic Sea (GEA).

The main issues of the WGS are substances of highest priority and estimates of the amounts discharged into the Baltic Sea. Substances of highest priority are

- DDT
- PCB's and PCT's
- mercury
- cadmium
- lead

- copper
- zinc
- oil

The work with these substances is organized according to the "lead country"-principle and the main goal is to demonstrate the effects of the substances in the environment, and to find possible ways to reduce discharges of these substances to the environment.

The discharges into the Baltic Sea from each country shall be reported annually. The discharges from industries, municipal sewage treatment plants, water courses and atmospheric deposition shall be compiled. Due to the difficulties in each country to obtain all necessary information the compilation has so far covered organic material, phosphorus and nitrogen. To be able to succeed in a relatively accurate estimate of the total pollution load to the Baltic Sea, essentially more resources and engagement are required.

The principal duty of GEA is to make an assessment of the state of the marine environment of the Baltic Sea. The work will be based upon, and be a follow-up of the assessment made in 1981 and which is estimated to be ready in 1986.

The principal duty of STC is to give advice to the commission (HELCOM).

The most important advice, which HELCOM has accepted and developed to recommendations are:

1. Limitation of the use of PCB
2. Elimination of discharges of DDT
3. Protection of seals in the Baltic Sea Area
4. Amendment of PCT´s to Annex 1

In 1981 the Commission made a recommendation in regard to the "assessment of the effects of pollution on the natural resources of the Baltic Sea". The Baltic Sea States should observe the results from this assessment when taking measures to minimize the pollution of the Baltic Sea. The recommendation is so generally formulated, that it seems difficult to know how to fulfil the recommendation.

By the review of the work of the Commission which will take place on account of its 10th anniversary the effects of the recommendations in the Baltic Sea States will hopefully be assessed.

Has the work, so far performed, to minimize the pollution from land-based sources been sufficient? No, that can hardly be stated, because many pollution problems still remain. Have any results been achieved? Yes, especially for hazardous substances, which have been given high priority DDT and PCB. Surveys show that the limitations on DDT and PCB have had intended effects. These substances have diminished in the organisms in the Baltic Sea, so the trend is positive, even if harmful effects still remain.

Regarding other hazardous substances, such as mercury, cadmium, lead, copper, zinc and oil comprehensive work is going on in the individual countries to find solutions to minimize the discharges. For example discharges of mercury have diminished, so that several areas earlier blacklisted due to high mercury content in fish no longer are blacklisted.

How is the work to be performed in the future7 It is important that the work on substances with high priority continues and to a larger extent is directed towards various kinds of technical measures to minimize discharges both from point sources and diffuse sources. This work ought to be supplemented by more general measures to minimize pollution taken within various important fields such as agriculture, urban areas and heavy industries.

Considering the costs involved in environmental protection measures, but also considering the environmental protection effects it is important to give the right priority to the measures. In the continous work of the STC it is therefore important to get a better understanding in several fields:

- the technological knowledge of which measures to take in industries, municipalities, agriculture etc to minimize pollution discharges ought to be developed

- the control and estimates of the amounts of pollution ought to be imporoved

- the effects of the discharges in the coastal areas ought to be studied and assessed together with

- monitoring programme of the Baltic Sea, which ought to be developed so as to give information on pollution important to reduce, and in that way influence which measures to take at first hand to improve the marine environment of the Baltic Sea.

To be able to perform a long-term meaningful environment protection work in the Baltic Sea, it is important that great interest and sufficient resources are given to all these fields.

Even now there is, however, comprehensive knowledge of which measures to take to minimize the pollution discharges from many different kinds of activities. For the STC it would be very valuable to get proposals from this seminar for concrete measures to reduce pollution to the Baltic Sea.

ASSESSMENT OF THE STATE OF THE BALTIC SEA *)

Terttu Melvasalo
Ministry of the Environment
Finland

1. ABSTRACT

An attempt was made to identify changes in the Baltic marine environment and their causes on the basis of whether such changes could be attributed to natural causes alone: partly natural causes and partly due to human activities: and wholly due to human activities. The changes which are considered to be due to natural causes alone are the increases in temperature and salinity in the deep and bottom waters of the Baltic Sea. Several changes identified for which doubt exist as to whether they can be attributed to natural causes, anthropogenic influences or both. One of them is the decrease of oxygen content of the bottom water of the Baltic Sea. Another change observed attributed to mixed causes is the increase of phosphate concentrations. Finally, the changes which can clearly be attributable to human activities are those in toxic or harmful synthetic organic chemicals (e.g. PCBs, DDT, chlorinated terpenes, PCTs) and organic wastes, which are not natural in origin (e.g. lignin sulfonates), as well as for increasing the amounts of certain natural substances (e.g. nutrients, trace elements, and hydrocarbons) in the marine environment. The most serious effects on biota from these substances have been attributed to the organochlorines, DDT and, especially, PCBs. Oil

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*) This paper has been printed in the journal Aqua Fennica 14,1:15-20 (1984).

spills have also had considerable effects on certain of the areas where they have occurred, depending on the location of the spill and the time of the year. Additionally, the contamination by mercury is still very serious in many coastal water areas.

2. INTRODUCTION

The most pessimistic forecasts predict a catastrophe in the Baltic Sea at the end of the millenium. Others think there might yet be some 30 years left. These predictions, however, have not been made by the scientists who have participated in the marine research carried out on the basis of the Convention on the Protection of the Marine Environment of the Baltic Sea Area (The Helsinki Convention). These scientists know that information on, and conclusions derived from the coordinated research on the Baltic Sea will certainly be brought to the attention of the State authorities, who decide on steps and measures affecting the Baltic Sea. The authorities deciding on the use of various technological measures are in a key position. Information on the development of the state of the Baltic Sea should be applied, when possible errors are corrected or preventive measures taken against the pollution of the Baltic Sea.

In this paper I intend to present a summary of the state of the Baltic Sea based upon the information gathered by the scientists in the different fields of the Baltic marine research (Melvasalo et al. 1981). This information has served as a basis for the joint conclusions on the state of the Baltic Sea and on the development of the condition of the sea within the framework of the Helsinki Convention.

In addition, an assessment of the importance of human activities on such changes which have been observed in the Baltic Sea have been made.

3. ON THE OXYGEN DEPLETION IN THE DEEP BASINS OF THE BALTIC SEA

When speaking of the depletion of oxygen in the Baltic Sea we mean a deficiency of oxygen in such areas and such depths as remain beneath the permanent halocline. Those are the basins where water renewal in the layers nearest to the sea-bed is slow and/or occasional. The organic material produced in the euphotic layer sinks down to the sea-bed and is degradated. In this process, nitrogen and phosphorus nutrients are released, and oxygen is consumed. The result is that the oxygen content of the stagnated water decreases.

Where there is a lack of oxygen, toxic hydrogen sulphide is generated. As a result there are so-called dead deep basins. The maximum value of such dead bottoms was estimated to be 100 000 km^2 in 1975. Thereafter, it has been possible to observe recolonization by fauna of such area in some deep basins (Table 1).

Table 1. Decrease in oxygen concentrations at stations in some Baltic basins. (Matthäus 1978, 1979, in Melvasalo et al. 1981, p. 144)

Basin and station	Depth (m)	ΔO_2 (cm^3/dm^3) 1900-197s	1952-1974
Arkona Basin	45	-0.76	
Bornholm Basin	80	-2.33	-0.75
Gdansk Basin	100	-2.02	-1.18
Eastern Gotland Basin			
BY 9	100	-2.43	
BY 15	100	-3.33	-1.13
	150	-3.05	-0.95
	200	-2.69	-1.44
BY 20	100	-3.51	-1.03
	150	-2.54	-0.42
Northern Central Basin			
BY 28	100	-3.27	-1.44
	150	-2.99	-1.36
BY 31	100	-3.08	-1.28
	150	-3.10	-1.25
	200	-2.93	-1.31
	300	-3.06	-1.31
	400	-2.87	-1.19
Western Gotland Basin			
BY 32	100	-4.06	
	150	-4.37	
BY 38	100	-3.66	-1.68

The variations in the quantitites of water with higher salinity, entering the Baltic Sea through the Danish Sounds seem to be the main cause of the variations in oxygen and hydrogen sulphide in the deep basins. Now and then the pulsating of heavy saline water, rich in oxygen, renews the water stagnating in the basins. A new body of water is now transferred from one basin to the other. Whether all layers of the waters near the sea-bed are replaced in the deep basins or only some of them, depends on the quantity and density of the waters penetrating into the Baltic. Often the water in the deep basins is more dense than the new water pressing into these basins, and in these cases the entire body of the waters near the sea-bed is not replaced. In the most important research area, the Gotland basin (240 m), there have occurred 21 new water impulses in 1954-1979. Since 1957, there have occurred eight periods of stagnation, which means that all oxygen is used up and hydrogen sulphide developed.

The Gulf of Finland is part of the Northern Baltic Proper. The changes taking place in the Baltic Sea proper are reflected here. On the other hand, the Gulf of Bothnia is separated from the Baltic Sea proper by low thresholds south of Åland. Therefore deep water from the Baltic proper does not penetrate into the Gulf of Bothnia. Permanent salinity stratification is not generated there either, and the vertical mixing conditions remain favourable. Oxygen depletions, consequently do not occur near the bottom. Only in coastal areas especially in the archipelago, where the water convection is prevented, harmful oxygen depletions can be observed. The main reason is the too heavy load of pollutants for the tolerance of the water.

From the beginning of the century, the oxygen contents of the Baltic Sea have decreased in the deep basins from 3 to 0 cm^3/dm^3. The studies of sediments show, however, that hydrogen sulphide periods often occurred in the Baltic Sea as early as several centuries ago. The decrease of oxygen in this century is connected with two great pulses of saline water, the first occurring during the First World War and the second in 1951.

It has been suggested that an essential reason for the alternation of oxygen and hydrogen sulphide lies in nature's own rythm, which significantly depends on geophysical and meteorological factors. However, the results do not make the Baltic Sea States free from their responsibility upon the pollution of the Baltic Sea. However, the pollutants discharged into the Baltic Sea are an important factor influencing on how soon the sea will recover the stagnation periods and how long a new period will last. In addition, the occurrence of the natural rythm of alteration periods in the Baltic Sea depends on the development of the pollution load into the water.

Even if what is said above gives quite a favourable interpretation of the oxygen balance of the Baltic Sea, it does not obtain it for the coastal waters. In the coastal waters off most important municipalities and industrial plants, the oxygen contents of those layers nearest to the sea-bed are diminished to an alarming degree, or at least there are periods when such a situation prevails. One gets the impression that the coastal waters, and in particular, the large archipelago serve as a sieve, a filter retaining the major part of the pollution load discharged to the coastal waters. Contrary to what is the case in the open Baltic Sea, the cause of the diminishing of oxygen or oxygen deficiency in the coastal waters can with few exception be traced to human activities, directly or indirectly to the increased load of pollutants. In this way, the coastal waters serve to purify the Baltic marine environment from oxygen consuming substances.

4. PHOSPHORUS AND NITROGEN COMPOUNDS AND THE PRODUCTION

During the last decade, phosphorus and nitrogen discharged into the sea or ending up there have risen, in spite of more effective measures for purification of sewage and waste water. The increasing use of fertilizer, extension of the sewage disposal system and even the load imposed on the sea from the air are of great concern to the scientists. Even if, the load imposed by airborne pollution is not taken into account, the annual net load of phosphorus in the Baltic Sea is assessed at 26.000 tons. This is about 6 . ..8 per cent of the phosphate-phosphorus quantity in the depths of the Baltic Sea (Table 2).

Table 2. Mass balance of phosphorus in the Baltic Sea. (Melvasalo et al. 1981, p. 167)

Input	Phosphorus W Y)
Domestic and industrial wasters	33 000
Dumping	0
Atmospheric fallout	9 000
Danish Straits	10 000
Natural river input	3 000
Ship-generated wastes	?
Release from sediments	7 000
Sum	62 000
output	Phosphorus W Y)
Danish Straits	10 000
Sedimentation	22 000
Fisheries	4 000
Aerosols	0
Sum	36 000
Net Supply	26 000

4.1 LONG-TERM MONITORING RESULTS

Long-term monitoring results show the phosphorus contents of the **sea** increasing. Moreover, it has been stated that there is a close correlation between phosphate and salinity and also between nitrate and salinity. This might mean that at least part of the increase of phosphorus is connected with long-time hydrographic changes in the Baltic Sea. To what extent, the eutrophication caused by human activities is responsible for the increase of phosphorus in the deep basins of the Baltic Sea is open.

The increase in the concentration of nutrients has caused an increased production of algae, a phenomenon well-known in the coastal areas. As for the open sea, it has not been possible indisputably to prove an increase of production with the research methods at our disposal, even if we do possess results which seem to point in this direction.

4.2 ON THE ALTERATION OF THE PRODUCTION OF THE ALGAE

In certain coastal areas, directly bordering on the open sea, the production of filamentous and epiphytic algae has substantially increased in the nineteen-seventies. Indirectly this has led to local disappearance of the bladder-wrack, *Fucus vesiculosus*. In the eighties, however, signs of a reversal of this trend have been observed.

A typical phenomenon, of the Baltic Sea, is the blooms of the blue-green algae in late summer. This phenomenon is caused by rising phosphorus contents of the water and the imbalance between nitrogen and phosphorus as compared to the actual need of the plants. So far, we have not scientifically proved results of expanse and possible increase of this phenomenon. On the other hand, there are experienced scientists, well-aquaintained with the conditions in the open sea, who say that such an increase is obvious. Arithmetically this theory is supported by the fact of the annually increasing load of phosphorus. This kind of blue-green algae have the capacity, unparallelled by other algae, to exist by utilizing water-soluble molecular nitrogen. When algae disintegrates, this nitrogen is released in the form of nitrogen compounds, which can be used by other algae.

4.3 ON THE IMPORTANCE OF NITROGEN

In connection with the N_2-fixation by blue-green algae nitrogen has been released in the biologic cycle and the nitrogen load of the Baltic Sea has risen again. The amount of nitrogen fixed in this manner has been estimated at 100 000 tons nitrogen per year for the Northern Baltic Proper and the Gulf of Finland. This figure is of the same magnitude as the land-based nitrogen load introduced into the marine environment. Consequently, the sole addition of phosphorus - since molecular nitrogen is available in unlimited quantities - is sufficient to create conditions favourable for the development of the blue-green algae and, consequently, for the increase of the nitrogen load of the Baltic Sea. In this manner, the phosphorus load can regulate the algal production in the sea.

When making observations on the primary production in the coastal waters in recent years, an answer has been sought to the question, whether purification of sewage and waste waters should also comprise the elimination of nitrogen as well as phosphorus, and whether the result of this will be increased production of algae, as described above. However, in the light of research results now at our disposal, it does not seem probable that this will happen. On the other hand, a heavy nitrogen load has clearly a harmful influence on the balance of nutrients in the coastal waters. Consequently, the problem will probably be one of finding an effective and economic purification technology and its implementation at our disposal.

5. HEAVY METALS

Heavy metals have become a problem for the environment research in all countries. Owing to difficulties of analysis, no reliable information is as yet available on annual fluctuations as measured in the sea water itself.

However, by analysis of sediments deposited in the deep basins, it has been proved that the heavy metal findings can be classified in three groups. To the first group belong for instance, nickel and chrome. No variations were found in the concentrations of these metals even during long periods. In the second group we include metals, whose concentrations have risen about 1.5...2 times, such as zinc and lead. In the third group we find metals whose concentrations more than tenfold exeed the basic values. Such metals are mercury and cadmium. The last concentrations are exceedingly high ones, especially compared with those found in sediments of the ocean deep basins.

Heavy metal concentrations have been measured in organisms living in the Baltic Sea for a short time, only. Therefore, we have no long-time comparison results at our disposal, so far. However, some scientists have lately discussed on the decrease of mercury concentrations in fishes.

6. CHLORINATED HYDROCARBONS

In addition to heavy metals, chlorinated hydrocarbons, i.e. the pesticide DDT, formerly used in the agriculture and forestry, and PCBs, still in use in certain branches of industries, have been investigated. Besides direct discharges, these substances have been found to spread through the air as well. It has been shown that they are involved in the rapid decline of the breeding capacity of the Baltic seal (PCB), and the drastic thinning of the shells of the eggs of certain predators, such as the white-tailed eagle, razorbills and certain guillemots (DDT), which prevents the normal development of the young birds from such eggs. After the Baltic Sea States had prohibited the use of DDT, reduced DDT contents in certain fishes and seals have been reported upon.

The feeding of predator birds which has been introduced in certain regions has also had a beneficial influence and caused a decrease of DDT contents in the birds. As for PCB substances, such a positive development has not yet been observed.

7. NEW HARMFUL SUBSTANCES IN THE FIELD OF RESEARCH

New causes of concern for the Baltic scientists are new harmful substances in the marine environment. Reports on such substances are coming in from abroad, and therefore we have begun to investigate them. There is, for instance, the PCT group (polychlorinated terphenils), which recently were recommended for the classification among the most hazardous substances, also among those enumerated in the Helsinki Convention. Other "new" harmful and accumulating substances - the occurrence of which in organisms in the Baltic Sea is the subject of research nowadays - are chlorinated terpenes, halogenated paraffins and chlordans.

A new subject of research in the Baltic and North Sea countries are various anomalies in fishes as well as genetically induced diseases which may be connected with the occurrence of various harmful substances.

When investigating the consequences of oil spills and oil accidents, it has been found that they depend to a significant degree on the place where the incident occurred and on the time of the year. The greatest damage has been suffered by the bird populations and the populations of organisms living in the vicinity of the coast and the sea-bed. In the open sea proper, the consequences of oil accidents soon disappear, while the recovery of the sea-bed populations takes several years.

In addition to the toxic chemicals listed above, we have a long range of chemicals used by the industry, or such as are generated as secondary products of the industry, which with good reason can be supposed to be harmful to marine life in the Baltic Sea. However, the research needs more time in this field. One matter on which we have no long-term research is radioactive isotopes.

Great concern is moreover felt over the waste water discharged into the sea by the wood-processing industry. In addition to local pollution, it has been found that certain substances, as for instances the lignin sulfonates, have spread over the whole Baltic Sea as a result of the activities of this industry. Even if, it is still impossible to give a detailed description of the damage caused, this is a good example of the "infestation" of the whole Baltic Sea by foreign substances. The same can probably be said of the substances used for the bleaching process of the wood-processing industry.

a. HUMAN OPTIONS

The state of the Baltic Sea is a matter of concern to all neighbouring States, and this concern has grown so serious that the Convention on the Protection of the Marine Environment of the Baltic Sea (The Helsinki Convention) has been concluded. Both in the co-operation with each other and individually the Baltic Sea States have started important investigations and monitoring projects, and information on causes and consequences is being compiled. The prohibition of the use of DDT and mercury in most Baltic Sea States has already brought encouraging results in the decrease of the contents of these substances in the ecosystem of the Baltic Sea. Yet these good results fade into insignificance before the steadily growing number of causes for serious concern.

Do we really make the best use of the Helsinki Convention? This question is open to criticism. Are our limited means jointly and individually directed at the most important objects? Changes in the condition of the sea at certain points in time have been reported upon, and we have tried to clarify the causes with the help of such information as we have at our disposal. Researchers and investigators have been working and still do their best to place as accurate information as possible in the hands of the authorities and co-operating bodies.

However, from the point of view of the researcher, there is a very long distance between receiving pertinent information and arriving at conclusions and decisions to take the appropriate measures. And while this long process takes its course, dozens of new problems can appear with the old ones still waiting for solution. The strict limitation of our means can limit and delay information on what is really happening in the waters, in the organisms and the sea-bed of the Baltic Sea. But in those cases, where the necessary information is at hand and the necessary technological skills exist, there is, from the point of view of the Baltic Sea, one viable alternative only: Immediate action must be taken.

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CO-OPERATION IN THE FIELD OF WATER PROTECTION TECHNOLOGY

Aaro Haverinen
Ministry of Agriculture and Forestry
Finland

The first joint seminar in the field of water protection technology was arranged between the Baltic Sea States at the Hanasaari Cultural Centre in Espoo, Finland seven years ago in 1976.

That seminar and proceeding meetings of the Interim Baltic Marine Environment Protection Commission (the Interim Commission) and meetings of the Scientific-Technological Working Group had observed that there was no direct co-operation between the authorities responsible for the practical water protection measures and other experts on water protection technology of the Baltic Sea countries, whereas between the experts on marine research of the Baltic Sea such co-operation existed, the Baltic Oceanographers and the Baltic Marine Biologists having their contacts regularly, and the International Council for the Exploration of the Sea (the ICES) having a special group for research of the Baltic Sea. The Helsinki Convention had however, changed the situation and established the framework for the co-operation in the field of the water protection technology.

One of the main purposes of the first water protection technology seminar was to find out the forms of co-operation to be developed between the Baltic Sea States in this field. Considering it essential to strengthen the co-operation the seminar proposed to the Interim Commission, among other things to

- activate the arranging of seminars, expert meetings, courses, etc. for different problem areas in water protection technology

- draft a programme of seminars, expert meetings and other forms of co-operation in water protection technology

Co-operation in the field of water protection technology has been discussed at the meetings of the Helsinki Commission and its subsidiary committees and working groups. The following important aspects have been presented at these meetings:

- technological factors are essential in the implementation of the Helsinki Commission

- seminars in the field of water protection technology increase the exchange of information and intensify the co-operation: they provide an opportunity for the authorities responsible for water protection measures and the experts on protection technology to get together and to exchange ideas and experiences on mutual problems

- seminars should be arranged at regular intervals, perhaps once a year, on the average

- seminars are a valuable tool for the Helsinki Commission in finding out possible problem areas for the implementation of the Convention

One of the most significant consequences of these efforts to improve the co-operation was the decesion taken by the Commission soon after the first seminar on water protection technology to establish a special working group, the ad hoc

Working Group on Criteria and Standards for Discharges of Harmful Substances into the Baltic Sea Area. This ad hoc working group subordinated to the Scientific-Technological Working Group (later called Scientific-Technological Committee) has focused at the problems in water protection technology. In particular, the working group has prepared the ground for measures directed at decreasing the emission of harmful substances.

After the first seminar on water protection technology in 1976 seminars have been arranged once a year on the average. The following is a short review of the aims and achievements of the earlier seminars. The purpose of the review is to orient the participants of the present seminar.

The second seminar on water protection technology, "Seminar on Heavy Metals, Technology Methods for the Limitations of Discharges", was held in Kollekolle in Denmark in 1978. There were numerous profound papers presenting problems connected to discharges of heavy metals, their effects on the marine environment, and the know-how on the reduction methods of heavy metals discharges.

The third seminar was held in 1979 in Stockholm in Sweden. The title of the seminar was "Seminar on practical and municipal water protection measures in Sweden". The seminar was based on excursions. The participants visited different industries, municipalities, and their treatment plants to discuss and exchange information in situ. It was a practical and very useful contribution to the co-operation.

The fourth seminar on water protection technology was held in 1980 in Lübeck in the Federal Republic of Germany. Its name was "Seminar on Control

Techniques for Municipal and Industrial Sewage Treatment Plants". The seminar considered comprehensively the existing juridical regulations concerning conveying of waste waters, the requirements established by the permits and other regulations, as well as the control and analyzing of the waste waters and the instrumentation of the treatment plants. Parallel with the seminar an excursion to waste water treatment plants was arranged.

The next seminar, the fifth one, on water protection technology was held in 1982 in Tallinn in the Union of Soviet Socialist Republics. Its name was "Seminar on water protection in fish industry". The seminar reviewed many-sidedly matters related to effluents from fish industries and different possibilities of diminishing the pollution load. During the seminar it was also possible to visit certain fishery collective farms and to get acquainted with fish-processing and the treatment of wastes there. The pollution caused by fish breeding and the preventive measures to protect the water were also discussed.

The sixth seminar on water protection technology was also arranged in 1982. That was the International Helcom Seminar on Agricultural Utilization of Sewage. It was held in Wrocław in Poland. The seminar reviewed widely the utilization of waste water, waste water sludge and manure in agriculture and related technical, economical, environmental and health aspects.

The consideration above indicates that several interesting seminars on water protection measures have been arranged. Undoubtedly they have benefitted the activities that aim at improving water protection at a national level.

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On the other hand, there remain several problem areas, which have not yet been comprehensively reviewed at the joint seminars of the Baltic Sea States. Therefore such seminars should be arranged frequently, conscious of the problem areas.

The participants at the earlier seminars have emphasized the need for arranging seminars on the special problem areas of the water protection technology. Also lists of possible conversation items for the forthcoming seminars have been prepared. It is an advantage that the participants at these seminars officially or inofficially outside the agenda discuss the problems that could be focused upon at the forthcoming seminars. Perhaps also this seminar would like to propose in its report themes for the next seminars. Another point that the seminars have stressed is the need to familiarige larger groups of people and experts with these matters, not only the authorities responsible for the implementation of the Helsinki Convention.

The seminars on water protection technology are not implemented by the Helsinki Commission. They are arranged by the individual Baltic Sea States at their own initative in the framework of the Convention. Since the seminars do not derectly prepare the implementation of the Convention the discussions between the experts can and should be as open as possible in order to clarify the technological and economical possibilities.

I hope these considerations inspire you at this seminar to an open discussion and an exhange of knowledge related to the water protection technology applied in the Baltic Sea States.

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NATIONAL REPORT BY FINLAND: PROGRESS IN WATER PROTECTION MEASURES AND TECHNOLOGY DURING AND AFTER THE 1970'S

Runo Savisaari
National Board of Waters
Finland

1. INTRODUCTION

The past ten years, starting from the signing of the Helsinki Convention, can be characterised as a period of increasing consciousness of water pollution effects. This holds true for inland waters as well as for the Baltic Sea.

The progress in water pollution control measures and technology was very rapid during the first half of the 1970's. This was due to growing public concern over water pollution at the end of the 1960's and the consequent establishment of the National Board of Waters in 1970 as well as to strong economic growth before the oil crisis. During the latter half of the decade and the beginning of 1980's this progress halted to some extent, but today activities seem to be reviving again. Emphasis has been increasingly directed to the economics and reliability of water pollution control measures, waste management, air pollution problems and the presence of a number of persistent contaminants.

Due to a slight statistical lag the data presented here does not completely cover the ten years after the signing of the Helsinki Convention. However, the data do adequately reflect the progress in water protection measures and technology.

2. URBANISATION AND CHANGES IN THE STRUCTURE OF INDUSTRY AND AGRICULTURE

The pace of urbanisation has been constant over the past decades. It has continued into the 1970's but today has clearly slowed down, as illustrated in Table 1. Another important phenomenon is internal migration. In addition to growing urban centres, large numbers of people have moved from sparsely populated regions to local population centres, or villages, which is not shown in Table 1. As trade and services and other conveniences of modern society have spread to the countryside, people have today become more reluctant to move away from their roots (Table 2).

Table 1. Population in urban centres and rural areas in Finland (%).

Year	Cities and towns	Rural municipalities
1970	50.9	49.1
1972	55.0	45.0
1974	58.1	41.9
1976	59.0	41.0
1978	59.7	40.3
1980	59.8	40.2

Table 2. Direction of internal migration.

Year	Urban centres to u-ban municipalities	Urban centres to rural municipalities	Rural areas to urban municipalities	Rural areas to rural municipalities
1970	72 155	63 700	84 244	47 645
1975	89 703	57 615	61 666	30 555
1980	71 447	49 333	50 027	26 796
1981	70 065	49 334	48 098	26 350

The population served by public water works, sewer systems and wastewater treatment plants is illustrated in Fig. 1. Water consumption has developed along the following lines:

1970	308	l/person/day
1975	328	"
1980	297	"
1982	283	"

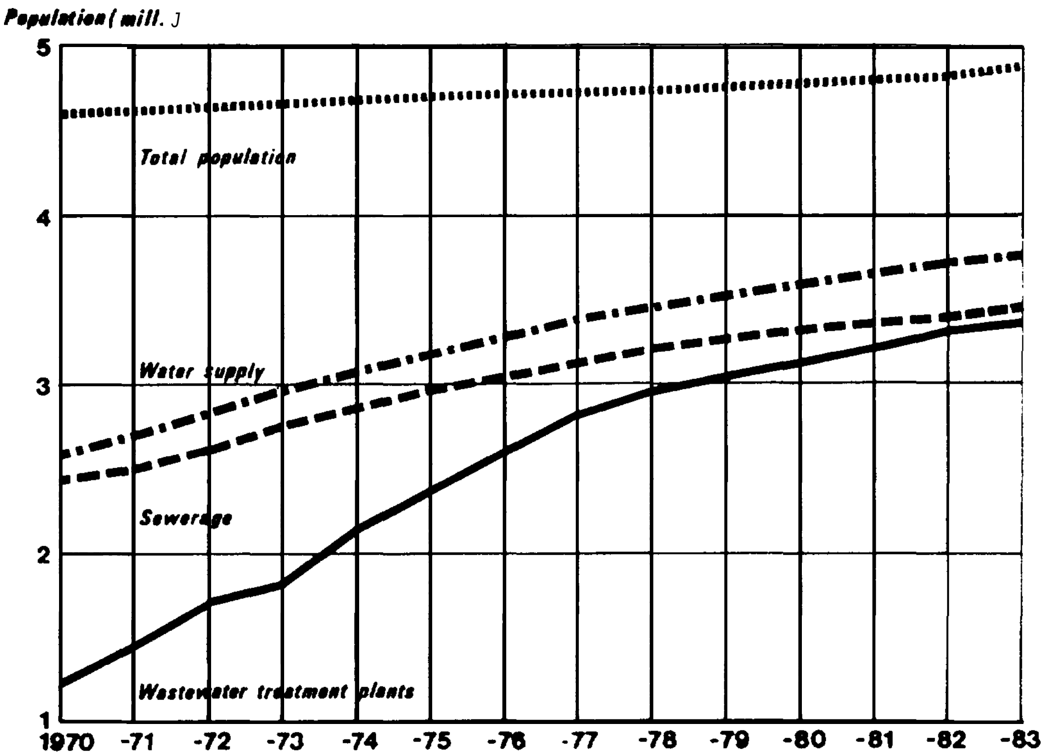

Fig. 1 Population served by public water works, sewer systems, and wastewater treatment plants

The sewage quantity and characteristics (influent to sewage works) show other trends which can be explained by hydrological phenomena as well as by the increasingly effective monitoring of overflows and by-passes (Table 3).

Table 3. Sewage quantity and characteristics.

Year	Flow (l/person/day)	Characteristics (g/person/day) BOD_7	Tot.P	Tot.N
1972	(335)	93.1	3.0	13.0
1975	406	95.0	3.6	15.6
1980	430	86.1	3.4	15.9
1982	460	87.9	3.6	16.4

Table 4 also clearly shows the trend of development, especially in the reduced number of people working in agriculture and forestry. As a results, an increase in the size of farms and a rationalisation of agricultural production have taken place (Tables 5-7). From the standpoint of water protection it is significant that the field area for hay silage has grown very rapidly from 52 200 hectares in 1970 to 244 100 ha in 1982. Respectively, the hog stock has increased by 50 % while the the number of pig farms has decreased by 70 8. The cattle stock has declined (by 10 %) along with the number of cattle farms (by 60 8). The expanding size of farms brings with it the growing potential for water pollution problems.

Table 4. Economically active population by industry (%).

Industry	1970	1975	1980
Agriculture and forestry	20.3	15.0	12.6
Manufacturing	25.9	27.2	26.3
Construction	8.3	8.5	7.1
Commerce and trade	18.9	19.3	19.1
Services	18.1	20.9	24.8
Other	8.5	9.1	9.1
Total 1 000 people	2119	2121	1984

Table 5. Number of farms according to arable area (ha).

Year	l-4.99	5-19.9	20-49.9	50-99.9	100-	Total ha
1969	108 806	179 812	20 625	1 620	292	297 257
1975	80 967	142 027	23 305	2 085	352	248 736
1980	69 444	125 978	26 346	2 566	387	224 721

Table 6. Use of arable land (1 000 ha)

Year	Cereals	Vegetables and root crops	Hay field	Other	Total
1970	1 197	87.4	1 171	212	2 667
1975	1 312	91.5	970	267	2 641
1980	1 171	76.9	951	364	2 563
1982	1 170	79.3	926	342	2 517

Table 7. Livestock (1 000 animals)

Year	Horses	Cattle	Pigs	Poultry	Sheep	Reindeer
1970	89.8	1 873	1 047	8 264	189	150
1975	38.2	1 843	1 078	8 669	124	156
1980	22.4	1 738	1 451	8 476	106	210
1982	20.3	1 705	1 505	6 913	104	208

Forest covers 30.5 mill. hectares of Finland, 74 % of which is highly productive. Forest fellings, given below, are an indicator of the economic activity:

1970	39 900	cu. m.
1975	29 300	"
1980	38 500	"

The load of nutriens to bodies of waster is partly dependent on the rate of fertilizer application. The quantities of mineral fertilizers used in agriculture and forestry were:

1970	1 058 mill. kg to agriculture,	184 000	ha of forest
1975		249 000	"
1980	1 126 "	87 000	"

Table 8 lists the estimated quantities of wastes which can be used directly or indirectly in agriculture and their corresponding current utilisation rate in agriculture.

Table 9 illustrate some aspects of industrial activity.

Table 8. Estimated currentwaste quantities in Finland.

Waste	Potential max quantity (m3/a)	Potential max quantity (tTS/a)	Current utilisation rate %
Decomposable household refuse	700 000		0
Human faeces			
-sewage sludge	930 000	130 000	40
-septic sludge	350 000	10 500	
-other faeces	350 000	26 000	
Animal wastes			
-totalquantity (incl. outdoor grazing)			
-manure	12 500 000	2 500 000	100
-urine	6400000	320 000	100
- proportion of above total production collected			
- manure	6400000	1 200 000	100
- urine	2 600 000	130 000	100
-liquid manure	3 500 000	350 000	100
Silage liquor	700 000	28 000	
Straw and tops	5000000		100
Organic wastes fran food proc.ind.	310 000		47
Other organic wastes		350 000	34
Pulp and paper industry sludges	300 000	75 000	35
Slag fran metal industry, etc.	1 400 000		52
Ash from power stations and sulphate liquor	830 000		25

Table 9. Index of industrial production (1970 = 100)

Year	Total	Investm. goods.	Consumers goods	Wood, pulp and paper	Metal ind.	Other manuf.ind.
1975	122	178	110	89	150	122
1980	155	242	138	133	185	145
1982	159	244	134	123	200	144

Fur and fish farming have increased dramatically in Finland in the 1970's, giving rise to serious concern about water pollution. While mink farming has only grown 1.5 fold from 1970 to 1982, fox farming has grown 30 fold compared to the 2 fold growth in the number of farms. The production of fish farms has risen from 1 800 tons in 1975 to 6 100 tons in 1982.

Gross domestic product has developed as shown in Table 10.

Table 10. Gross domestic product in 1975 prices (mill. FIM)

Year	Gross domestic product
1970	84 150
1972	92 160
1974	101 290
1976	102 140
1978	104 850
1980	119 630
1981	121 220

3. WATER PROTECTION ADMINISTRATION AND WATER PROTECTION REQUIREMENTS

3.1 WATER PROTECTION ADMINISTRATION

The administration of water protection is in principle based on three levels:

- water administration
- water courts
- municipal water boards

The national water authority in Finland is the National Board of Waters and its 13 Water District Offices. The National Board of Waters was founded in 1970 and was subordinated to the Ministry of Agriculture and and Forestry. In October 1983 the Ministry of the Environment was established. The new ministry has assumed responsibility for environmental protection, nature conservation, outdoor recreation, water protection, oil pollution, protection of the marine environment, assessment and control of environmental hazards from toxic substances and other chemicals, land use planning and matters within the scope of building and housing, to the extent to which these do not fall within the sphere of competence of some other ministry. Since the beginning of October 1983 the Water Administration is attached to the Ministry of the Environment as concerns matters of water protection. The National Board of Waters will thus continue its work under two ministeries. Several alternatives for possible additional reorganisation are under deliberation.

The function of the Water Administration is to promote the utilisation, management and research of all Finnish water resources and water areas. It supervises the exploitation of waters and the prevention of damage and accidents. The Water Administration also manages water bodies in state ownership. Most Finnish water areas are privately owned.

The legal responsibilities of the Water Administration are, in particular:

- integrated water resources development planning
- water pollution control
- development of water supply and sewerage
- promotion of the recreational use of waters
- promotion of the use of water power
- flood control
- supervision of bodies of water and their exploitation
- promoting and conducting water research.

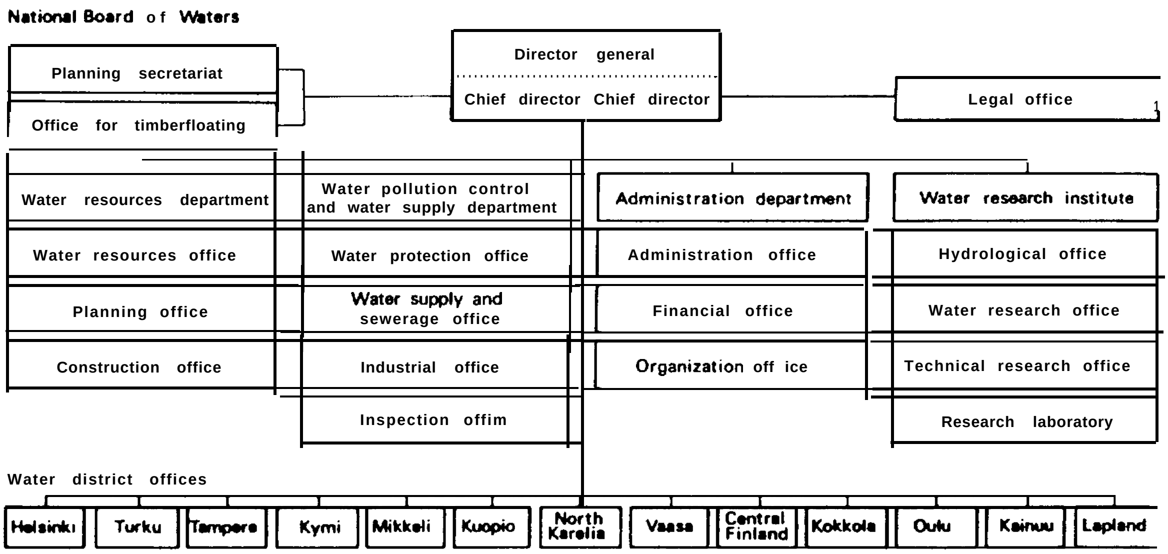

Fig. 2 Finnish water administration from March 1, 1981

The Water Administration employs 1 200 people on a permanent basis. Moreover, 440 people are employed on a temporary basis, and about 700 people are working at the maintenance and repair shops and on field construction sites. The staff is highly qualified and comprises the expertise of lawyers, economists, hydrologists, limnologists, engineers, chemists, biologists, microbiologists, geologists and other professions.

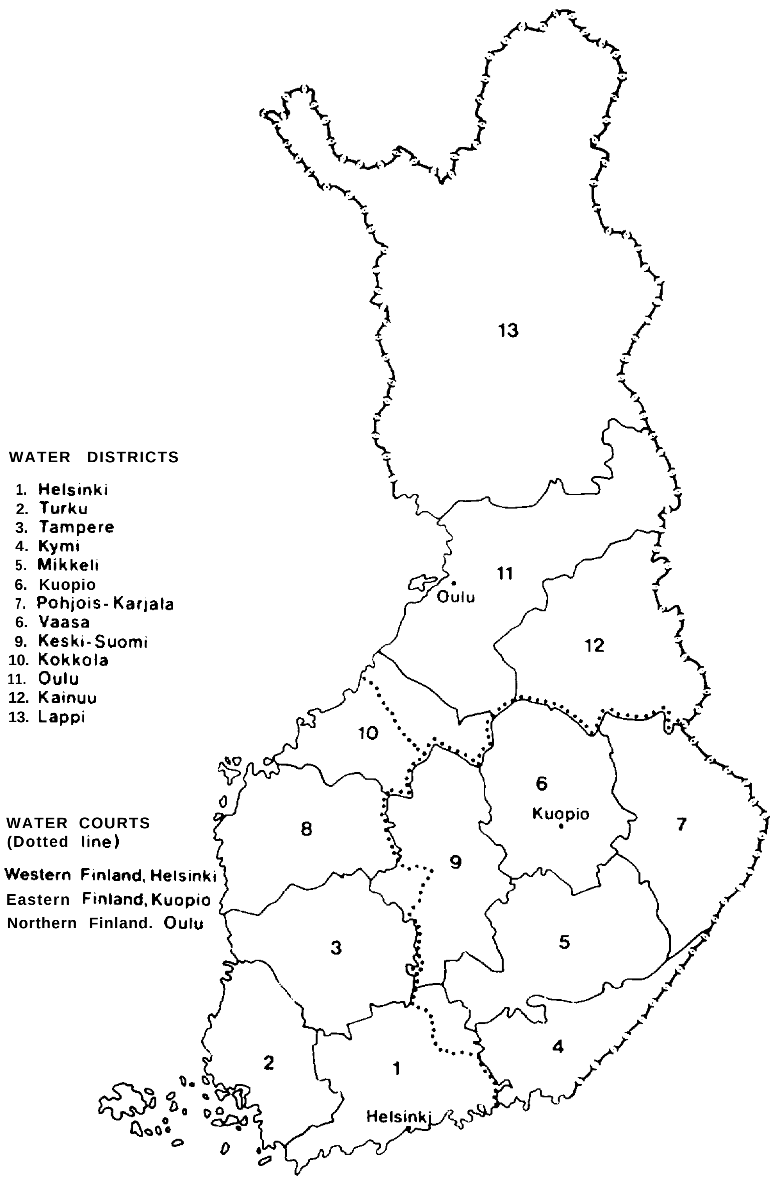

Fig. 3 Water districts and water courts

A reorganisation of the Water Administration was carried out in 1981 (Fig. 2-3). This reorganisation endeavoured to improve co-ordination between the different sectors of expertise and interests within the Water Administration and to further refine the quality of work, in response to public criticism of the administration.

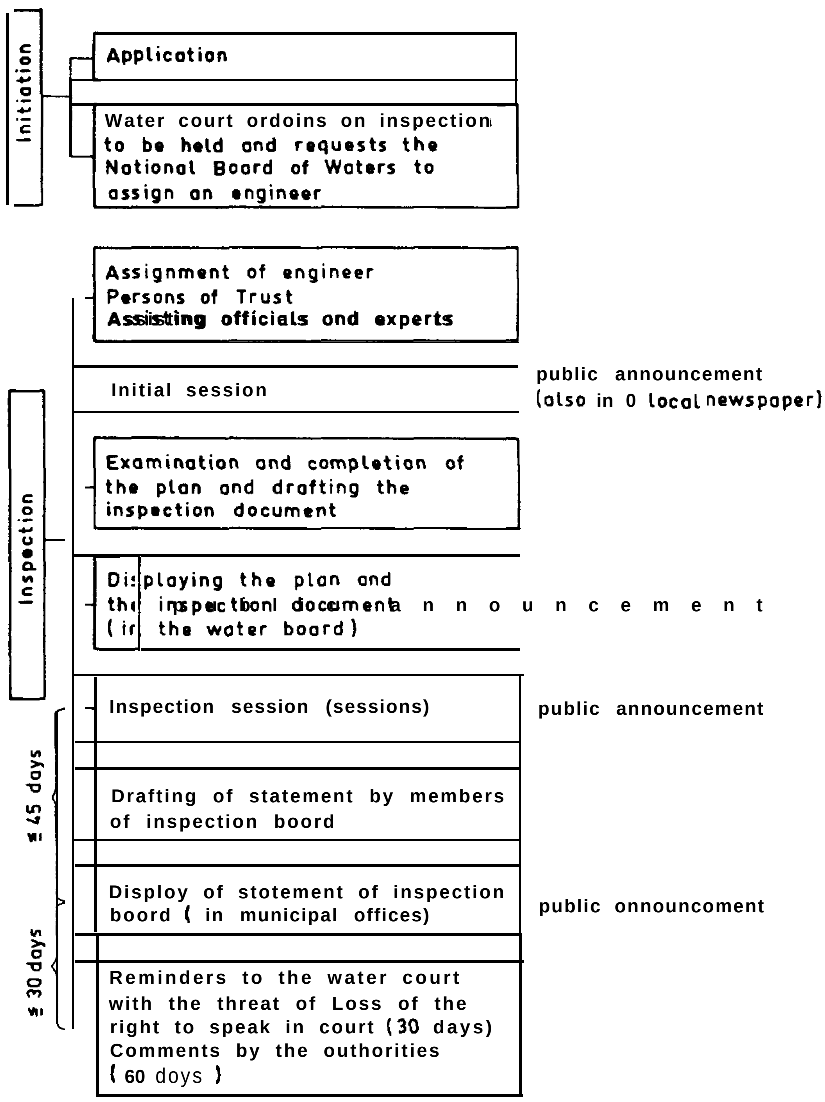

Fig. 4 The inspection procedure

The Courts of Law responsible for granting permits concerning closing off, altering or polluting a watercourse have basically remained the same over the last decade. The Water Courts, where such matters are first introduced according to procedure, are illustrated in Figs 3 and 4. The courts of appeal, the Superior Water Courts, the Supreme Administrative Court and the Supreme Judicial Court, retain jurisdiction over the Water Administration to see that the Water Act and decisions and regulations under it are observed. Since the Water Act has such far-reaching impact upon society, several minor amendments have been made to it. A more comprehensive reform is also under preparation.

Every self govering municipality in Finland (there are nearly 500 municipalities) must have a Municipal Water Board. The function of the Municipal Water Board is to act as a local supervisory authority concerning drainage, water supply and wastewater. Other boards associated with water affairs are the Municipal Board of Health, which supervises local public health conditions even as far as concerns waters, and the voluntary Municipal Utilities Board which administers local waste management. The voluntary Municipal Environmental Protection Committee is also of influence in this context. At present, the role of the local environmental administration is under reconsideration.

Other progress of importance in this context has taken place in many other sectors of governmental administration. Examples of new legislation are the Act on the Prevention of Marine Pollution and the Waste Management Act. Legislation on air pollution control has recently passed the Parliament.

In the Ministry of the Interior the Department of Environmental Protection was established in 1973. This department, now incorporated in the Ministry of Environment, administered many environment protection matters outside the scope of other governmental bodies, such as the development of waste management, air pollution control and noise abatement and respective legislation. Regional administration for environment protection is vested in the Environmental Protection Sections established in each Provincial Office.

In addition to the authorities and bodies above many other ministries and national boards are to some extent naturally involved in the protection of water bodies. Moreover, there are a number of advisory boards also taking an interest in environmental protection and matters related thereto. For example, since 1981 matters related to the work of the Helsinki Commission have been co-ordinated by the Advisory Board for the Marine Environment, established by the government.

Also worth mentioning is the recently begun construction of a special hazardous wastes treatment plant. The plant will certainly contribute in reducing the discharge of harmful substances into the environment.

Moreover, a number of unofficial organizations such as the voluntary water protection associations, the Water Association, and the Finnish Limnological Society, take an interest in matters related to water protection. Several federations of municipalities and industrial branches also look after the interest of their members in water affairs.

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3.2 WATER PROTECTION REQUIREMENTS

The specific conditions for wastewater discharge permits are laid down as shown in Fig. 4 in the Water Court. In drafting the conditions the National Board of Waters gields significant influence, since the comments of the Board are usually strongly reflected in permit conditions. The conditions for discharge permits are usually revised periodically. Thus it is possible to reconsider conditions taking into account the recent development of the state of the watercourse concerned and the technologial potential to reduce pollution.

The Water Administration establishes medium-term nationwide principles of water pollution control as well as regional water resources development plans. These are used as guiding instruments inter alia in defining the specific conditions for waste discharge permits.

The conditions for waste water discharge permits have been considered case by case taking into account the following factors: the characteristics, protection and use of the watercourse in question, the characteristics and quantity of wastewater, existing treatment installations and location of the treatment plant, available treatment methods, costs of treatment etc.

The reguired degree of treatment has been increased step by step. Usually the permit conditions are largely uniform all over the country. Exceptional requirements are, on one hand, usually based on a special need to protect the watercourse in question or, on the other hand, on a situation which cannot be essentially improved even by effective wastewater treatment. Sea areas have not had significantly different requirements compared with inland waters.

In the beginning of the 1970's phosphorus removal was found to be necessary due to the shallowness of watercourses and long detention times in lakes as well as in the many shallow bays protected by islands on the coastline of the Baltic Sea. Therefore the first measures for municipal sewage often consisted of chemical precipitation instead of biological treatment. The optimal start to pulp and paper effluent treatment was mechanical treatment and internal process modifications. Later on these measures are to be complimented by biological and, if necessary, chemical or other treatment processes.

The conditions for waste discharge permits today are more stringent than they were ten years ago (Table 11). Typical improvements for municipal sewage works are inclusions of percentage removal requirements, more stringent requirements, especially for simultaneous precipitation, and almost complete abandonment of periodical or continuous disinfection due to the disadvantages of chlorine compound introduction in the water environment. In addition to these conditions, other requirements have recently been introduced in the terms of waste discharge permits, such as the obligation to

- reduce the quantities of drainage and infiltration waters in sewers to a minimum
- see that industrial wastewaters and other exceptional waste disharges are appropriately pretreated before discharge into municipal sewers to avoid any disturbances in the sewage network or at the treatment plant

- treat and dispose of sludge so that it will not cause pollution of water
- monitor influent and effluent flows and quality, performance of treatment and influence on receiving waters in a way which has been approved of by the water authorities.

Table 11. Typical requirements for municipal sewage treatment. The requirements concern average results during a specified time period (3,6 or 12 months), including by-passes. BOD_7 refers to determinations including nitrification (without ATU).

Treatment method	1975 Effl.conc. (mg/l)		1983 Effl.conc. (mg/l)		1983 Removal %
Simultaneous precipitation	25	1.5	20-25	0.8-1.5	85-90
Post precipitation or simultaneous precipitation including sand filtration	< 20	0.5-l	< 20	0.5	> 90

No requirements have so far been set for total nitrogen reduction. However, the removal of ammonium nitrate has been required in a few cases, by nitrification in the activated sludge process. In these cases, the maximum permitted ammonium nitrate concentration has been 4 mg/l with a requirement of 80 per cent reduction.

Utilisation of sewage sludge is regulated by heavy metal contents and the calculated addition of Cd via sludge. Stabilization is required if the sludge is utilised. Sludge dewatering is required for sewage works serving more than 1 000-2 000 inhabitants.

The conditions for industrial wastewater discharge permis are different, since a number of internal process changes and modifications often are extremely important. It is therefore meaningful to define the maximum discharge figures in terms of

- total discharges per time unit or
- specific discharges per product units or
- concentrations and removal efficiencies instead of, or in addition to, the previous.

In reality, two of these alternatives are usually stated in the permit conditions.

In the beginning of the 1970's the main water protection measures in the pulp and paper industry were devoted to reduction of solid discharges. Towards the end of the decade, however, BOD_7 discharges have received increasing attention. Recently also phosphorus, chlorophenols, lignine and COD discharges have been introduced as parameters in discharge permits. The special discharge figures for BOD_7 have been as follows (achievable figures for new processes are in brackets):

- sulphate pulp	12-38	(10)	kg/t
- sulphite pulp	56-76	(20)	"
- chemimechanical	12-25	(15)	"
- mechanical pulp	1-35	(2-10)	"

It should be emphasized that the above variations in range are due to the different age of and process technology in individual mills and the condition of the receiving waters.

The conditions for waste discharge permits for other industries are very difficult to describe concisely due to the multitude of parameters used in individual cases. Most foodprocessing, textile and leather industry are connected to municipal sewer networks. Examples of different requirements for plants with own sewerage are:

- petrochemical and plastics industry: lately numerical values for phenols, oil etc. discharges
- fertilizer industry: 7-30 kg/d phosphorus discharges
- chloroalkali industry: 0.2-0.25 g Hg/t Cl produced
- food processing industry:
  - potato processing: wastewater irrigation
  - sugar beet processing: one year storage of wastewater
  - dairies: BOD_7 30 mg/l and tot.P 1.5 mg/l
  - slaughterhouses: BOD_7 50 mg/l and tot.P 1.5-2.0 mg/l
- textile industry: BOD_7 35-70 mg/l, removal 60-90 %, and tot.P 0.8-3.0 mg/l
- leather industry: BOD_7 SO-75 mg/l (2.5-4.0 kg/t of treated leather), also obligation to limit tot N, Cr and sulphide discharges to the extent possible
- mining industry: limit values depend on the type of the industry. Conditions for metals and As exist as well as an obligation to recirculate process water and enrichment chemicals in order to reduce oil, ammonium, cyanide and sulphuric acid discharges
- steel industry and other metal industries: metal discharges limited in terms of concentration and total discharge, also obligations to implement direct measures exist
- surface plating industry: Ni 3 mg/l, Zn 5 mg/l, Cu 2 mg/l, Cr 2 mg/l, Fe 5 mg/l

During the last few years a number of instructions on supervision have been issued. They set requirements on sanitary landfills, manure utilisation, silage liquor utilisation, fur farming, fish farming, peat production, forest drainage etc., to prevent water pollution. They contain extensive detailed information on storage arrangements, technical structures, capacities, spreading limitations etc. that lie beyond the scope of this paper. The objective of these instructions has been to reduce the pollution of waters wherever it is technically and economically possible.

The principles of water pollution control were first established in 1974. The purpose of these principles was to serve as guidelines and define objectives to water authorities in developing discharge criteria. The objectives listed in Table 12 were approved of, after a wide round of opinion of all those concerned was heard. Comments concerning the reduction of other undesirable or harmful substances were also submitted. The status of these principles is not mandatory, but they instead provide the framework for developing nationwide water pollution control measures.

Table 12. Pollution load from different sources and respective goals according to the first principles of water pollution control (t/d)

Source	1972	goals 1980	goals 1985
Municipal sewage			
- BOD_7	126	60	45
- tot. P	6	3	2.5
- tot. N	26		Stop increase
Pulp and paper industry			
- ss	750	200	
- BOD_7	1 300	650	400
- tot. P	1.9		1.5
- tot. N	15		Stop increase
- lignin			500
Fertilizer industry			
- tot. P	0.8	0.2	0.1
- tot. N	3.5	2	1
Other industry			
- BOD_7	100	20	10
- tot. P	1.2	0.2	0.1
- tot. N			Stop increase

As mentioned earlier, unexpected changes influencing the previously steady economic growth took place in the 1970's. These changes necessitated the reconsideration of the pollution control principles once again. This work was initiated in 1982 and will be finished at the end of 1983. The new principles will then be distributed for comment to all those concerned and will be finally approved of on a high governmental level. At this time it seems that the new principles will focus considerably more attention on industrial discharges and various harmful substances than the previous programmes. Thus the past ten years can be characterised as a decade of increasing awareness of these substances.

Regional water resources development plants have been made for 19 regions covering the whole country and forming convenient hydrological units. Even these plans do not have an official or mandatory status, but they serve to promote the appropriate use of water and protection in the regions concerned. The plans span:

- water supply
- water pollution control
- recreation
- fisheries
- hydropower
- timber-floating and traffic
- flood control and drainage
- water landscape conservation.

The intention was, depending on the region, to revise the plans about once every five years to enable updating of the plans in accordance with changing environmental conditions and the needs of society.

In addition to planning of this nature, the water administration also carries out separate regional or local planning concerning e.g. water supply and water pollution control. These are especially important in areas where the co-operation of different municipalities is obliged due to problems caused by limited or low quality water resources.

4. INVESTMENT AND ANNUAL OPERATING COSTS OF WATER PROTECTION MEASURES AND THEIR FINANCING

4.1 PRINCIPLES OF FINANCING

According to the Water Act the polluter is responsible for all costs of pollution control measures taken as well as compensation for damage, i.e. the polluter-pays-principle is followed in water pollution control. However, since large and urgent investment has been needed for carrying out water supply and water pollution control projects, the state assists in arranging the financing of investments during a transition period.

To cover the cost of water supply and water pollution control measures municipalities can receive interest subsidy loans to cover a maximum of 60 % of the investment in population centres and 75 % of the investment in sparsely populated areas. Municipalities can also receive water pollution control subsidies covering up to 30 % of the investment. However, the total amount of interest subsidy loans and state subsidies may not exceed 60 % of total investments. In addition to loans and subsidies the state itself carries out water pollution control projects.

Since 1974 the state has also arranged, in the framework of the financing system of industrial water pollution control, low-interest state loans and interest subsidy loans for existing industry, covering 38.5 % of investment in nonprofit water pollution control measures. Other loans from public sources at slightly lower than normal interest have been arrenged to cover an additional 38.5 % of investment.

4.2 INVESTMENT

Investments in municipal water pollution control are presented in Fig. 5, showing the substantial increase in investment in the beginning of the 1970's, followed by a small decline to then level off. Annual investment including the different forms of state support are given in Table 13. On an average 20 % of investment has been financed by interest subsidy loans and 10 % by direct financial state support.

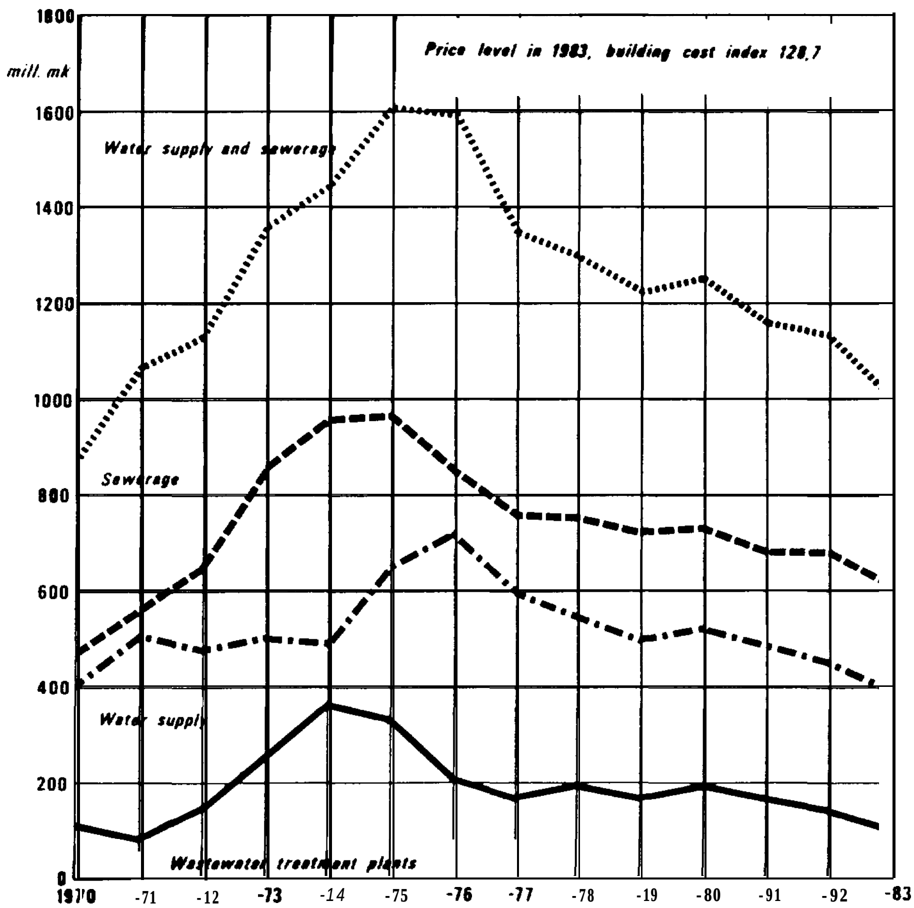

Fig. 5 Municipal investment in water supply and sewer systems

Investments in industrial water pollution control encompass internal measures concerning processes as well as external measures including sewerage and sewage treatment plants. Annual investment is given in Fig. 6. The annual figures for low interest loans and for other public loans are presented in Table 14. All the figures point to a considerable decline after the middle of the 1970's with a recovery towards the end of the decade. On an average 22 % of investment has been financed by low interest state loans and interest subsidy loans and 26 % by other types of public loans.

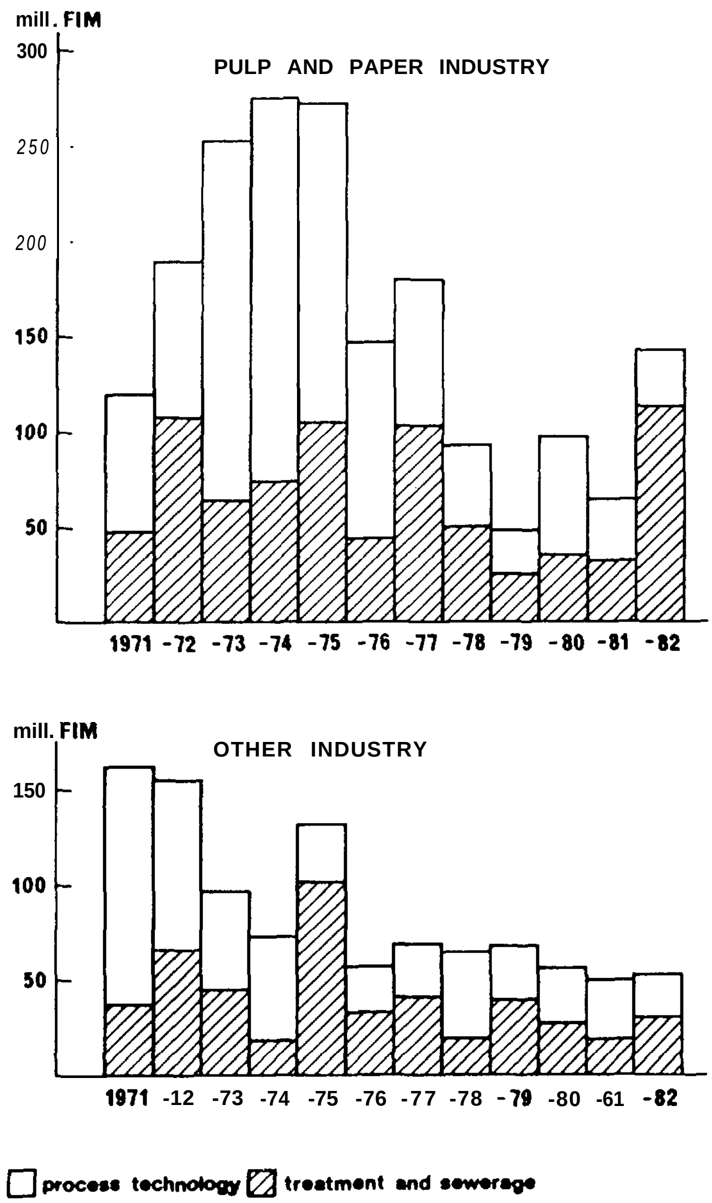

Fig.6 Industrial investments to water pollution control in the 1970's in 1980 price level

Table 13. Municipal and state investment in water pollution control in mill. FIM without index adjustment.

Investment	1971	1973	1975	1977	1979	1980	1981	1982
Direct from the municipalities	31	106	123	96	75	131	103	
Interest subsidy loans	6	13	36	17	68	35	45	47
From the state								
- direct subsidies		2	12	a	0	6	7	a
- sewerage projects		5	a	a	9	10	9	a
- unemployment grants			2	0	1	0	1	1
Total	37	126	181	129	153	182	165	160

Table 14. State loans, interest subsidy loans and other public loans granted for industrial water pollution control in mill. FIM without index adjustment according to the financing system for industrial water pollution control.

Investment	1974	1975	1976	1977	1978	1979	1980	1981	1982
State loans and interest subisidy loans	41	63	49	15	22	15	44	48	77
Post office bank loans	2	7	4	4					
Mortage of Bank of Finland Ltd.	54	70	52	19	11	13	57	31	73
Industries´ own share	a9	109	33	138	97	77	51	74	163
Total	186	249	138	176	130	105	152	153	313

4.3 OPERATING COSTS

The operating costs (operation and maintenance) of all sewer systems including also sewerage without sewage treatment, are shown in Table 15. The annual operating costs per connected inhabitant reflect the increasing efforts devoted to sewage treatment during the past ten years.

Table 15. Operating costs of sewer systems in Finland. The total operating costs are at the price level of the year concerned. The annual operating costs per connected inhabitant are in 1980 prices.

Year	Total operating costs (mill. FIM)	Annual operating costs per connected inhabitant (FIM/person)
1971	23	26.4
1972	34	40.2
1977	189	78.9
1978	221	84.8
1980	298	90.5
1982	377	90.4

The operating costs of industrial wastewater treatment are illustrated in Table 16, revealing a clearly increasing trend.

Table 16. Operating costs of industrial wastewater treatment in 1980 prises (mill. FIM).

Year	Pulp and paper industry			Other industry
	Internal	External	Total	
1971		13.2	13.2	
1972	0.7	27.0	27.7	25.4
1973	0.9	34.5	35.4	
1974	2.2	41.2	43.5	30.2
1975	8.8	45.2	54.0	
1976	11.1	51.2	62.2	39.5
1977	13.8	53.8	67.5	
1978	16.9	60.6	77.6	62.1
1979	17.8	58.7	76.5	
1980	16.9	58.8	75.7	76.9

5. WATER POLLUTION CONTROL TECHNOLOGY

5.1 MUNICIPAL SEWAGE TREATMENT

In a sparsely populated country like Finland, the number of treatment plants is fairly high as the average plant scale is very small. The size distribution of municipal sewage plants is given in Table 17. However, it is important that this statistical information does not contain the majority of the smallest sewage works (for less than 200 inhabitants), the number of whixh exceeds 3 000.

The progress in offering water supply and sewerage services to the population is reflected in Fig. 1.

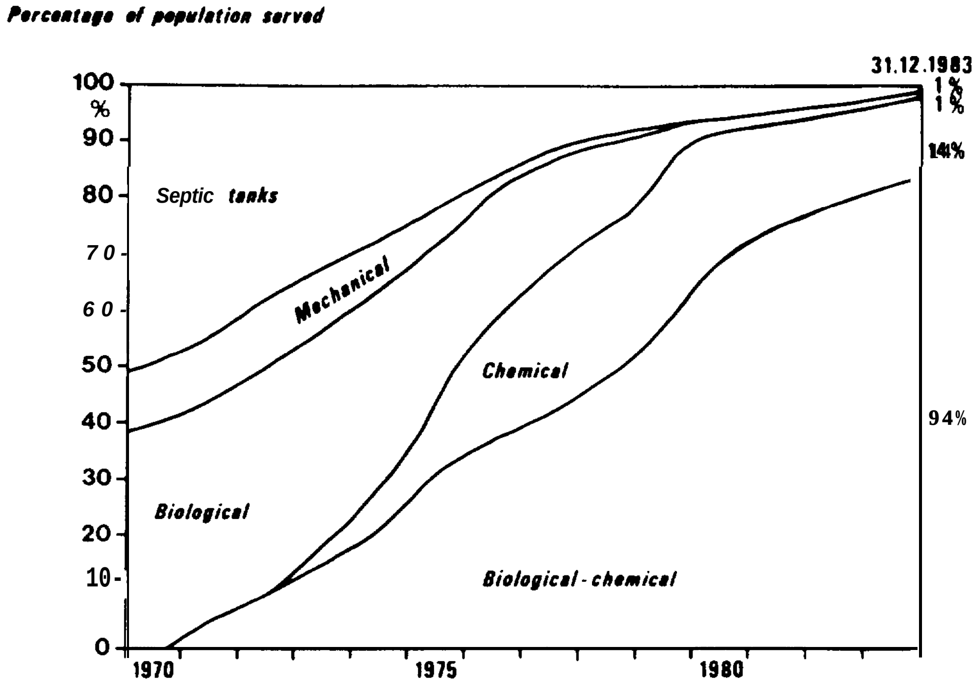

Fig. 7 Development of municipal wastewater treatment in 1970-1982

The methods applied in sewage treatment can best be illustrated by Table 18. Comparing this table with Fig. 7 gives the sharpest picture of progress in exploiting technology.

Table 17. Size distribution of municipal sewage works according to design flow in 1980

Design flow (m^3/s)	Number of works
199	112
200 – 499	149
500 – 999	93
1 000 – 1 999	68
2 000 – 4 999	68
5 000 –	70
Total	560

As can be seen, simultaneous precipitation, i.e. using ferrous sulphate in the activated sludge process, is employed for treating two thirds of sewage. This technology is very economical in terms of investment and operating cost: the inclusion of ferrous sulphate precipitation into the activated sludge process is extremely simple and ferrous sulphate is abundantly available as an industrial waste product. The sewage treatment results are sufficient in most cases and practically no operating problems are encountered. However, in some cases treatment needs to be even more effective. In such cases, and especially in the future, further upgrading of treatment will be required at many treatment plants. The obvious alternative will perhaps be to include sand filtration with simultaneous precipitation, which at present is the case only at a few small sewage works. The requirements for ammonia removal will in the future probably be met by designing the biological processes in accordance with nitrifying processes.

Table 18. Municipal sewage treatment plants by treatment method 31.12.1983

Treatment method	Number of treatment plants	Number of persons served	
		1 000 inhab.	%
Septic tanks		46	1.3
Mechanical treatment	3	2	0.1
Chemical precipitation	57	483	13.9
Biological filtration, oxidation ponds	37	34	1.0
Oxidation ponds with chemical precipitation	50	69	2.0
Simultaneous precipitation	389	2 579	74.3
Pre- or post precipitation	40	256	7.4
Total	576	3 469	100.0

Since 1974 efforts have been made to discover the reasons for poor operation and to improve the functioning of existing sewage works. As a result of this systematical work the performance of many sewage works has been improved.

Leakage and storm water inventories have recently started and no information on trends are at present available. However, the requirements to minimize leakage etc. have already proved to be more than justified. By renovating and renewing sewage networks, a considerable reduction of the load to watercourses can be achieved without involving treatment plants.

Sewage sludge treatment has become more complete as a result of guidelines, commonly requiring stabilization and dewatering of the sludge.

5.2 INDUSTRIAL WASTEWATER TREATMENT

Reduction of wastewater discharges from industry has been attained through internal process measures as well as external wastewater treatment measures. Usually, both measures are applied.

The pulp and paper industry is using the following process measures:

- dry debarking which reduces the BOD load by two thirds
- increasing the recovery of sulphate liquor from 96-98 % to 98-99 % and sulphite liquor from 85 % to 95 %
- stripping of cooling water by steam
- reduction of occasional overflows or their collection and treatment
- reduction of water consumption by closing some water cycles
- reduction of bleaching effluents by recirculation of chemicals, external effluent treatment or selection of less polluting bleaching chemicals.

External wastewater treatment measures are as follows:

- mechanical sedimentation
- biological treatment
    - aerated lagoon
    - biofilter
    - the Pekilo-process
    - anaerobic treatment
- chemical treatment (only to the extent of using chemicals to improve sedimentation).

The water pollution measures of other industry vary according to the branch concerned and from one factory to another:

- petrochemical and plastics industry: chemical and biological treatment, incineration, process modifications
- food processing industry: recirculation, sedimentation, oxidation ponds, infiltration, irrigation, biological treatment, connection to municipal sewers
- mining and metal industry: recirculation, process modifications, sedimentation, neutralisation and precipitation
- textile industry: process modifications, biological treatment, connection to municipal sewers
- leather industry: reduction of water consumption, biological treatment

5.3 DIFFUSE SOURCES

As stated earlier (chapter 3.2), requirements concerning diffuse sources and including relevant technological measures have appeared in many instructions on supervision. They cannot be explained in detail in this context.

6. ESTIMATED EFFECTS OF WATER PROTECTION MEASURES ON THE POLLUTION LOAD ON THE BALTIC SEA

The water protection measures described above have resulted in considerable reductions of the pollution load to watercourses, especially when the increased number of the population connected to sewerage systems and increases in industrial production are taken into account. The effluent and discharge requirements are basically the same inland and on the coast.

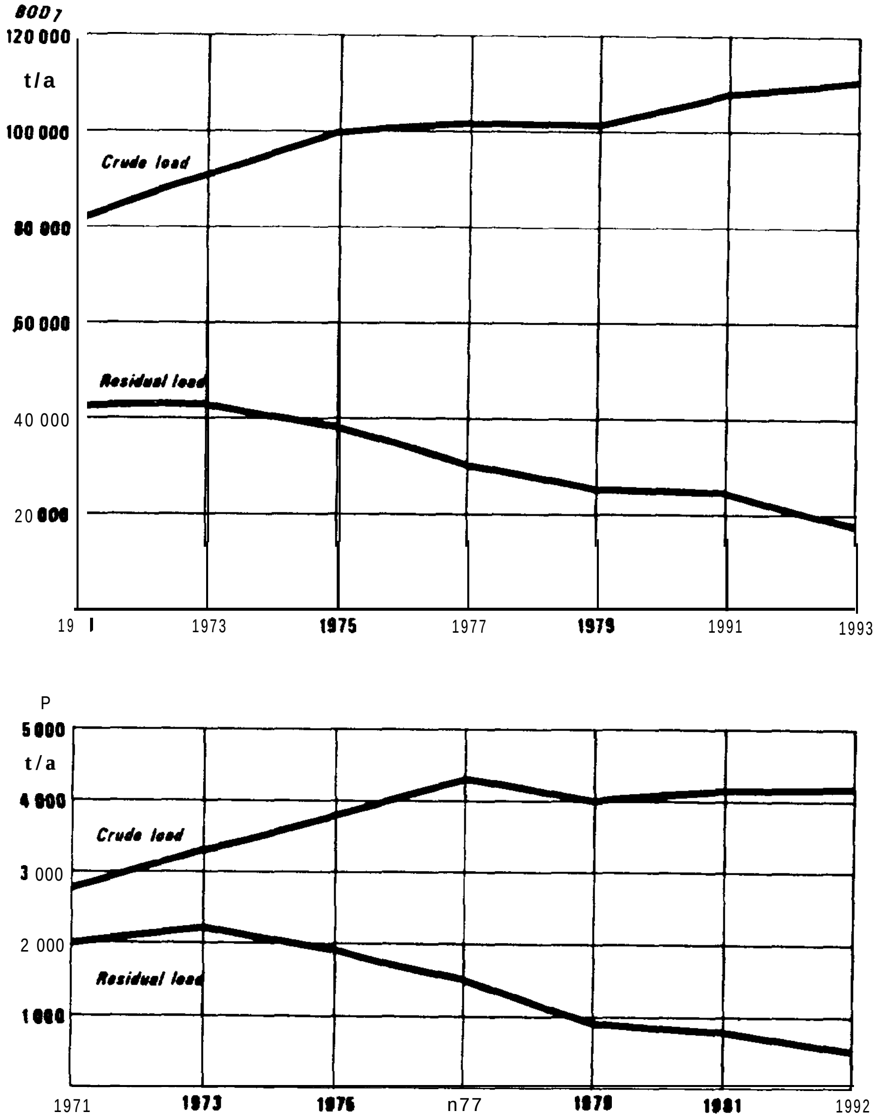

Fig. 8 BOD and phosphorus loads in municipal wastewater 1971-1982

6.1 OVERALL POLLUTION LOAD REDUCTION IN MUNICIPAL DISCHARGES

The development of the pollution load on watercourses is illustrated in Fig. 8 and 9. Municipal sewage treatment had reached the goals set for the total discharges of phosphorus (tot.P) for 1980 in the first programme, the water pollution control principles. The BOD_7 reduction goals had not been reached owing to unpredicted difficulties in the economy mentioned earlier. Further goals will soon be established in the new water pollution control programme under preparation.

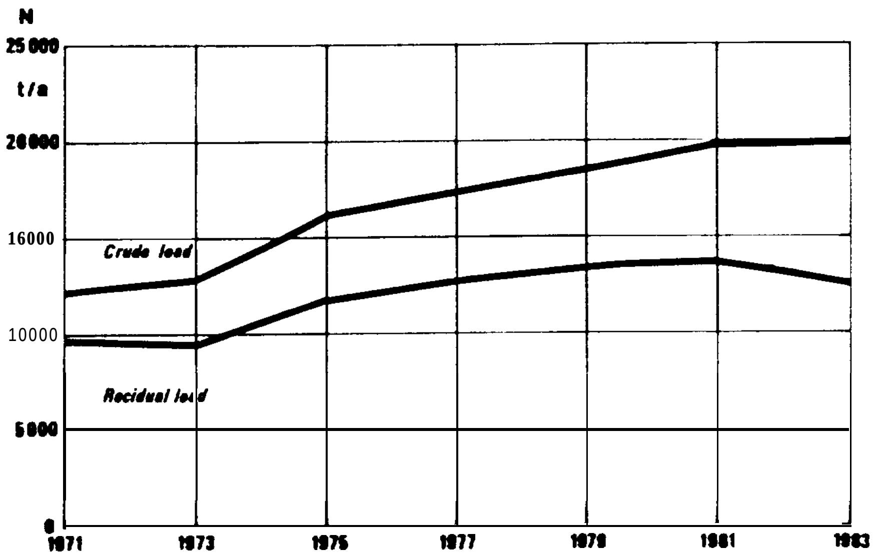

Fig. 9 Nitrogen load in municipal wastewater 1971-1981

6.2 OVERALL POLLUTION LOAD REDUCTION IN INDUSTRIAL DISCHARGES

The progress in pulp and paper industry wastewater discharges and the respective volume of production is illustrated in Fig. 10 and 11. The development of waste discharges from other branches of industry is shown in Fig. 11. Studying the goals set for 1980, it is apparent that the phosphorus reduction goals have been reached, while the rest of the reductions have not quite yet been realized.

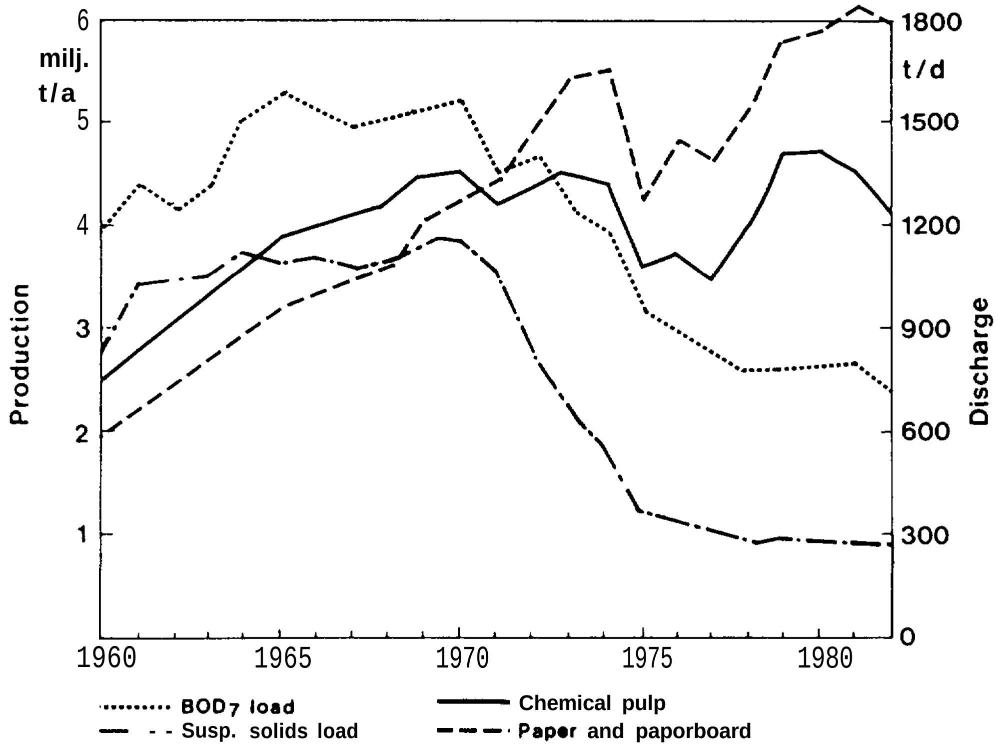

Fig. 10 The production and the suspended solids and BOD_7 loads of pulp and paper industry in 1960-1980 as well as the respective goals for 1980

6.3 OTHER POLLUTION LOAD REDUCTIONS

The load from agriculture, forestry, scattered dwellings etc. has not been evaluated systematically. No trends can therefore be given. However, many recently issued requirements have not yet produced an effect on the pollution load. Additionally, their influence may be more pronounced in local circumstances than is reflected in national reviews. The difficult-to-control or-limit run-off from agriculture and forestry and factors like the price of mineral fertilizers seem to create stronger short-term effects than the long-term requirements on reducing the pollution load.

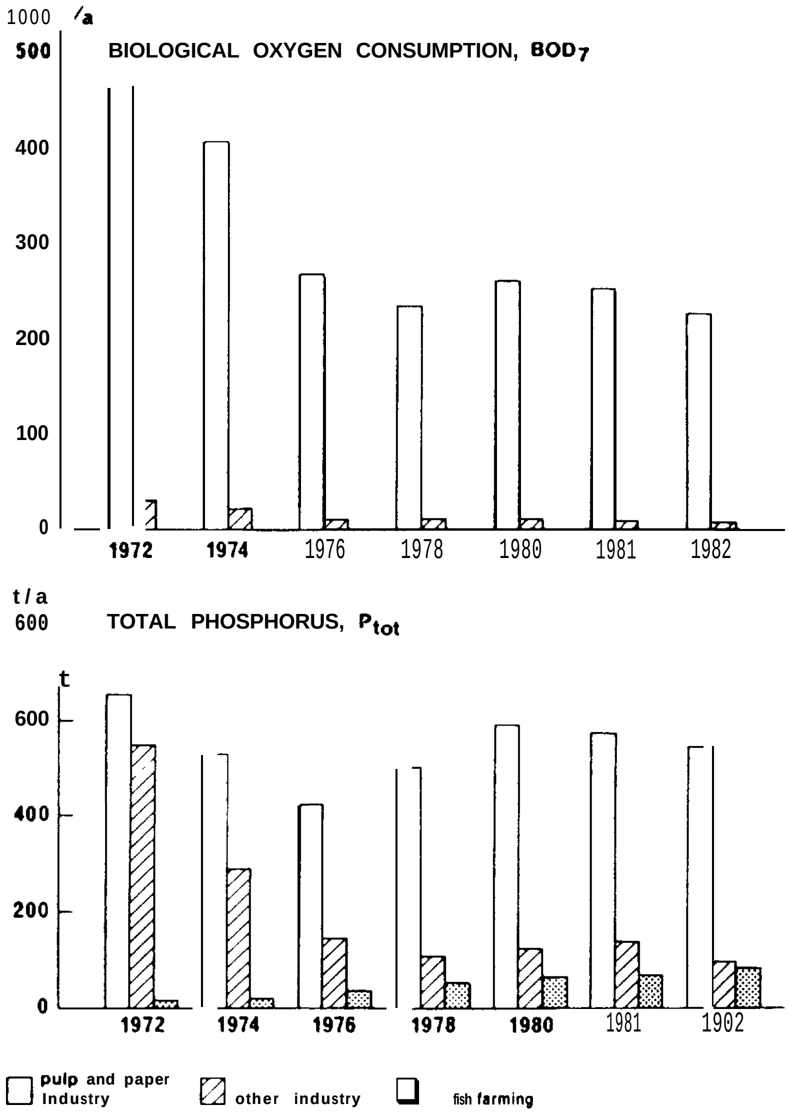

Fig. 11 The development of industrial waste water discharges in the 1970's

6.4 QUALITATIVE CHANGES OF FINNISH WATERCOURSES

The quality of lake water has improved to some extent during the last decade due to water pollution control measures (Fig. 12).

The effects on river water quality are less favourable (Fig. 12). This is partly due to the initially lower quality of river waters mainly caused by diffuse loadings, parly to extensive hydraulic engineering activities.

Table 19. Quality of inland waters in Finland.

	1970-71	1976-77	1980-81
Lakes (km*)			
Good/Excellent	24 550	24 950	25 000
Satisfactory	5 950	5 850	5 900
Passing	850	550	500
Poor	150	140	130
Rivers (km)			
Good/Excellent	11 500	10 900	11 500
Satisfactory	7 300	7 700	7 400
Passing	1 900	2 000	1 800
Poor	200	200	160

Note:

The quality of inland is classified as:

Excellent (1): Very adequate for all purposes. For municipal water supply only mechanical treatment and disinfection are needed.

Good (2): Adequate for all purposes. For municipal water supply chemical treatment is often needed due to humic acids common in Finnish waters.

Satisfactory (3): Adequate for many purposes, but only to a limited extent. Adequate for irrigation. Efficient treatment measures and continuous quality monitoring are needed in municipal water supply.

Passing (4): Adequate for navigation, timber floating and hydropower production. Adequate only to a limited degree for irrigation and cooling purposes.

Poor (5): Inadequate for any purpose.

Chemical and physical parameters are used to define the classifications.

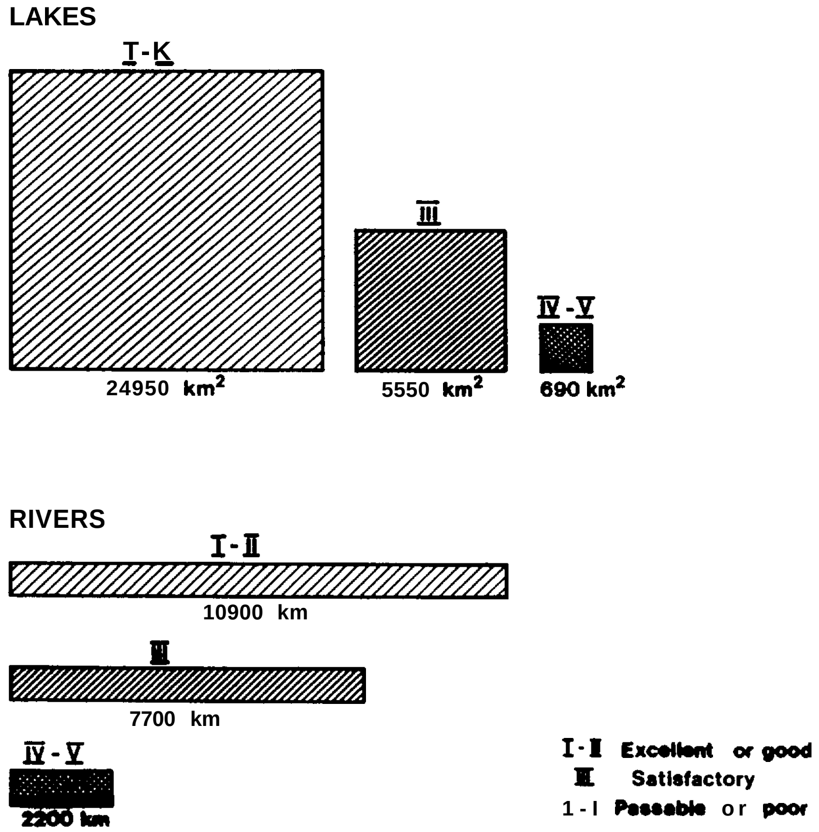

Fig. 12 Usability of inland waters in 1976-77

The evaluation of the quality of the Finnish coastal waters is based on another classification. About 320 km^2 of the coastal water area was estimated to be polluted in 1980-81. The polluted areas are around the outlets of municipal and industrial effluents and river mouths. Measures to reduce the pollution will therefore have a direct impact on the quality of sea water.

6.5 POLLUTION LOAD ON THE BALTIC SEA

The discharges of organic matter and nutrients to the Baltic Sea are given in Table 20. As shown, rivers carry a considerable volume of substances into the Baltic Sea. The fiqures are not directly comparable, however, since hydrological and other uncontrollable factors play a major role and since e.g. phosporus in river waters may be mostly bound to solids. The water pollution control work undertaken in the 1970's and thereafter is to some extent visible in municipal and industrial discharge figures for phosphorus.

In addition to the conventional discharge parameters illustrated above, much more progress has been achieved in reducing many specific pollutants. Examples of these are the following reductions achieved in industrial discharges in the 1970's:

Mercury	> 90 %	reduction
Cadmium	> 60 %	"
Iron	> 85 %	"
Oil	> 78 %	

Table 20. Discharges of organic matter and nutrients into the Baltic Sea fran Finland (10^3 t/a)

	1972	1974	1976	1978	1980	1982
GULF OF FINLAND						
River discharges						
BOD_7			36.0	32.0	45.5	47.0
P			0.40	0.47	0.60	0.49
N			8.00	9.10	11.9	12.0
Municipal discharges						
BOD_7	7.11	5.27	5.50	5.35	5.42	5.54
P	0.55	0.52	0.51	0.41	0.20	0.21
N	1.98	3.14	3.26	3.84	4.29	3.84
Industrial discharges						
BOD_7	40.15*	37.10	23.90	21.00	25.20	22.6
P	0.05*	0.04	0.04	0.05	0.04	0.04
N	0.47*		0.49	0.62	0.51	0.35
THE GULF OF BOTHNIA						
River discharges						
TOC			450	450	600	780
P			1.7	2.0	2.2	3.2
N			29	20	34	48
Municipal discharges						
BOD_7	8.95		7.60	6.53	5.74	5.95
P	0.45		0.35	0.25	0.22	0.24
N	1.92		2.81	2.89	2.94	3.09
Industrial discharges						
BOD_7	100.7	88.5	60.6	51.6	65.4	55.4
P	0.25	0.23	0.17	0.22	0.25	0.23
N	1.87	3.20	1.97	2.12	2.29	2.53

* Includes discharges from pulp and paper industryonly

7. CONCLUSIONS

The water pollution control problems today are quite different from the situation faced before the signing of the Helsinki Convention. The application of modern technology to water protection measures has resulted in considerable reductions of many discharges.

It seems today that the most significant reductions of many parameters have already been achieved, although progress has not been quite as rapid as was originally pictured. Completing the measures aiming at reducing the load of oxygen-consuming substances and phosphorus is still necessary. However, the challenges of the future definitely lie in the careful consideration of the necessity of nitrogen removal and especially in the reduction of persistent harmful substances. Decisions on the approach, further technological development and required measures must be taken soon.

THE DANISH NATIONAL REPORT

Gunver Bennekou
National Agency of Environmental Protection
Denmark

1. INTRODUCTION

In Denmark the supply of water is almost fully based on groundwater resources, and the groundwater may be used almost without prior treatment. Therefore, a very high priority is given to the protection of the groudwater resources. Only the waste water of about 1 million person equivalent is disposed of by land treatment. Percolation concerns mainly sewage from rural and recreational areas with summer houses, whereas irregation of waste water is permitted only for special types of waste water from the food industry.

In order to protect the groundwater, most of the waste water is discharged to rivers, lakes and the sea.

The Danish waste water policy is based on two main pinciples. First, the discharge of particularly harmful substances shall be reduced to the greatest possible extent, and, second, the discharge of other substances whose impact is more moderate and confined to the local area, shall take place with due consideration of the quality objectives laid down for the receiving waters in question.

2. URBANIZATION AND CHANGES IN THE STRUCTURE OF INDUSTRY AND AGRICULTURE

Denmark covers an area of 43 100 km^2 with a population of 5.1 million people. The population density of 118 inhabitants per km^2 is high compared to the other Scandinavian countries, but relatively low compared to the continental countries. However, the Danish population is very unevenly distributed in the country. About 1/3 of the population is living in the Copenhagen area on the eastern side of the island of Zealand.

In spite of the fact that formerly Denmark was known as an agricultural country most of the population is living in towns - that is to say around 4 mill. people. About 300 000 people live in villages and about 700 000 live in scattered builtup areas. This scale has not changed much during the last 10 years.

The economic crisis has had a great influence on industry. The crisis as well as the modernization and rationalization have caused a drastic reduction in the numbers of jobs in the industry.

With regard to water pollution especially two facts are of interest, namely the development of the chemical industry and the location of the industries.

The chemical industries and especially the medical industries have expanded enormously during the last 10 years as well with regard to production as to employment.

This development has among other things caused that part of the chemical industry has moved from the towns into less built-up areas, for instance out along the coasts. Also other large new industrial works have to a considerable extent been established outside the towns.

The agriculture has during the last 10 years changed very much. The total agricultural production has been almost unchanged, but the production takes place on fewer and larger and more specialized farms today. The number of farms with cows has been halved during the period in question, and the same has occurred to farms with pigs. These circumstances have sometimes caused water pollution problems, as some farms have been unable to use the farmyard manure on their own fields. The total consumption of fertilization has increased during the period especially with regard to nitrogen fertilizer.

3. WATER PROTECTION ADMINISTRATION AND WATER PROTECTION REQUIREMENTS

Since 1974 the planning of the water quality has been carried out within the framework of the Environmental Protection Act which aim is to prevent and combat pollution of air, water and the soil.

The central authorities have not laid down national emission standards – in Denmark the planning of the water quality takes place at the local level, i.e. by the regional and municipal authorities. However, the National Agency of Environmental Protection, NAEP acts as adviser to the local authorities, and it has for instance issued guidelines for the discharge of waste water. The guidelines list examples of particularly harmful substances that should be controlled at the source, for instance mercury, cadmium and halogenated phenols. It further gives guiding directions for the emission values to be applied to a number of substances, e.g. nutrient salts and metals - differentiated according to the nature of the receiving waters (Table 1). These guidelines have to a very large extent formed the basis of the discharge permits issued by the local authorities.

Table 1. Guiding discharge limit values for receiving waters.

Parameter	a Lakes and watercourses to lakes and landlocked inlets	b watercourses to open bays, straits, belts and the sea	c Landlocked inlets and other enclosed salt and brackish waters	d Open bays, straits, belts and the sea
pH	6.5 - 8.5	6.5 - 8.5	6 - 9	-
Temperature	30° C	30° C	30° C	35° C
BOD_5	20 mg/l modified	20 mg/l modified	100 mg/l	400 mg/l
COD (Chemical oxygen demand)				
NH_3-N: (NH_3+NH_4^+)	2 mg/l			
Total N				
Total P	1 mg/l		1 mg/l	
Settable matter	0.5 ml/l	0.5 ml/l	1 ml/l	1 ml/l
Floating substances	.... should not be visible			
Suspended solids (TSS)	30 mg/l	30 mg/l	80 mg/l	

The NAEP has also issued guidelines for the regional authorities surface water quality planning. The guidelines contain the objective set in EC Directives concerning salmonid waters, cyprinid waters and shellfish waters.

The parameters stipulated in the Directives are incorporated in the form of quality requirements for the objectives in question. Besides the guidelines contain provisions for the content of iron compounds, saprobie index and flow of water in water courses.

The NAEP is the authority of appeal concerning most of the decisions made by the local authorities. Some of the decisions made by the NAEP especially concerning discharge permits and approval of certain categories of industries can be appealed to an Environmental Appeal Board which is independet of the politically controlled authorities.

Denmark is divided into 275 municipalities and 14 regional areas. In accordance with the provisions of the Environmental Protection Act the regional authorities are responsible for the quality of the receiving waters. Each regional authority has in, co-operation with the municipalities involved, prepared a provisional plan for the quality of the receiving waters in its area. The plan sets up the objectives to be achieved in the individual receiving waters - i.e. watercouses, lakes and coastal waters.

After 1984/85 these plants will be binding for the municipalities.

Each of the municipal authorities has, partly on the basis of the regional surface water quality plans, partly on the basis of the physical and economic development in the area, worked out a waste water disposal plan. The plan contains information on existing waste water treatment plants and information on how the waste water is disposed of in the area, for instance by percolation, irrigation or individual discharge. The plan has further to describe necessary new plants and to show which surface waters to be used for waste water discharge.

Before the regional council approves a waste water plan, the plan shall be presented to the public, and a hearing shall be made in order to hear the opinion of the local residents.

When the waste water plans are approved, the regional authorities grant a permit to discharge the waste water concerned. It is then up to the municipalities to have a plant designed which is able to meet the discharge permit. No design guidelines exist from the NAEP, as such guidelines are believed to act restraining on the development of new technologies. If the plant fails to meet the discharge permit or creates other nuisances to the neighbourhood the regional authorities can demand changes made in the operation of the plant.

4. INVESTMENT AND ANNUAL OPERATING COSTS

In Denmark the disposal and treatment of waste water are financed primarily by the producers of the waste water.

The municipal authorities are responsible for the construction and running of public sewage systems and wastewater treatment plants. The costs involved are paid by the users according to rules laid down by these authorities, and the principles governing the distribution of costs vary throughout the country.

The costs are divided between 3 groups of users, private households, industry, and the municipality. All users are charged with a contribution to construction and an annual contribution to operation and maintenance.

It is statutory for the municipality to contribute to at least either construction or running costs. On average these authorities finance 20 % of the construction costs.

As a main rule the charging systems are based on the quantity of waste water discharged to the public system and its content of pollutants. In this context domestic waste water sets the standard, and consequently an additional charge per unit (m^3) is put on industrial effluents with a higher degree of pollution.

An important difference between Denmark and most other countries has been that no government grants to the municipalities exist to aid them in financing the treatment costs. As a consequence the Danish treatment plants have been constructed on a lower cost than in the neighbouring countries, where such grants have existed.

Private sewage discharges, for instance industrial enterprises, discharging directly to surface waters via its own waste water treatment plant, pay the expenses themselves.

However, the state has had the possibility to grant contribution to the investment on special occasions.

During the last 10 years on an average 1 000 mill. DKK have annually been invested in public sewers and waste water treatment plants. The operating costs represent above 1 000 mill. DKK annually. (US$ = DKK 9.50 (1983)) (Fig. 1).

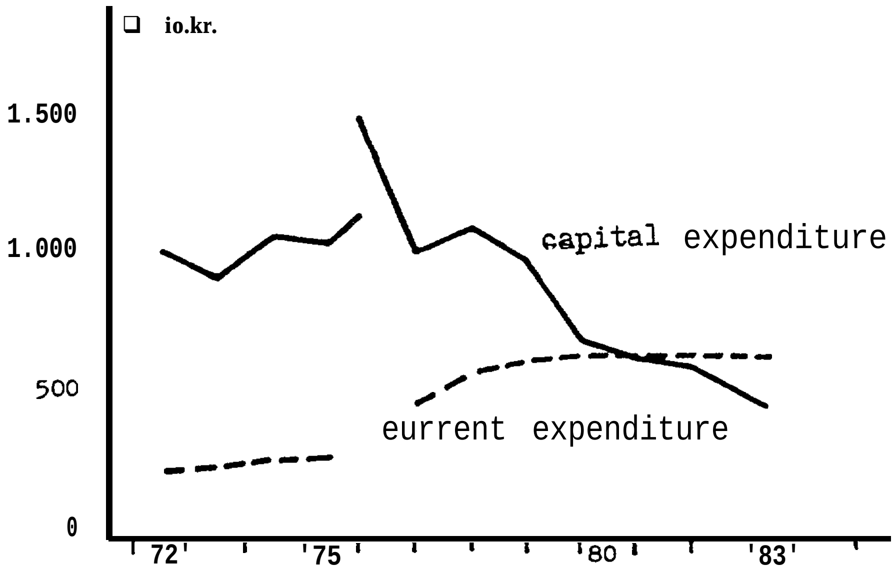

Fig. 1. Current and capital expenditure of sewage and waste water treatment plants in 1977 prices.

Since 1980 the annual capital costs has decreased from 1 200 mill. DKK to 800 mill. DKK in 1983. Around 200 mill. will this year be invested in treatment plants only. Running costs have been increasing and will this year amount to 1 400 mill. DKK.

The industries have since 1974 invested 40-100 mill. DKK annually in waste water treatment plants. The running costs for the industries are approximately 5-10 mill. DKK annually.

5. WATER POLLUTION CONTROL TECHNOLOGY, METHODS AND THEIR APPLICATION

92 % of the Danish population discharge their waste water into public sewers. At present about 65 % of the waste water is biologically treated, 25 % mechanically treated and about 10 % untreated. 5 % of the waste water is treated for either nitrogen or phosphorus. This effort means that almost all the waste water discharged to inland waters now is either biologically or more advantageously treated. However, as some of the pollution especially caused by nutrients have been moved to the coastal zone, some events of low oxygen concentrations and algae blooms have been observed here during the last years. These problems are currently investigated to find out, if the causes are the increasing use of fertilizers in the agriculture, waste water discharge or just natural variations in the environment. As a consequence an increased nutrient removal from the waste water may be a necessity in the future.

During the sixties and the early seventies many of the largest cities in Denmark were building conventional mechanical plants or trickling filter plants, typically designed for a capasity of 50 000-150 000 population equivalents (PE).

Most of these plants are still in operation. For the cities situated along the coastline, the effluent quality is often sufficient to get approval from the regional authorities, but for the cities discharging into streams and lakes an upgrading has been required during the last 5-10 years.

Upgrading is normally performed by activated sludge treatment, either as an additional step or as a new one-step process.

During the last 15 years about 500 treatment plants in the size of 1 000-30 000 PE have been put into operation. Almost all of them are activated sludge plants, of which about 50 % are oxidation ditches. Today the oxidation ditch is the type of plant most frequently used for smaller communities.

The design and operation of these oxidation ditches are carried out individually according to the various discharge requirements regarding nitrification, denitrification, and phosphorus removal.

Because of its size, the wastewater treatment system for Copenhagen is not comparable to that of any of the other cities in the country. Copenhagen's sewage corresponds to about 2.4 mill. PE, of which about 50 % is domestic waste water and the remaining part is coming from different industries.

After a number of different pilot plant tests carried out during 1972-1978, a pure oxygen plant was chosen. The plant, called Lynetten, was designed for a dry weather flow of 300,000 ov.m./day of approximately 500 mg/l. In 1980 the plant was put into operation, and the effluent quality is now satisfying the intergovernment agreement between Denmark and Sweden for discharge into Øresund.

Only Lynetten and one more large treatment plant in the Copenhagen area use incineration as means of sludge disposal. The amount of sludge from these two plants corresponds to 40 % of all wastewater treatment sludge produced in Denmark. The remaining 90 000 t dry sludge produced per year are evenly disposed of to landfills and agriculture.

Dewatering before disposal to landfills is normally performed by filter presses and sieve belt presses.

The big cities normally have private consultant engineering companies to make the design of new plants or upgrading old plants.

For smaller cities, communities, and industries it is common to invite tenders for the treatment plants as turnkey jobs. When evaluating bids the municipalities consider the cost of operation just as important as the cost of construction.

This market situation has resulted in a very strong competition between the different Danish engineering companies, who have developed some very simple treatment plants, low in investment and running costs.

The performance of the turnkey plants is normally guaranteed by the contractor.

The research and development in treatment plant design has especially dealt with new methods for nitrogen and phosphorus removal, as will be described in the technical papers from Denmark, and with automatic control of treatment plants.

A main difference from the wastewater policy of most other countries is that no centrally issued design guidelines exist for the construction of waste water treatment plants. When a regional council has issued a discharge permit, it is the responsibility of the municipality to mett the requirements. The municipality needs no approval from a higher authority of the technical design of the treatment plant. The economy of the plant is a municipal responsibility too, as there are no governmental grants to help them cover the costs.

6. ESTIMATED EFFECTS OF WATER PROTECTION MEASURES ON THE POLLUTION LOAD OF THE BALTIC SEA

As mentioned earlier almost all the waste water discharged to inland waters is now either biologically or more advantageously treated.

In 1972 only about half of this waste water was treated biologically or chemically. The increasing treatment and the facts that part of the waste water which was earlier discharged to the inland waters is now discharged to the marine areas have caused that the water pollution in the inland waters has been reduced by more than 50 %.

In the area of Øresund the treatment of the waste water has improved very much. In some other towns discharging to the marine area the situation has been improved.

Many municipalities have plans for better treatment. In 1990 it is expected that more then 50 % of the waste water from sewers discharging to marine waters shall be treated biologically.

The ongoing investigation of loss of oxygen in the Danish marine waters among others have the purpose the explain whether the plans made for treatment are sufficient in order to avoid loss of oxygen.

Besides, the pollution from discharge of waste water the Baltic Sea is polluted from agricultural discharges and atmospheric fall-outs.

The National Agency of Environmental Protection has made a calculation of the pollution of the Baltic area with regard to N, P, and organic matter (COD) during the years from 1975-1981 (Table 3 and 4).

In this calculation the load of waste water is estimated unvariable. The above mentioned modifications are of special importance to the discharge of COD, which is smaller at the end of the period than mentioned in the table. The increasing discharge from agricultural areas is caused exclusively from the increasing run-off during the mentioned period.

Table 3. Estimated total loads from Danish land to the Baltic sea in the period 1975-81. Measured in tons per year.

	Total-N	Total-P	Total COD
Average	90 000	10 000	500 000
Maximum (1981)	120 000	11 000	550 000
Minimum (1976)	60 000	9 000	450 000

Table 4. Load distribution related to source (to the nearest five percent) on average over the period 1975-81.

	Total-N	Total-P	Total COD
Sewage plants	30	75	50
Direct discharges from industries	5	10	25
Fish farms	(no)	(no)	(no)
Contribution from rural areas	40	5	(no)
Urban run-off	(no)	(no)	5
Scattered housings plus discharges from farm areas (liquied manure etc.)	25	10	20
	100	100	100

However, many other substances than N, P, and COD are discharged with the wastewater.

The National Agency of Environmental Protection has started an investigation of the circumstances, but the conclusions of the investigation are not yet available.

WATER PROTECTION IN THE FEDERAL REPUBLIC OF GERMANY UP TO 1983 FROM A LEGISLATIVE POINT OF VIEW

Bernd Bayer
Federal Environmental Agency
Federal Republic of Germany

1. ABSTRACT

Following a brief description of the organisation and major responsibilities of water protection in the Federal Republic of Germany, a survey is given of the numerous legal regulations and complementary measures. A distinction is made between national regulations, EEC-regulations, international regulations – including agreements in the framework of the Council of Europe, international river basin conventions, conventions for the protection of the marine environment, work undertaken by the United Nations, by OECD and NATO –, regulatory actions having an indirect effect in water protection, as well as complementary measures such as investments aids, research and development projects, expert opinions by the Council of Environmental Advisors, and the implementation of monitoring programmes. The Federal Government and the federal states (Lander) are making efforts to ensure consistent compliance with three principles of environmental protection policy: the principle of anticipatory action, the "polluter-pays" principle, and the principle of co-operation. Owing to the fact that waters are subject to various and sometimes conflicting user claims, compromises must be sought as a rule. In principle, limitations of emissions are preferred to regulations for the control of immissions. As a result of the considerable efforts undertaken in particular during the past decade – for instance, the proportion of inhabitants

connected to biological sewage treatment plants was virtually doubled – it was possible to improve the quality of many waters considerably; this is proved by the example of different sets of monitoring data from the river Rhine. However, numerous problems have yet to be solved; *in* the first instance these are problems connected with the dispersion of critical pollutants in the environment. Attention is drawn to a number of further concrete and basic task of focal importance to be tackled in the future.

2. INTRODUCTION

In recent decades – and especially since the beginning of the 1970's – many waters of the Federal Republic of Germany have been subjected to increasing strains as a result of hazardous pollutants and waste heat. The first and initially the most important counter measures for the protection of waters are concentrated on eliminating the worst pollution, particularly that caused by easily degradable substances, which provide and immediate danger to aquatic life due to their consumption of oxygen. Now it is more essential than ever to combat also other kinds of water pollution, caused by other harzardous substances, particularly those which are harder to break down and have more long-term effects, such as heavy metals and organic micro-impurities, including chloro-organic compounds, some of which have carcinogenic effects. To deal with this range of problems, especially in the last 10 years the existing regulations have been extended and new ones have been set up.

3. ORGANIZATION AND COMPETENCES

To understand the relativly complicated water protection-organization in the Federal Republic of Germany it is essential to know that pursuant to Article 75 para 4 of the Basic Law (Grundgesetz) the Federation has only the right to enact general provisions concerning water management. The remaining legislative competence concerning water management in particular as regards fulfilment of the framework specified by the Federation and organization of execution, is in the hands of the Laender (estates).

In this way the Land and municipal anthorities competent for water management and water rights and whose competence varies from Land to Land attend to the licensing procedure in accordance with the Land Water Laws and issue the appropriate notices on water rights.

The Land anthorities are also responsible for fulfilment of obligations and ensuring that they are complied with. Several regional water boards have, in accordance with the Land water laws, been assigned competence governed in the various Land Water board Laws. They are of considerable significance.

Waters pursuant to Article 1 Federal Water Act (1) are:

- surface waters
- coastel waters and
- ground water

The areas of the High Seas of the Baltic Sea and the North Sea that means areas outside of the national territory are not covered by these classic water laws. The protection of these are mostly regulated by international conventions. The fulfilment of obligations of these conventions are in the responsibility of the Federation.

Measures in the fields of air pollution, waste management or chemicals, which are also partly very important for water protection, are regulated by federal laws. In these fields the Federation has the right to enact comprehensive laws. The execution of these laws, however, is also in these fields largely in the hands of the Laender authorities.

4. LEGISLATIVE REGULATIONS AND SUPPORTING MEASURES

4.1 NATIONAL REGULATIONS

The most important regulations within the field of water protection are the following three laws:

- Federal Water Act, (Wasserhaushaltsgesetz, WHG) in the version of 1976, (1)
- Waste Water Charges Act, (Abwasserabgabengesetz, AbwAG), 1976, (2)
  and
- Detergent Act, (Waschmittelgesetz), 1975, (3)

The 1976 version of the Federal Water Act, together with the water legislation of the various Lander, covers the entire field of water management. It imposes the following basic regulations on the discharge of waste water into waters:

- any release of waste water into waters is subject to the approval of an appropriate authority:

permission to release waste water many only be issued if certain minimum requirements are fulfilled, which comply with the generally acknowledged rules of technology. This means, for example, that municipal sewage must be purified in a fully biological way. This also applies for sewage released into coastal waters:

- management plans are intended to regulate the various uses of waters. Priority is given to obtaining drinking water. Particularly strict requirements can be imposed on the treatment of sewage and waste water.

The 1976 Waste Water Charges Act concerns the following basic regulations:

- a levy is payable on the release of waste water into waters, and this is assessed according to the hazardous nature of the waste water. It applies regardless of whether the receiving waters are of good or poor quality;
- the levy is used for cleaning up the receiving waters.

Previously there had been no such levies, and this regulation represents a considerable improvement. It exerts and economic stimulus for the construction of more water purification plants, for improving the available sewage treatment, for the development of manufacturing processes producing little or no waste water and for the introduction of such processes as well as a reduction in the amount of products that can only be manufactured with large resulting quantities of waste water, and for the more limited use of such products.

On the basis of Article 7a Federal Water Act up to now 27 General Administrative Regulations (4), containing minimum requirements for the discharge of wastewater into waters have been enacted. Another 5 General Administrative Regulations are ready to be issued in the near future.

On the basis of the Detergent Act of 1975 two Administrative Regulations have been enacted, setting minimum requirements for the degradability of anionic and non-ionic tensids (at least 80 %) (Administrative Regulation concerning Tensid) (5) and the concentration of phosphate in washing and cleansing agents (Administrative Regulation concerning the maximum amount of phosphate) (6).

4.2 EEC-REGULATIONS (= supranational regulations)

As well as the Federal Government with his environmental program of 1971 the European Economic Community began a large action-program concerning environmental protection by a corresponding declaration of the council in 1973 (7). EEC-regulations concerning environmental protection are enacted in form of directives pursuant to Article 100 and Article 235 of the Agreement on the foundation of the European Economic Community (8). National legislation is being increasingly supplemented by the lawgiving activities of the European Community. In the past 10 years more than 50 directives concerning environment have been laid down which are binding for the member states. Within a certain period, mostly 2 years, the member states have to transfer these directives into national legislation.

In Table 1 EEC-directives relevant to water protection (the offical titles of the directives are listed in the chapter References) are listed (9-31).

The most important of all these directives is the "Water Protection Directive", the so - called ENV 131, in its basic function for far-reaching requirements for the discharge of pollutants not only into waters but also into sewerage systems (indirect discharge). This directive represents a framework, i.e. concrete requirements for particular substances are set in special follow-up or execution directives. Up to now, two follow-up directives were enacted:

- Directive on mercury-emissions of chlor-alkali electrolysis industry
  and
- Directive on cadmium discharges.

Other follow-up directives are in preparation, at present a directive on mercury discharges by sectors other than the chlor-alkali electrolysis industry is discussed.

Besides the directives exists furthermore a decision of the council on introducing an uniform procedure for exchange of information on quality of surface fresh water in the EEC (31).

4.3 INTERNATIONAL REGULATIONS

4.3.1 COUNCIL OF EUROPE

Even before the EEC became active in the fields of water - and environmental protection, the Council of Europe passed some important resolutions. So on May 6, 1968 the European Water Charta was declared which pointed out for the first time internationally the significance of water as base for life and economy and which put water protection within the field of water management in the centre of interest as a priority task to be solved internationally.

Table 1. EEC-Regulation (9-31)

Directives		Decision
- Degradability of tensid (3 directives)	- Waste from the titanium oxid industry	- Exchange of information on quality of surface fresh water in the EEC
- Waste oil disposal	- Toxic and dangerous wastes	
- Quality objectives for surface water for drinking water abstraction	- Ouality of fresh water to support fish life	
- Waste	- Phyto-pharmaceuti-cal products	
- Quality of bathing water	- Classification, packaging and labelling of dangerous substances	
- PCB's and PCT's	- Methods of measurement analysis surface waters for drinking water abstraction	
- Protection of surface waters	- Waters favourable to shellfish growth	
- Mercury from chlor-alkali electrolysis industry	- Groundwater	
- Cadmium	- Ouality of water for human consumption	
- Issue and application of dangerous substances		

In 1968 the important "European Agreement on Detergents" (32, 33) was passed which contains similar regulations as the above mentioned "Administrative Regulation concerning Tensids" (5) resp. the corresponding EEC-directives on the degradability of anionic surfactants (9, 10, 29, 30). In 1972 this agreement was transferred in the Federal Republic of Germany by law into national right (33).

Furthermore it is necessary to point to the preparation of a "European Water Protection Convention" which exists only as a draft.

4.3.2 INTERNATIONAL RIVER BASIN CONVENTIONS

Internationally agreed regulations and programs - especially for rivers belonging to several countries - are very important for a succesful water protection. As effective instruments are to denominate international river basin commissions as it was set in force, e.g. 1961 for the rivers Mosel (34) and Saar (35) and 1963 for the river Rhine (36). Within the scope of the International Commission for the Protection of the Rhine against Pollution there have been conventions since 1976 governing the reduction of salinity (37) which is unfortunately not yet in force - and the avoidance of chemical pollution (38). A convention on limiting the thermal loading of the Rhine is being drawn up.

Extensive water protection measures were agreed upon in the International Commissions for the Protection of the Mosel and Saar Against Pollution and also in the Water Protection Commission for Lake Constance (39).

On the basis of bilateral agreements the Federal Republic of Germany looks after the interests of boundary waters together with its neghbouring countries.

4.3.3 CONVENTIONS ON PROTECTION OF THE MARINE ENVIRONMENT

Appropriate conventions exist as regards the prevention of pollution of the marine environment: these conventions also contain guidelines on the prevention of pollution of the marine environment outside the EEC. The most important international regulations are:

- Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (Oslo 1972) (40)
- Convention for the Discharge of Waste into the Sea (London 1972) (41)
- Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki 1974) (42)
  and
- Convention for the Prevention of Marine Pollution from Land-Based Sources (Paris 1974) (43).

The Federal Republic of Germany participates in the work of the member country commissions set up by the Conventions.

4.3.4 UNO, OECD AND NATO

For the sake of completeness it is mentioned that there exist partly extensive works within the OECD, the UNO and even NATO in the field of water - and environmental protection (Table 2).

Table 2. International activities on water protection. Regulations with indirect effect for the water protection

UNO	OECD	NATO
UNEP	Recommendations, e.g.	CCMS:
1972 Conference Stockholm	- Analytical methods Degradability of Tensids	Study: Advanced Wastewater treatment
1982 Conference Nairobi	- Control of Eutrophication of Waters Control of Pollutants Testing of Chemicals	
ECE		
1980 Principles - Water Protection		
1982 International Co-operation - Commun Water Resources		

Tasks of the UNO – important for the Federal Republic of Germany – are executed within the European Commission of Economy (ECE). So in 1980 e.g. very important principles in the field of water protection were adopted and in April 1982 passed a further resolution concerning the international co-operation as regards commun water resources.

Within the Organisation for Economic Co-operation and Development (OECD) since many years recommendations in the field of environmental protection are prepared by various groups of experts. These recommendations often served as a basis for supra -and international regulations and measures. Important for water protection are e.g.:

- Recommendations on methods of determing the degradability of anionic and non-ionic tensids,
- Recommendations on the control of water eutrophication,
- Recommendations on strategies of controlling specific pollutants,
- Test guidelines and principles for Good-Laboratory-Practice (GLP) and
- Methods of testing chemicals on properties relevant to the environment.

Within the North Atlantic Treaty Organisation (NATO) the Committee on the Challenges of Modern Society (CCMS) was created in 1969 to assist member states in the exchange of technical research and in co-operative projects on commun problems. So in 1980 a study on Advanced Wastewater Treatment was finished.

4.4 REGULATIONS WITH INDIRECT EFFECTS FOR WATER PROTECTION

More and more the interaction of the various environmental media are realized, e.g. air, water and soil mutually and as living space for human beings, animals and plants. The transformation of these understandings into legal regulations, however, may be duplicated only step by step.

The following regulations are indirectly of partly great importance to water protection:

- Chemicals Act (ChemG) on protection against dangerous substances (1980) (44); this law is based on the
- EEC-Directive relating to the classification, packaging and labelling of dangerous substances (1979) (22)

During the time before the Chemicals-Act came into force on January 1, 1982 inter alia the following ordinances have been enacted:

- Ordinance on existing chemicals (1981) (Art. 28 para 2, ChemG) (45),
- Ordinance on the notification and the dossier of data (1981) (Art. 10 para 1, ChemG) (46) and
- Ordinance on designating the competent anthority to recieve the notification according to the Chemicals Act (1981) (Art. 12 para 1, ChemG) (47).

Other important regulations are:

- Federal Immissions Control Law (BImSchG) for the prevention of harmful effects on the environment caused by air pollution, noise, vibration and similar phenomena (1974) (48),

- Ordinance on limiting PCB, PCT and VC (1978) pursuant to BImSchG (49),
- First general administrative regulation pursuant to BImSchG:
  Technical instructions for maintaining air purity (1983) (SO),

- DDT-Law (1972) (51),
- Waste disposal Act (AbfG) (1972) and amendment (52) of 1982 as legal basis for
  - Ordinance on sewage sludge establishing limit values for heavy metals in sewage sludge and soil receiving sewage sludge (53),
- Plant protection Law (1968) (54) which is revised at present,
- Federal law on epidemic diseases (1961), last amended in 1975 (55) as basis for the
  - Ordinance on drinking water (1976) and (1980) (56),
- Foodstuff Law (1974) (57),
- Environment statistics Law (1974 and 1976) (58) as basis for offical statistical investigations and until now three
  - Ordinances on the harmfulness of wastewater (1975, 1977, 1979) (59-61).

4.5 SUPPORTING MEASURES

Besides this rather extensiv package of regulations a lot of supporting measures with important effects for water protection are undertaken by the Federation and the Länder (estates), some of them are, e.g.

4.5.1 INVESTMENT AID

For the construction of treatment plants and sewerage systems municipalities invested approx. 39 Mrd. Deutschmarks (DM) only in the time from 1971 to 1982, merely since 1975 27 Mrd DM. About one third hereof was given as investment aid by the Federation and the estates.

The grants of the Federation are from:

- Rhine-Lake Constances-Programmes (1972 to 1982),
- Community task "Amelioration of the agrarian structure and the protection of the coasts" and
- Community task "Amelioration of the regional structure of economy".

In addition to that in the years from 1975 to 1981 favourable credits up to a total of 2.13 Mrd DM was granted from the ERP-Wastewater Treatment Program.

4.5.2 RESEARCH AND DEVELOPMENT PROJECTS

The preparation, the execution and the realization of regulations concerning water protection require as a rule an intensive accompanying research.

The necessary means for this are to be raised mainly by the public authorities.

So, the Federal Government raised since 1975 in the field of water protection about 250 Mill. DM for research and that essentially in the frame of the research point "New technologies of wastewater- and sludge treatment" of the Federal Minister of Research and Development (BMFT) and in addition to that within the environmental research plan (UFOPLAN) of the Federal Minister of the Interior (BMI) for the development of legal norms in the field of water protection.

In the scope of basic research of the German Society for the Advancement of Scientific Research (DFG) since about 1975 means of annually 20 to 25 Mill. DM could be raised for projects in the field of water protection. Other bodies for research are in this connection the EEC, board for water management and the estates which are responsible for the execution of the water laws.

4.5.3 REPORTS OF THE COUNCIL OF EXPERTS FOR ENVIRONMENTAL QUESTIONS

In the beginning of the 1970's a Council of Experts for Environmental Questions was appointed by the Minister of the Interior. This Council published since then, in addition two comprehensive annual reports (62, 63), also other important reports concerning water protection, such as:

- Wastewater charge (1974) (64),
- Environmental problems of the Rhine (1976) (65) and
- The state of the North Sea (1980) (66).

These reports helped to work off and to assess the existing knowledge, to inform wide sections of the population, as well as to initiate further discussions among experts and politicians.

4.5.4 MONITORING PROGRAMMES

The success of any measure concering water protection stands and falls with the efficiency of its control. For this purpose every wastewater discharge and all important waters are monitored in the frame of individual monitoring programmes.

Relating to emissions, in the case of wastewater discharges, the objective a sensible combination between a regular self-control of the manager of a wastewater treatment plant and a more seldom practised control of the authorities. The motive powers for this monitoring system are the Wastewater Charges Act (2) which became effective on January 1, 1981 and the new minimum requirements pusuant to Article 7a Federal Water Act (4).

In the field of immissions various monitoring programmes are practised by the Federation and the estates relating to the different requirements on waters concerned. The following monitoring programmes merit to be mentioned:

- Monitoring programmes of the German and International Commission for the Protection of the Rhine against Pollution,
- Monitoring programme of the International Commission for the Protection of the Mosel and Saar against Pollution,
- Monitoring programme of the International Water Protection Commission for Lake Constance,
- Monitoring programme of the working groups of the Laender for the conservation of the Elbe and Weser,
- Commun coastal monitoring programme of the Federation and the Laender,
- German-Dutch monitoring programme for the conservation of the Ems-Estuary,
- Monitoring programmes of the German Hydrographic Institute (DHI) for physical and chemical investigations of the North Sea and the Baltic Sea in the area of the high seas,
- International monitoring programmes in connection with the conventions for the Protection of the Marine Environment.

These monitoring programmes are regulary adapted to new knowledge and requirements. The results of the investigations are normally published in the form of annual reports and numerical tables.

5. RESULTS OF WATER PROTECTION MEASURES

Considering the enormous effort which was pursued especially in the last decade for water protection, successes did not fail to appear. Some examples will clarify this:

It has been possible to achieve a considerable increase in the number of treatment plants built. Whereas in 1969 approximately 35 % of the population had access to biological treatment plants, by 1981 this figure had risen to over 65 %. As a whole in the Federal Republic of Germany there are over 7.000 such treatment plants in operation, dealing with the sewage from more than 80 % of the population (Fig. 1).

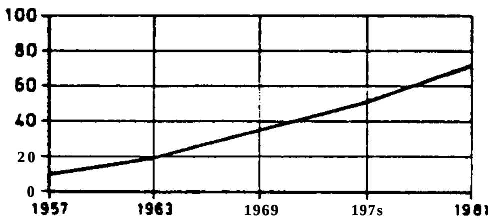

Fig. 1 Biological wastewater treatment in the FRG. % of the population connected to a public sewage treatment plant

One particular solution for treating wastewater that had previously been released into lakes has been the construction of sewage drains in a ring around these lakes, with a centrally located treatment plant below the lake itself. This has taken place with considerable success.

One of the main aspects of the water protection policy in the 1970's has been the cleaning up of Lake Constance, along with the Rhine and its tributaries (Rhine and Lake Constance Programme). Pollution is caused to rivers and canals by the pumping of bilge water containing oil by ships. Special vessels are now being used to prevent such pollution, and will accept such bilge water free of charge.

Investments by industry aimed at protecting waters have been in the scale of about 12 Mrd DM. So meanwhile it was possible to suppress largely the emissions of the hard to break down lignin sulphonic acid, furthermore in 1981 in one cellulose plant the chlorine bleaching was replaced by oxygen bleaching which is due to a reduction of the charge of chloro-organic compounds.

In a big plant of the chemical industry on the Rhine it was possible to reduce within a few years the emission of chromium by 99 8, of mercury by 94 % and of chloro-organic compounds by about 95 % with a combination of in-plant measures and putting into operation a central biological wastewater treatment plant. All these various measures have resulted in a measurable improvement in the state of waters.

Concerning this some examples from the river Rhine at the station of measurement Bimmen/Lobith at the German-Dutch boarder pursuant the measurements of the International Rhine Protection Commission:

The mean annual concentration of BOD_5 sank since 1971 from about 10 mg/l to 4 mg/l (Fig. 2), of Ammonium from 2.5 mg/l N to less than 1 mg/l N (Fig. 3); in the same time the average oxygen content rose from 4.3 mg/l to approximately 9 mg/l (Fig. 4).

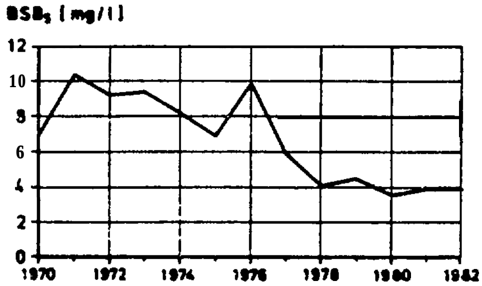

Fig. 2. Mean annual BOD_5 concentration Rhine-Bimmen/Lobith

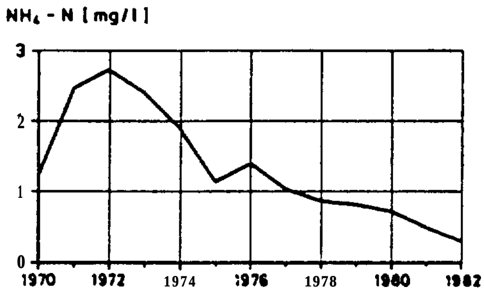

Fig. 3. Mean annual Ammonium concentration Rhine-Bimmen/Lobith

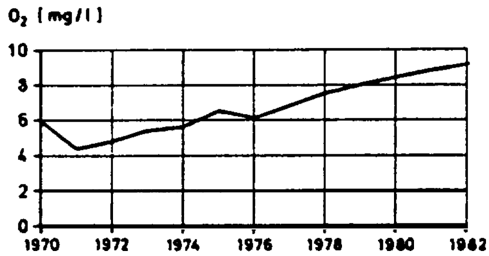

Fig. 4. Mean annual Oxygen-content Rhine-Bimmen/Lobith

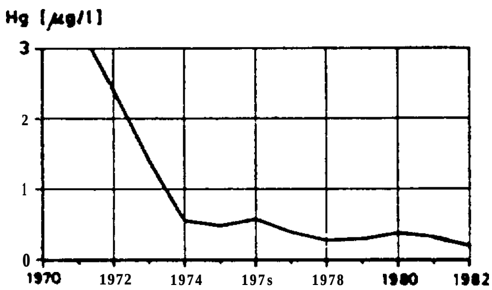

Fig. 5. Mean annual Mercury concentration Rhine-Bimmen/Lobith

Due to the important improvements concerning the technology of the chlor-alkali-elektrolysis the concentrations of mercury sank in the same time from about 3 µg/l to values less than 0.5 µg/l (Fig. 5). Similar reductions were detected for the various pollutants that do not easily decompose and which represent a hazard like DDT, PCB's, HCH and HCB.

6. CONCLUSION

With the survey of the numerous legal regulations and complementary measures which are despite their big quantity only a selection of all activities, it was organized a largely designed instruments for water protection.

Based on the Environmental Programme of the Federal Government in 1971 and by its addition in the Report of the Environment in 1976 (67), the Federation and the Estates are endevoured to follow consequently three principles of their environmental policy:

- the principle of precaution
- the polluter-pays-principle and
- the principle of co-operation.

The principle of precaution means: environmental policy is not limited merely to resisting menacing dangers and eliminating damage that has already occurred. The balance of nature as a whole must be protected and any claims made upon it should be as sparing as possible in order to maintain the ability of such systems to function over a long-term period. The principle of precaution imposes particular requirements on all levels of planning, and all planning decisions should take into account their possible effects upon the environment (environmental impact assessment). All those with a social and governmental responsibility are obliged to act so as to protect the environment. Moreover, relief in one area should not lead to added pressure in other areas. The interconnection should always be kept in mind between natural systems and those created by men, particularly those of a technical and industrial nature.

According to the polluter-pays-principle the costs of avoiding, eliminating or compensating for environmental pressures are to be borne by those causing them. This principle is one of cost accountability, and does not provide the basis for any obligations regarding damages or liability.

The main instruments for implementing such a principle consist of process and product standards, rules, prohibitions and special individual regulations. These also include offset regulations, producing an economic inducement for the originators of environmental pollution to reduce or compensate for such pollution from their own means and resources. This principle does not exclude the application of state funds in particular cases, if it proves impossible to determine who is responsible or if it is not possible to solve acute problems quickly enough.

The polluter-pays-principle represents the application of free-market principles to environmental problems.

The co-operation principle is a recognition that effective environmental policy relies on the co-responsibility and involvement of those concerned be they industry and science or the individual. For this reason it is both desirable and is indeed encouraged in the Federal Republic of Germany to involve various groups of society in the process of environmental initiatives and decision-making.

One indispensable basis for the preparation of programmes and steps to be taken in environmental protection is the involvement of science and research. A working group for environmental matters, the "Arbeitsgemeinschaft für Umweltfragen (AGU)", has been set up to ensure a constant exchange of information and views between state and all those effected by its actions. Environmental associations are working in this group with representatives of the various governments, industry and the trade unions.

Despite increased manufacturing activity and the rise in consumption, improvements have been achieved in a number of areas. In other areas it has at least been possible to avoid exacerbation of the situation.

Since about 1975 the quality situation of large surface waters in the Federal Republic of Germany has in part markedly improved or remained stable. Nevertheless the concentrations of hazardous pollutants such as heavy metals and halogenated organic compunds are still considered too high, especially with regard to drinking water supply.

Efforts should be made in the following direction:

- substitution of dangerous substances,
- more stringent discharge requirements on the basis of follow-up directives relating to the EC Council Directive 1976 for the protection of waters, especially the establishment of maximum permissible pollutant loads relating to specific production sectors or substances (for the particularly hazardous substances or groups of substances),

- follow-up (tightening) of the minimum requirements to be met by effluent discharges pursuant to the Federal Water Act,
- approximation of the requirements to be met by indirect discharges with regard to hazardous substances to those to be met by direct dischargers.

This environmental policy is being pursued uninterrupted in the 1980's, despite unfavouralbe developement of economic conditions.

Objectives for the future are to consolidate what has been achieved already and to build upon this basis. In this respect, efforts will concentrate on protecting actual resources and using them more carefully. The long-term aspects of all kinds of intervention in the balance of nature must be studied and taken into account to a greater extent than has so far been the case. We must learn to understand the balance of nature as an overall system in which negative effects often appear in areas where no direct involvement is apparent.

The maintenance and improvement of the environment on a domestic and an international level is a common goal of all the major political and social forces in the Federal Republic of Germany. Environmental protection is regarded by our population as being of major significance. This is apparent, for example, in the work of environmental associations and citizens' action groups.

The problems mentioned above cannot be solved by any nation on its own. Whether the solutions refer to specific regions or are world-wide ones they must be prepared and carried out by many people working together, and we must act according to the knowledge at our disposal. The Federal Government is prepared to play its part.

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REVIEW OF CHANGES IN STATE OF ART, METHODS AND MEASURES FOR WATER PROTECTION IN POLAND IN THE YEARS 1974 - 1983

Zdzisław Jarmołowicz
National Inspection for Environmental Protection
Poland

1. INFRASTRUCTURAL, ECONOMIC AND ECOLOGICAL PRECONDITIONS

In the period under review in Poland particularly dynamic development processes of various technologies and first of all industrial ones have occurred. Owing to the natural location of the northern macroregion of Poland, closely connected with the Baltic Sea, especially rapid development of maritime economy and other complementary industrial branches has occurred there. Location and extension of harbours within the seaside zone of Poland contributed to the development of shipyard industry, trans-shipment and other maritime branches. The development of industry has also caused dynamic urbanization processes and development of centralized industrial areas.

That concentration mechanism under the influence of maritime economy has particularly occurred in the regions of agglomerations of the Vistula river estuary and the Odra river estuary.

In those regions essential demographic changes resulted from a considerable increase of population. Strong development of maritime economy and other industrial branches of various interdependence with seaside location has caused some disproportions in the sphere of technical and social infrastructure in both of those harbour agglomerations.

The area of Poland nearly totally, i.e. in 99.9 % belongs to the catchment of the Baltic Sea. That catchment covers the area of 311 400 km^2 and includes the drainage-basin of the Vistula river - 174 300 km^2, of the Odra river - 106 200 km^2 and parially of the rivers of the littoral zone, Pregola and Niemen.

Thus, it is evident that the pollution load is discharged into the Baltic Sea almost from the whole area of Poland and is transported mainly by the Vistula river and the Odra river.

However, the sanitary-epidemic state is, first of all, influenced by the pollution sources located in the seaside zone.

The number of those sources has increased owing to the dynamic development of complementary industrial branches to the maritime economy, and by the essential demographic changes.

That situation is illustrated by examples in Tables l-5. E.g. the Gdańsk agglomeration introduces into the coastal sea waters in the direct and indirect discharges approx. 90 million m^3 of waste water per annum (therein approx. 75 % of municipal sewage).

Table 1. Share of particular pollution sources in annual load of organic substances discharged from the area of Poland

No	Source of pollution	BOD_5 t O_2/a
1.	Vistula river	183 300
2.	Odra river	52 530
3.	Rivers of the littoral zone	11 680
4.	Direct spot discharges	13 010
	Total	260 520

Table 2. Specification of amounts of waste water in 1981

No of Voivodeship		Amount of waste water in mill. m^3/a
1.	Elblag	43.3
2.	Gdańsk	117.5
3.	Koszalin	35.3
4.	Słupsk	23.5
5.	Szczecin	166.9
	Total	386.5

Table 3. Specification of the amounts of pollution emissions

No of Voivodeship		Dust pollution emissions in 1 000 t/a	Gaseous pollution emissions in 1 000 t/a
1.	Elblag	6.7	4.5
2.	Gdańsk	24.8	50.9
3.	Koszalin	4.4	6.4
4.	Słupsk	3.2	3.9
5.	Szczecin	38.8	165.5
	Total	77.9	231.2

Table 4. Specification of industrial wastes and municipal sewage generated in the seaside voivodeships

No of Voivodeship		Industrial wastes in 1 000 t/a	Municipal wastes in 1 000 t/a
1.	Elblag	899.4	161.1
2.	Gdańsk	9 025.0	610.3
3.	Koszalin		192.0
4.	Słupsk	122.4	111.5
5.	Szczecin	29 288.4	490.8
	Total	39 335.2	1 565.7

Table 5. Dynamics of changes in population number in the seaside voivodeships in 1975 and 1981

No	Voivodeship of	1975			1981		
		Nunber of pop. total in 1 000	% of pop. in towns	Number of pop. per km2	Number of pop. total in 1 000	% of pop. in towns	Number of pop. per km2
1.	Elblag	423	53.8	69.3	446	57.6	73.1
2.	Gdańsk	1 249	75.4	169.1	1 345	76.3	181.9
3.	Koszalin	435	57.1	51.3	465	60.6	54.9
4.	Słupsk	356	49.2	47.8	374	53.0	50.2
5.	Szczecin	854	72.0	85.5	907	73.9	90.8

In the areas of the seaside voivodeships the emission of dust and gaseous pollutions in 1981 was reduced in comparison with 1980 by:

32 229 tons / annum - dust pollution
12 503 tons / annum - gaseous pollution.

The amount of the emitted dust and gaseous pollutions from industry reges from:

50 t/km^2 in the voivodeships of Gdańsk and Szczecin
to 5 t/km^2 in the voivodeships of Elblag, Koszalin and Słupsk.

A crucial influence on the amount of dust pollutions have heat and power generating plants, shipyards and gas-plants.

In the seaside zone only the voivodeship of Koszalin represents the area of almost natural parameters of the natural environment. The other voivodeships include the areas which are more or less degradated.

The aggravated pressure on the environment, and first of all the marine environment has caused serious effects in form of excessive pollution, mainly of the coastal water bodies and resulted in occurrence of individual disease epidemics in fish. The further development of that macroregion has been hampered by the essential ecological barrier, which undoubtedly can not be surpassed. Bearing in mind the above, in result of the signing inter alia of the Helsinki Convention, Poland has taken a number of actions and measures for counteracting the progressive degradation of the marine environment.

2. CHANGES IN PRINCIPLES AND REQUIREMENTS FOR PROTECTION OF MARINE ENVIRONMEN AND PARTICULARLY SEA – WATERS

Directly after signing the Helsinki Convention in 1974 a program for the marine environment protection was elaborated.

That program involved:

1. Determination of quantities and types of pollutions discharged into the Baltic Sea from
   - land sources by water ways and as airborne pollution
   - ships and floating facilities
   - harbours and seaside objects
   - exploitation of the bottom and subsoil of the sea.

2. Forecast of the pollution increase up to 1990 relative to the planned development of the country.

3. Assessment of possibilities for pollution elimination: state of legal regulations; scientific and research works as well as control and investigation works under implementation.

4. Determination of particular requirements and tasks connected with implementation of the obligations arising from the Helsinki Convention provisions.

That program approved by the Decision No 44/77 of the Government Presidium dated April 29, 1977 has been under implementation.

That program is at present amended. Simultaneously work aiming at regulation of legal principles for the water environment including the marine environment was carried out. A part of those problems had already been regulated previously.

The process of modification and codification of the environmental laws was initiated with establishing the water law in 1974, which covered with its provisions internal sea waters, and in the range of water protection against pollution as well as flood protection it also refers to the territorial sea waters.

Some of the executory regulations are essential from the point of view of the responsibility for damage, and in particular legal acts concerning water protection, protection against flood, supervision of the water management and finally the water Management Fund.

The administration and legal standards dealing with the problems of damages are contained in 1956 Decree on the protection of the national frontiers.

A new legal act in that context is the Act of 1977 on the territorial sea waters of the Polish People's Republic.

The problem of utilization of marine living resources was regulated in 1977 by the Act on establishing of the Polish marine fishing zone. The earlier legal acts are dealing with the rational cultivation of the sea, i.e. Act on the geological law (1960) and Decree on the mining law (1953) as well as Chapter XX of the Penal Code of 1969 concerning pollution of the sea by harmful substances (Art. 140 para 1 item 2 of Penal Code) amended by Act dated June 7, 1982 which inreases fines for offences, and also the offence Code of 1977.

However, The Act mentioned above on the fishing zone establishing fines for offences (Art. 8 para 1) and the Act on the continental shelf of 1977 (Art. 8, para 1 and Art 8, para 2) should be considered as the turning point in the legislation policy in the sphere of penal responsibility for damages caused to the coastal state. Irrational cultivation or pollution of the sea cuases also civil-legal consequences.

The principal law in that range is the Act on the protection and development of the natural environment of 1980 inclusive the executory orders concerning the marine environment (Chapter 2 Art. 18 and 19). However, the text of the Act did not contain a particular regulation of the problem of the marine environment protection. That problem is to be regulated in a separate Act on the marine environment protection.

A sucessive draft proposal for that act is under discussion. As it has been mentioned above the fundamental importance for the water protection has the Water Law, which adapted inter alia to the internal law the provisions of Article 5 and Annex I of the Helsinki Convention (ban of the discharges of DDT and its derivatives and of PCB), and also some provisions of Art. 6 and Annexes II and III. Article 7, **para** 2 of the Water Law provided that its regulations concerning the protection of sea waters against pollution deal, first of all, with internal, and in a limited range territorial waters.

Waste waters discharged into those water bodies should not contain: easy settleable suspended matter, floating solids, oils in quantities causing visible spots on the water surface, substances causing a permanent smell and taste to the water or to fish in a catch, morbific bacteria, hazardous substances, heavy metals and other toxic substances in quantities hazardous to human health or harmful for the marine living resources as well as radioactive substances in quantities greater than determined by separate regulations.

Article 48, **para** 3 of the Water Law provides a total ban for general utilization of extraction of gravel, sand and other materials as well as cutting out of any plants. In accordance with Article 77, **para** 3 regulation and maintenance of sea waters and sea-shore belong to the competence of the marine administration bodies (Marine Boards in Gdynia, Koszalin and Szczecin).

Irrespectively of the Water Law, specific harbour regulations dealing with appriopriate equipment for ships securing the marine environment protection, especially oil separators of 15 ppm have been introduced. The harbour regulations introduced in 1980 established a ban for discharging pollution and damping of wastes in the territorial waters of Poland.

However, the supervision system and the system of administrative and legal prosecution of polluters of the sea waters outside the harbours is still inadequate. The level of fines is very low and does not create an effective repression instrument.

A separate package of problems involves matters concerning combating extreme hazards for the marine environment. Combating those hazardous impacts in the marine environment belongs to the authority of the marine administration, and on the sea-shore it is the obligation of the local government bodies co-ordinated on the merits of the case by the National Inspection for Environmental Protection.

The principles and methods of the procedure in that range have partially been elaborated, the others are still under elaboration and the technical equipment of respective service groups is still completed.

An essential influence on implementation of international requirements for the marine environment protection is brought about by respective Conventions ratified by the States concerned and by adapting the national regulations to the provisions of those Conventions.

The Polish People's Republic has ratified inter alia the following Conventions of IMO:

- on prevention of pollution of the sea by oils (OILPOL - 54),
- on intervention at open sea in case of oil pollution (Intervention - 69) inclusive Protocol on intervention in case of pollution by other substances than oils (Intervention Protocol - 73),
- on prevention of pollution of the sea by discharges of wastes and other materials (Dumping - 72),

- on civil responsibility for damages caused by oil pollution (CLC - 69).

However, the following Conventions have not been ratified yet:

- MARPOL 73/78,
- SOLAS 74/78,
- FUND - 71 and amendments to OILPOL - 54 of 1969 and 1971.

Those matters are essentially connected with the provisions of the Helsinki Convention.

Bearing in mind that a part of the provisions of MARPOL 73/78 enters into force in 1983 or by July 1, 1984, Poland has been taking respective measures for adapting and providing the ships with indispensable facilities.

The present state of equipment of the merchant marine and fishing fleet with those facilities is comparatively good. The new tonnage is constructed and aquipped on the basis of the international provisions of IMO. Whereas the ships under exploitation are successively modernized. The most expensive works connected with adaptation of 16 tankers to the requirements of MARPOL 73/78 - have already been completed.

The sea ports are provided, within the allocated investment limits, with specialistic equipment for washing, cleaning and reception of wastes from ships. Inter alia the Northern Harbour in Gdańsk has been provided with a treatment plant for ballast waters.

Poland has actively been participating in providing security for the shipping in the areas under the Polish jurisdiction in accordance with the provisions of the Helsinki Convention, i.e. in complying with relevant principles of transport and reloading of harmful and hazardous substances, establishing a reporting and warning system on the shipping of hazardous cargoes, establishing of open sea pilotage and delimiting permanent international shipping routes, etc.

3. INVESTMENTS AND OUTLAYS

The financial funds for investments in the range of the natural environment protection are mainly designated from the central or local budgets. Tables 6 and 7 illustrate the level of those outlays in the years 1976-1981.

Table 6. Investment outlays for the natural environment protection in the years 1976-1981 (according to voivodeships - current prices in million PLZ)

No	Voivodeship of	Year					
		1976	1977	1978	1979	1980	1981
1.	Elblag	45.2	245.6	363.2	698.3	311.4	106.7
2.	Gdańsk	173.1	321.2	270.0	248.8	287.2	274.5
3.	Koszalin	34.6	74.5	49.6	130.8	50.2	38.6
4.	Słupsk	33.0	45.0	24.7	16.2	31.5	25.7
5.	Szczecin	216.0	220.2	260.8	315.7	359.1	425.8

Table 7. Investment outlays for the air protection (according to voivodeships - current prices in million PLZ) in the yaers 1975-1979

No	Voivodeship of	Year				
		1975	1976	1977	1978	1979
1.	Elblag				46.2	166.5
2.	Gdańsk	120.1	9.7	103.3	105.0	97.9
3.	Koszakin	-	3.0	22.1	0.1	1.4
4.	Słupsk				0.1	-
5.	Szczecin	103.7	40.9	52.1	42.0	46.1

The greater investments, e.g. the sewage treatment plant in Elblag are financed from the central funds. However, the majority of the sewage treatment plants is constucted by the local funds.

The problem is partially resolved by additional financing from the fund of the water management and environment protection. A part of those centrally designated means remains at the disposal of the local authorities (voivodeships).

The outlays planned in the years 1983-1985 (for the seaside voivodeships) amount to 13.8 per cent of the national outlays for the investments under implementation. In the same period it is planned to designate for the new investments 3.6 milliard PLZ, therein in the voivodeship of Gdańsk - 1.9 milliard PLZ (52.8 %).

Among the most important investments in the sphere of the natural environment protection is to be considered the extension of the sewage treatment plants Gdańsk - East and Gdynia - Debógorze.

The investment outlays planned for the next years will involve:

1. Tasks in the sphere of combating oil spillages at open sea. Those tasks will be implemented by the Polish Salvage Company, responsible for technical matters of salvage in catastrophic cases.

Draft

Ships of PLO, PZM, PZB
canons, fishing
cutters, yachts

Radio station Szczecin
- " - - " - Witowo
- " - - " - Gdynia

support units
ships of PLO
salvage vessels
marine tugboats
tankers
Bunker vessles

Co-operating organisations
Navy
Frontier Guards
Polish Salvage Company
Chemical Salvage Stations
Organizations from the Baltic Sea states

Special aircraft units, Inspection units, coastal dxervation points

NATION?& CENTER
for
Marine Salvage

Operations Forces

Task commander
Oil barriers
Oil picks-up
Elastic tanks
Pneumatic boats
Helicopters and aircrafts, floating units, coastal salvage stations

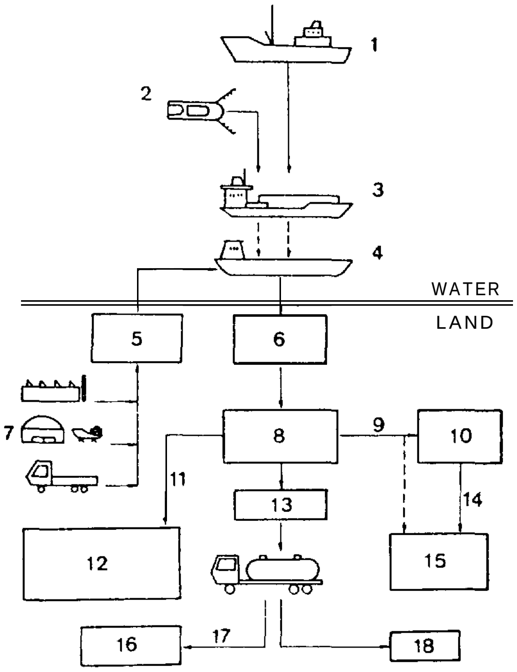
Military aircraft, Frontier Guards Units, Navyunits

Operation officer of the Neavy

support means
Picks-up "Vikoma"
Picks-up "Destroil"
Oil barriers
Floating tanks
Marine bumpers
Submersible pumps
Sorbents + air blowers
Dispergents + sprayers
Land service for combating spillages

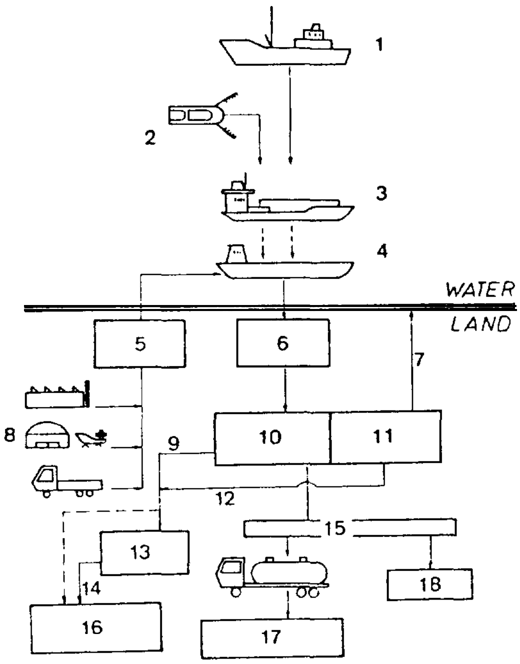
Fig 1. Organization structure of marine salvage services in Poland for preventian and compating of oil spillages.

Figure 1 illustrates the organization structure in that sphere established by Decision No 22 dated June 7, 1976 of the Minister of Foreign Trade and Shipping. Director of the Marine Board in Gdynia has been appointed to the post of the leading plenipotentiary in those actions. Figure 1 illustrates the present equipment for the salvage actions.



1. Merchant ships, fishing vessels and others
2. Oil collector
3. Tanker
4. Lighter - cistern without oil separator
5. Oil tank
6. Surge tank
7. Land back - up facilities of harbour and shipyard
8. Liquid fuels regeneration phant
9. Solid wastes
10. Incineration furnace
11. Waste water to sewerage system
12. Municipal mechanical - biological sewage treatment plant
13. Recovery of orude oil derivatives
14. Ashes
15. Municipal garbage dumping ground
16. Plant boiler houses
17. Boiler fuel oil
18. Commercial Center for Oil Industry (CPN)

Fig. 2 Diagram of reception of waters polluted by oils for harbours: Gdynia and Gdańsk.



1. Merchant ships, fishing vessels and other
2. Oil collector
3. Tanker
4. Lighter - cistern without oil separator
5. Oil tank
6. Surge tank
7. Treated waste water
8. Land back-up facilities of harbour and shipyard
9. Solid wastes
10. Liquid fuels regeneration plant
11. Oil-separated waste water treatment plant
12. Sludge
13. Incineration furnace
14. Ashes
15. Recovery of crude oil derivatives
16. Municipal garbage dumping ground
17. Plant boiler houses
18. Commercial Center for Oil Industry (CPN)

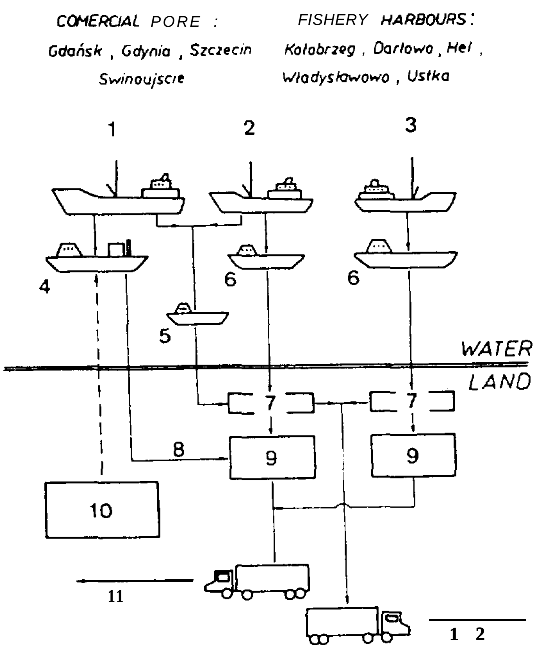
Fig. 3 Diagram of reception and regeneration of waters polluted by oils for harbour Szczecin.

It is plannet that the Polish Salvage Company will be provided with 3 sets of equipment for elimination of oil patchiness and modernization of tugboats and land back-up facility will be carried out.

2. Tasks in the sphere of wastes reception from ships and maintenance of cleanness in the harbour docks and basins.

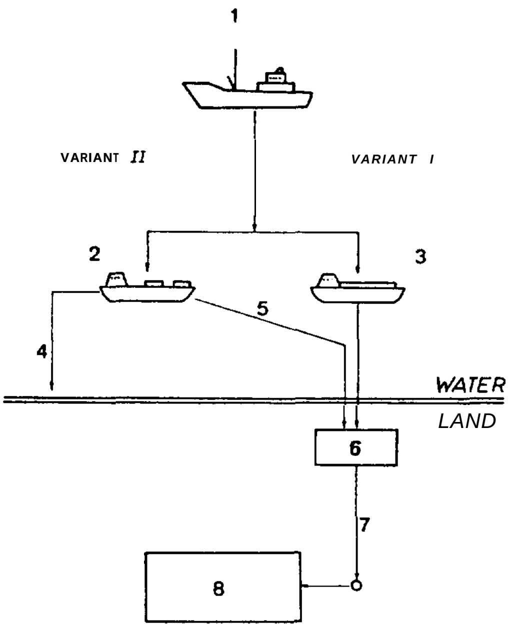
It is plannet to purchase transport vehicles and construct prototype floating vessels for collection of wastes and garbage from harbour water surface and reconstruct the sewage system in the area of the harbour of Gdynia.

Figures 2-6 present the organization schemes for reception of those pollutants.



1. Group I:
   Merchant ships out of the Baltic Sea
2. Group II:
   Baltic Sea merchant ships
3. Baltic Sea merchant ships and fishing vessels
4. Barge equipped with garbage incineration plant
5. Garbage from oleaning holds
6. Barge for garbage transport
7. Segregation
8. Ashes
9. Containers
10. Oil recovered in fuels regeneration plant
11. To garbage dumping ground
12. To Purchasing Center of Recyde Stock

Fig. 4 Diagram of reception and utilization of garbage from merchant ships and fishing vessels.



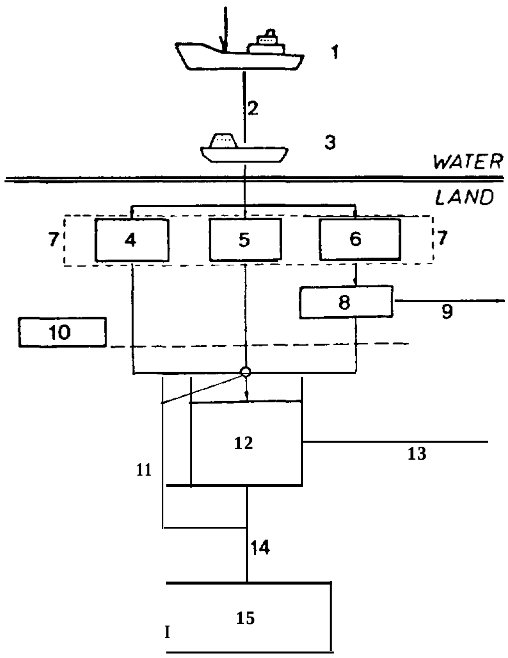
1. Merchant ships of the Baltic Sea and out of the Baltic Sea
2. Barge equipped with biological sewage treatment plant
3. Barge for reception, disinfection and sewage transport
4. Treated waste water
5. Sludge
6. Pumping station
7. To Municipal Sewerage System
8. Municipal mechanical-biological sewage treatment plant.

Fig. 5 Diagram of reception and utilization of foul Sewage from ships in harbours: Gdańsk, Gdynia, Kołobrzeg Szczecin, Świnoujście

3. Tasks in the sphere of modernization of merchant marine and fishing fleet.

It is assumed to replace the old type oil separators by new ones meeting the international criteria.

It is assessed that better effects in the sphere of the marine environment protection may be achieved in result of implementation of the program for construction of municipal sewage and industrial wastes treatment plants as fundamental measures for the purity of the Vistula and the Odra rivers to be located in the interior of the country and in the seaside zone.



1. Ship under cleaning
2. Washihgs from cleaning holds
3. Liqher-cistern
4. Acid washings
5. Alkaline Washings
6. Fatty washings
7. Primary tanks
8. Oil separator
9. Fat as recycle stock
10. Laboratory
11. Waste water - pretreatment not required
12. Chemical-mechanical pretreatment plant for washings
13. Sludge for utilization in municipal sewage treatment plant or to garbage dumping ground
14. Waste water to municipal sewerage system
15. Municipal mechanical-biological sewage treatment plant.

Fig. 6 Diagram of reception and neutralization of washings from cleaning rolds

4. SUPERVISION AND INSPECTION OF ABIDING BY REGULATIONS ON THE NATURAL ENVIRONMENT POLLUTION

At present working investigations on unification of the control-measurement system implemented by environment protection and sanitary service groups in the coastal waters zone as well as on the in-shore monitoring and in particular in the Gulf of Gdańsk and in the Gulf of Szczecin (Zatoka Pomorska) have been caaried out. The surveillance in the range of detection of pollutions is taken over by the aircraft team in Gdańsk. Technical tests with the helicopter "Falcon" (Sokoł), and also work aiming at the construction of a "surveyor" prototype has been carried out.

5. POLLUTION LOADS AND TECHNOLOGIES APPLIED

The estimated effects of reduction of the pollution load discharges into the Baltic Sea are difficult to determine at the present stage. At present work on elaboration of the protection program of the Baltic marine environment in Poland is carried out for the years 1983-85 and the following years.

Among the effects achieved so far, to the most spectacular ones belongs a ban on production and trade of DDT and its derivatives, and in consequence a reduction of DDT loads.

In connection with the above a systematic reduction of concentrations in the flowing up waters, mainly in the Vistula river, has been determined. A reduction of oil pollution from ships after starting operation of the ballast waters treatment plant in the Northern Harbour of Gdańsk has also been determined. The scientific and research as well as technological investigations have been carried out by numerous stations and scientific-research institutes. Those investigations are aimed at elaboration of technologies for reduction of pollution discharges directly in industrial plants and municipal works. However on September 1, 1983 a separate central agency dealing with the natural environment protection and the water management was established. Thus, it will be easier to co-ordinate numerous, hitherto scattered activities for the benefit of the environment protection, inclusive the marine environment. It is also assumed that certain amendments to the standards concerning the water protection against pollution will be made.

Annex 1

List of Legal Acts on Problems of Water Protection against Pollution in particular sea waters.

Laws

1) Act of April 19, 1969 - Penal Code (Nation. Reg. of 1969 No 13, para 94; amendm.: Nation. Reg. of 1974 No 27 para 157).

2) Act of May 20, 1971 - Code of Offences (Nation. Reg. No 12, para 114).

3) Act of October 24, 1974 - Water Law (Nation. Reg. No 38, para 230).

4) Act of January 31, 1980 - on protection and development of the natural environment.

Decrees of the Council of Ministers

1) Decree of the Council of Ministers of March 24, 1965 on establishing protection zones for water intakes and springs (Nation. Reg. No 13, item 93; amendm.: Nation. Reg. of 1970 No 22, para 181.

2) Decree of the Council of Ministers of October 30, 1975 on charges for special use of water and water installations (Nation. Reg. No 33, para 181).

3) Decree of the Council of Ministers of No 29, 1975 on classification of waters, criteria for waste waters and fines for violation of those criteria (Nation. Reg. No 41, para 214).

4) Decree of the Council of Ministers of August 6, 1976 – on works and activities forbidden in the vicinity of water installations (Nation. Reg. No 30, para 174).

5) Decree of the Council of Ministers of September 30, 1980 – on the natural environment protection against wastes and other pollutions as well as maintenance of cleanness and order in towns and settlements (Nation. Reg. No 24, para 91).

6) Decree of the Council of Ministers of September 30, 1980 – on detailed rules for creation and utilization of the Natural Environment Protection Fund and relevant bodies for managing of this Fund (Nation. Reg. No 24, para 94).

7) Decree of the Council of Ministers of September 30, 1980 – on detailed rules and procedure for the Minister of Administration, Local Economy and Environment Protection in the sphere of co-ordination of activities concerning the environment protection (Nation. Reg. No 24, para 95).

8) Decree of the Council of Ministers of September 30, 1980 – on the National Inspection for Environmental Protection and carrying out inspection in the sphere of the natural environment protection (Nation. Reg. No 24, para 96).

9) Decree of the Council of Ministers of September 30, 1980 – on organization, detailed rules and terms of reference for the National Council of Environmental Protection (Nation. Reg. No 24, para 97).

10) Decree of the Council of Ministers of September 30, 1980 - on principles of co-operation in the sphere of natural environment protection by the local bodies of the national administration with other bodies and organizations (Nation. Reg. No 24, para 98).

11) Decree of the Council of Ministers of September 30, 1981 - on the level, principles and procedure for administering and defining fines owing to violation of the natural environment protection requirements (Nation. Reg. No 24, para 99).

Other regulations

1) Act of December 17, 1977 on the Continental Shelf of the Polish People's Republic (Nation. Reg. No 37, para 164).

2) Decree of May 6, 1953 - Mining Law, unified text, (Nation. Reg. of 1978 No 4, para 12).

3) Decree of the Council of Ministers of June 2, 1978 - on detailed rules for protection of mining areas (Nation. Reg. No 15, para 64).

Harbour Regulations

1) Routine Order No 1 of the Director of the Marine Board in Gdynia of December 10, 1979. Harbour Regulations Reg. of Voivodeship Council in Gdańsk of 1980 No 1, para 1.

2) Routine Order of the Director of the Marine Board in Koszalin of December 30, 1972. Harbour Regulations - Reg. of Voivodeship Council in Koszalin of 1973, No 1, para 1.

3) Routine Order No 4 of the Director of the Marine Board in Szczecin of December 30, 1972. Harbour Regulations – Reg. of Voivodeship Council in Szczecin of 1973, No 5, para 26.

Orders of Ministers

1) Order of the Minister of Agriculture of November 8, 1977 on sewage disposal from ships (National Monitor No 30, para 149).

2) Order of the Minister of Agriculture of July 11, 1979 – on water measurement facilities and shipping marks (National Monitor No 17, para 108).

3) Order of the Minister of Helath on the sanitary regulations in sea ports and landing – places (Nation. Reg. of 1948 No 45, para 335; amendm.: Nation. Reg. of 1954 No 37, para 160).

4) Order of the Minister of Shipping No 31 of April 21, 1967 – on prevention of the sea pollution by oil introducing into force the provisions of the London Convention of 1954 with amendments of 1962 (Nation. Reg. of the Ministry of Shipping No 5, para 26, amendm.: Nation. Reg. of the Ministry of Shipping of 1968, No 1, para 5).

Orders of the President of the Central Agency for Water Management (CUGW)

1) Order of the President of the Central Agency for Water Management of February 7, 1969 – on the range and delimitation of the area boundaries for protection zones of water intakes and springs (National Monitor No 5, para 53).

2) Order of the President of the Central Agency for Water Management of April 18, 1971 – on classification of internal sea waters in respect of the permissible pollution (National Monitor No 27, para 175).

3) Order of the President of the Central Agency for Water Management of February 15, 1972 – on classification of a number of rivers in respect of their purity (National Monitor No 15, para 103).

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PROGRESS OF WATER PROTECTION MEASURES AND TECHNOLOGY IN SWEDEN 1974 - 1983

Gunnar Sedvallson
National Environment Protection Board
Sweden

1. STRUCTURAL CHANGES AFFECTING THE ENVIRONMENT

Changes in the location and production of industry and energy producing facilities, in agriculture, in transportation and in urbanization will have effects on the environment.

During the last decades the concentration of industrial production to fewer, bigger and more modern plants has been quite evident. Several new plants have been located to the south and west coasts of Sweden. Examples are oil refineries and petrochemical industries. At the same time many older plants in the inland and along the north coast have been shut down.

During the period 1970-1980 nine out of 38 iron and steel works were shut down. The production of crude steel has decreased from six million tons in 1974 to about four million tons at the beginning of the 1980's. Only two works are now producing steel starting from iron ore, one in Luleå on the Bothnian Bay, the other in Oxelösund on the Baltic.

There has been a drastic change in the structure of the Swedish pulp and paper industry. In the year 1970 there were 106 pulp and paper industries. During the 1970's 21 industries were shut down completely and 12 partially. The capacity at the remaining factories was increased and one new factory was constructed at **Bråviken** on the east coast. Despite the shut-downs the capacity for pulp production increased up to the year 1978 and has since then stagnated. The production of pulp decreased from 9.8 million tons in 1974 to 7.7 million tons in 1982. The pulp and paper industry is mainly located along the east coast and around Lake **Vänern.**

In the energy sector the production of electricity has increased in nuclear power plants and decreased in fossil-fuelled condense power plants. In urban areas more and more houses are heated by district heating. These and other changes mean that the burning of fuel oils has decreased from 21 million cubic metres in 1974 to 13 million cubic metres in 1982. This means lower emissions of sulphur and nitrogen oxides to the air and thus lower pollution of the Baltic Sea.

The urbanization process in Sweden has continued. In the early 1930's half of the population lived in the countryside and half in population centres with more than 200 inhabitants. Since then the population in the countryside has decreased, whereas 83 percent of the population lived in built-up areas in 1975. The trend has continued, but at a very slow rate. In recent years the population has even decreased in many large cities.

The population centres in Sweden are relatively small. Only 18 have a population of more than 50 000 (Fig. 1). The figure also shows the very uneven population distribution. Only one seventh of the Swedes live in the northern half of the country.

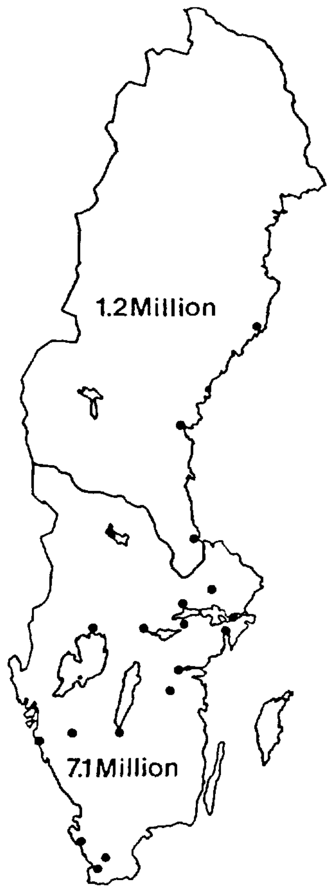

Fig. 1 Population distribution.City with more than 50 000 inhabitants ●

The growth of the urban areas entailed sanitary problems in and around the cities as a result of the discharge of waste water and the production of solid waste. The problems led to demands for countermeasures, and in the 1930's the first big treatment plants were constructed.

Transportation of goods and people has shown a great increase *in* the last decades. Goods are now to a greater extent than before transported by lorries, and people travel in private cars. That is one **of** the reasons why the emissions of nitrogen oxides increased from 115 000 tons in the year 1955 to 317 000 tons in 1978. Part of those emissions has undoubtedly been transported to the Baltic sea by streams and rivers or by direct deposition.

The centre of gravity of industrial production has shifted in a south-westerly direction. The population has increased more in Southern than in Northern Sweden. The consumption of fuel oils has decreased. These facts have had a profound implication on transportation in Sweden. The transportation increases have been bigger in Southern than in Northern Sweden. For certain products the transports in Northern Sweden and on the Bothnian sea have decreased.

The agricultural area in Sweden is 3 million hectares, which is equal to 7 percent of the land area, with a concentration of agriculture in Southern Sweden.

The increase in agricultural production per hectare during the last 30 years is a result of many factors, one of which is the increased use of fertilizers, Fig. 2. The efficiency of fertilizers decreases with increasing input. This means increasing amounts of nitrogen and phosphorus discharges to the environment at a higher intensity of agricultural production. The leaching of nitrogen is moderate up to 80 – 100 kg/hectare of application and is then very drastic, see Fig. 3.

The figure even illustrates the great dependence on climate (precipitation) for the annual run-off and thus the load on water courses.

The load of nutrients on groundwater and surface water from agriculture has increased during the last 15 years. As at the same time the load from municipalities and industries has diminished, the role of agriculture has increased. Since soils are "slow" systems big and rapid changes are not possible (except on sandy soils). However, as there are certain threshold effects in eutrophication, even smaller improvements are of importance.

The losses of nutrients to the environment can be diminished by:

- application rates of nutrients which are governed by the actual needs

- field production mthods which give greater safety

- much greater use of animal manure in agriculture

- storage capacity for manure products for application close to the spring sowing period.

The Swedish guidelines for animal production have been revised considering the increasing role of agriculture as a source of pollution by nutrients.

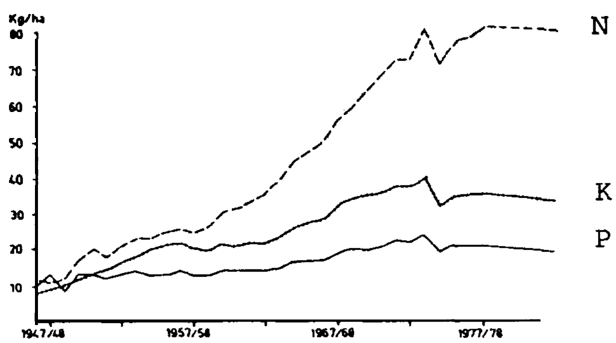

Fig. 2 The use of commercial fertilizers in Sweden 1947-1978 in kg/ha of nitrogen, potassium and phosphorus.

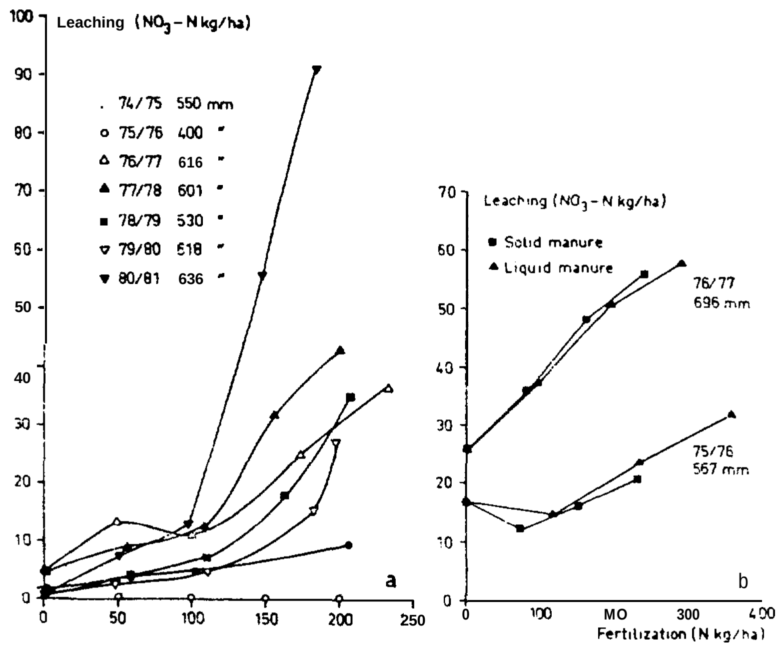

Fig. 3 Nitrate leaching as a function of nitrogen dose. From plot experiments with commercial fertilizer on clay (a. Lanna) and manure on sand (b. Plönninge). N Brink 1982.

The conclusion of the structural changes mentioned is that the location of activities in Sweden has shifted in a south-westerly direction. That sould lead to positive effects vis-à-vis the Baltic Sea and especially the Bothnian Sea. However, there are also changes negative to the Baltic Sea, e.g. the increased emissions of nitrogen compunds, acidification, and the increased comsumption of products with harmful consequenses to the environment.

2. WATER PROTECTION ADMINISTRATION AND WATER PROTECTION REQUIREMENTS

2.1 THE NATIONAL SWEDISH ENVIRONMENT PROTECTION BOARD

The Environment Protection Board is the central administrative authority in the environmental field, i.e. the authority which has to execute the decisions of Parliament and the Government in this field. The Board also has to watch over developments and to suggest any necessary measures to the Government. In some fileds of environment protection, the Board has a direct decision-making function, while in others it has influence as an expert or advisor. It is also the central supervisory authority under the Nature Conservancy Act and the Environmental Protection Act and the Act on Products Hazardous to Health and to the Environment and this involves a certain amount of control over the work of the county administrations.

Under the environment protection legislation, the Board has primarily advisory functions. It has also the right to appeal to the Government and to the Franchise Board. Under the legislation of products hazardous to health and the environment, the Board has a preparatory function, in that it furnishes office facilities to the responsible decision-making body. Under the Act prohibiting the dumping of waste in open waters and the Act on sulphur-containing fuel, the examination of applications for permissions and the admission of exceptions from general prohibitions or other general rules are the Board's duties. The means of control which the Board uses in most cases consists of subsidies, grants and supervision.

A central water protection authority has been one of the cornerstones of Swedish water conservation policy.

2.2 THE NATIONAL FRANCHISE FOR ENVIRONMENT PROTECTION

The Franchise Board for Environment Protection has functions similar to those of court of law. Its activity falls entirely within the schope of the Environmental Protection Act and consists chiefly in examinig applications for permits to carry on activities that are injurious to the environment, and to grant permits for such activities.

2.3 THE PRODUCTS CONTROL BOARD

The Products Control Board's field of activity lies within the framework of the legislation on products that are hazardous to public health and to the environment, and the Board is a completely independent authority. It issues general regulations for the handling, storage, etc. of products that are hazardous to health and the environment, decides on questions concerning the registration of pesticides, insecticides and weed-killers, and publishes lists giving guidance on poisons, dangerous substances, etc. However, applications for permission to trade, manufacture and use such products in individual cases are generally examined by other authorities.

2.4 THE COUNTY ADMINISTRATIONS

The County Administration is the regional authority for environment protection. The greater part of the decisions made under the Nature Conservancy Act and the Environmental Protection Act devolve upon the County Administration.

2.5 THE MUNICIPALITIES

Considerable responsibility as regards environmental protection falls upon the municipalities, in which the housing committee and the public health committee have a particular responsibility. Especially the public health committee has in recent years increasingly appeared as the municipality's environment protection agency.

2.6 WATER PROTECTION REQUIREMENTS

Permission must be sought to carry on activities which are adjudged to involve particularly serious interference with the environment. The Franchise Board and the county administration, which are the authorities which examine applications for such permissions – the Franchise Board examining the more complicated applications and the county administration the others – will notify the conditions as regards measures of environment protection, etc. which must be satisfied before the activity will be permitted to be carried out. In laying down the conditions, the starting point of the authorities will be what is technically feasible. The financial reasonableness will also be assessed and, in addition, public and private interests will be taken into consideration. The legislation also contains rules on supervision to complement the examination of applications for permissions. This refers both to activities for which permissions have been notified to the Board and other activities which in any way interfere with the environment. The supervision is exercised nationally by the Environment Protection Board and locally by the county administration. In some cases also the municipalities have voluntarily taken responsibility for parts of the supervisory work.

Legislation on the assessment of installations has made it possible to make assessments from case to case, thus avoiding fixed immission or emission standards. Such standards tend to tie the terms of permits to knowledge and values that soon become outdated. This has been particularly true of water quality problems in industry, where frequent changes in production have required now permits. In this way it has been possible to make use of the latest advances in wastewater treatment technology. The individual assessment prosedure has made it possible for new advances in this field to be applied promptly, thus greatly accelerating progress.

A typical permit for a municipal waste water treatment plant normally requires that the discharge concentration should not exceed 15 mg/l of BOD_7 and 0.5 mg/l of total phosphorus. Depending on the wastewater characteristics, the treatment process and the capacity of the recipient, the discharge permitted usually varies between 10-20 mg/l of BOD, and 0.2-1.0 mg/l for total phosphorus. Lately, nitrification has also been demanded for discharges in exceptionally sensitive waters.

Up to now, the environment protection efforts in industry have mostly concentrated on a number of very obvious and serious environmental effects calling for counter-measures. Examples of such effects are, in the aquatic environment, oxygen limitation resulting in fish mortality, severe discolouration and eutrophication of receiving water bodies. At the same time, the number of technically feasible alternatives to reduce discharges has been limited. In many cases only one technical solution has been possible. If that solution has been economically acceptable, it has been rather easy to agree on its implementation. The counter-measures have almost all aimed at reducing the total discharge of pollutants, as measured by for instance total flow, suspended material or COD. The greatest effects have primarily been achieved through internal process alterations and improved technique, and secondly by treatment of waste water. The BOD analysis has also been used to measure organic substances in general although this method in reality is related to an environmental effect, oxygen limitation.

Today, it has become clear that the long-term environmental effects, due for instance to discharges of persistent and toxic compounds, could be much more serious and more difficult to detect than the obvious effects which have been focused upon earlier. At the same time the main interest in the risk assessment has shifted from general considerations of the amounts of pollutants towards knowledge about the effects of the discharges. Also the number of economically acceptable technical means to reduce the discharge has increased. This implies that the authorities today have a much more difficult choice to make.

To speed up the investments in environmental protection equipment the Swedish Government used subsidies and grants. Subsidies are now used only for new technology or if the waste water is going to be discharged into especially sensitive waters. More than before, the problem is now to see to it that the equipment is used in the right way - that is a question of supervision for both industry and the authorities. The Environmental Protection Act was amended two years ago so that it is now easier than before to make industry or municipalities pay fines or fees if the discharge is higher than permitted.

It is now being discussed whether industry and municipalities should pay for permits and supervision in accordance with the Environmental Protection Act. That would be an extension of the "polluter pays principle".

2.7 CONTROL OF INDUSTRIAL LOCATION

For a long time it has been possible to prevent industrial facilities, which involved serious water pollution, from being inappropriately sited from the viewpoint of water quality protection. Thus in the mid-sixties steps were taken to prevent the establishment of a new pulp mill on the shores of Lake Mälaren, which provides about 1.5 million people with fresh water and which is also an important recreation amenity.

Due to factors such as the intense competition for coastal sites earlier, Parliament has decided to protect certain stretches of coastline from industrial development and to direct the establishment of heavy and environmentally disruptive industry to suitable areas. Industrial facilities of this kind may not be established without Government permission, which is preceded by a special assessment procedure in which other aspects besides environmental implications are taken into consideration.

3. INVESTMENTS AND ANNUAL OPERATING COSTS OF WATER PROTECTION MEASURES AND THEIR FINANCING

During the five-year period ending in 1974 investments in environmental protection measures within the industry were slightly more than SEK 400 million per year, on an average and in current prices. Subsidies from the Swedish state were around 30 per cent. Operational and capital costs for environmental protection measures have for the same period been estimated at SEK 1 000-l 200 million per ***year*** in ***current*** prices.

In 1979 investments in environmental protection measures in the industry were around SEK 500 million and that figure was estimated to increase to 600 million per year ***in*** the period 1980-1985, of which 55 per cent were for water protection measures.

The corresponding cost in 1979 was SEK 1 600 million and for the period 1980-1985 it was estimated at around 2 000 million per year.

During the six-year period ending in 1974 investments in municipal wastewater treatment plants were slightly more than SEK 400 million per year, ***on an*** average and in current prices. Subsidies from the Swedish state were nearly 50 per cent. Operational costs for treatment plants were around SEK 500 million in 1974.

In 1979 investments in municipal wastewater treatment plants were nearly SEK 500 million and they have been estimated to decrease to 280 million per year for 1980-1985, expressed in the prices of 1979. Operational costs for the period 1980-1985 have been estimated at around SEK 800 million per year.

A rough estimate of the investments in water protection measures in both industry and municipal wastewater treatment plants in Sweden in the 1970's amounts to SEK 500-700 million per year. The corresponding yearly costs are two-three times higher.

4. WATER POLLUTION CONTROL TECHNOLOGY, METHODS AND THEIR APPLICATION

4.1 MUNICIPALITIES

There are about 1 300 municipal wastewater treatment plants Sweden, treating a total of 1 500 million m^3 annually. This corresponds to a waste load of 9.4 million person equivalents (pe), of which 2.2 million are of industrial origin. Outside urban areas treating 0.3 million pe. Approximately 1 million people have their own sewage facilities.

Currently, 75 per cent of the urban population are served by advanced treatment plants equipped with biological treatment and chemical precipitation - 2 percent of these plants also have a final filtration unit. 2 percent of the population are served by plants equipped merely with primary clarifiers. Alum is the principal chemical used for phosphorus removal, but many large facilities have switched to iron salts. The use of lime is also increasing.

4.2 INDUSTRY

Industry has also considerably reduced the pollution load in its effluents. Internal measures were first applied, such as process changes or even applying new processes, use of new raw materials and better process control. If these measures did not prove sufficient external treatment was applied.

Smaller industries are often connected to a municipal sewage treatment plant but in many cases it is nevertheless required that those industries pretreat the waste water e.g. by pH-adjustment or

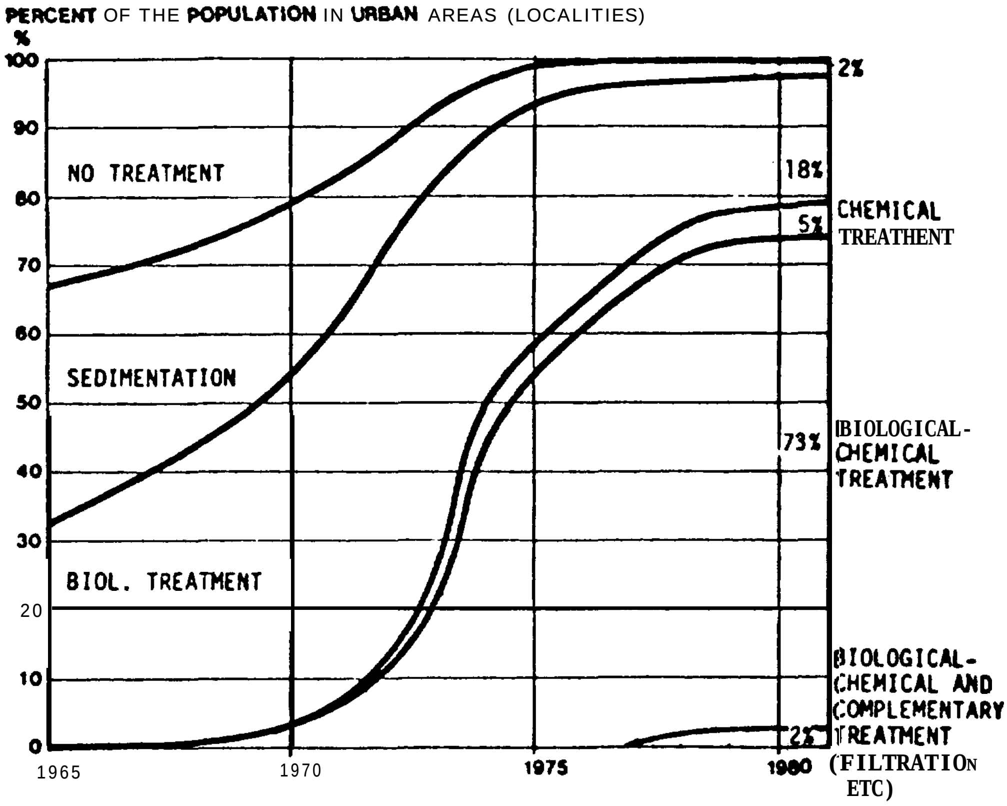

Fig. 4 Municipal wastewater treatment in Sweden 1965 - 1981

sedimentation. Heavy industry mostly has its own treatment plants. Nearly all pulp and paper industries have sedimentation basins for the waste waters. Chemical precipitation and biological treatment are also used to a great extent.

Those methods are also used in the iron and steel industry, the chemical industry and in oil refineries. Other methods used are oil separation and sand filtration. Most of the advanced treatment plants in industry were installed in the 1970's.

Generally, there are two ways to reduce the negative effects of a discharge. The first one involves considerations of the discharge itself. The discharge from for instance a chemical industry contains at least traces of all the raw materials and additives used as well as all the various wanted and unwanted products and byproducts of the processes in the industry. The discharge thus consists of a mixture of a great number of chemical compounds. In the predominant number of cases, it is not possible to make a thorough analysis of all these compounds, followed by a risk assessment of the different chemicals and finally of the discharge as a whole. In most cases it is more fruitful to look at the discharge as a whole from the start and in some cases to combine this approach with chemical analysis of a few selected compounds. According to today's thinking in Sweden it is desirable to test discharges (or part-streams) directly with biological test methods. The negative effects thus indentified can then be reduced by external measures or by changes in the industrial processes. The different measures of interest could be tried on a laboratory scale, and the resulting wastewaters could then be subject to further biological tests. In this way it is possible to select the purification method that is most appropriate from the environmental point of view, without having to do a very extensive, and expensive, chemical analysis.

The second way to reduce the negative environmental effects of a discharge concerns the different chemical additives used in the industry and other activities hazardous to the environment. This approach will be applicable where a lot of different chemicals are used, and where the chemicals pass through the industrial processes to the wastewater. The different chemicals used are evaluated and ranked according to environmental properties. If the chemicals in such an evaluation are interchangeable, it will be possible to substitute more harmful substances for less harmful ones for a given application. Three sectors have been studied in this respect in Sweden, namely the tanneries, the textile industry and the paper industry. Certain groups of chemicals that are widely used in society have been identified as being of interest for this type of study. Consequently projects on surfactants and synthetic lubricating oils are presently running.

Close co-operation between industry and the environmental authorities has played an important part in the development of water protection measures.

5. ESTIMATED EFFECTS OF WATER PROTECTION MEASURES ON THE POLLUTION LOAD OF THE BALTIC SEA

As can be seen from Figure 4 the 1970's can be characterized by a very quick introduction of advanced methods for the treatment of municipal sewage water. As a consequence the content of polluting matter in the sewage waters has decreased drastically.

5.1 DISCHARGE FROM MUNICIPAL TREATMENT PLANTS IN 1980

Only plants located directly on the coast

ton/year	BOD_7	Total-P	Total-N
Bothnian Bay	1 470	62	480
Bothnian Sea	1 740	142	1 310
Baltic Proper	4 200	239	6 140
Total	7 410	443	7 930

The dominating emissions of organic matter measured as BOD_7 comes from the pulp and paper industry (Fig. 5), which has also very high emissions of fibres, measured as suspended solids. Even if most of those industries have now reduced their emissions considerably, and many have been shut down, there still remain very high loads.

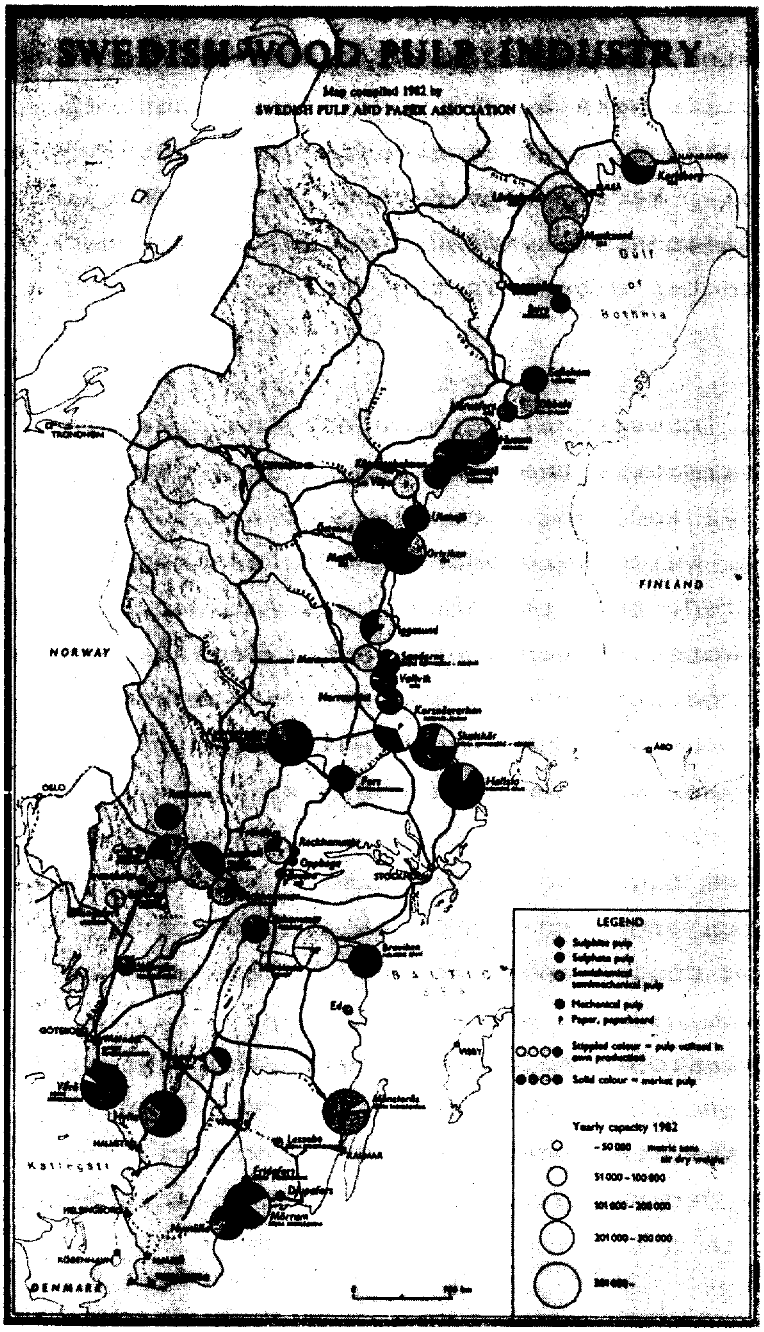

Fig. 5 Swedish wood pulp industry

5.2 DISCHARGE FROM THE PULP AND PAPER INDUSTRY IN 1981

Only plants located directly on the coast

ton/year	BOD_7	Suspended solids
Bothnian Bay	14 600	7 340
Bothnian Sea	86 300	30 400
Baltic Proper	28 250	5 550
Total	129 150	43 290
Total for Sweden	195 200	80 400

In the year 1975 the discharge of organic matter was 360 000 ton, measured as BOD_7, whereas the suspended solids were 90 000 tons. The amount of suspended solids did not decrease so much between 1975 and 1981. Partly that depends on the fact that the emissions of suspended solids were reduced to a much greater extent in the period 1969 to 1975.

The chemical industry situated along the coast re-leased approximately the same amount of organic matter in 1972 and 1982, according to the BOD_7-measurements, which were about 2 000 tons both years. The fact that the amount has not decreased in spite of water protection measures depends on changes in production. The amount of nitrogen-compounds on the other hand decreased from 1 970 to 60 tons per year between 1972 and 1982.

There are four big metal works along the coast, two producing iron and steel in Luleå and Oxelösund, one producing copper and lead in Rönnskär and one producing aluminium in Sundsvall. The environmental problems connected with those works are, of course, the considerable amount of metals released to the atmosphere and to the water. The amounts have decreased during the last decade, as can be seen in the example.

5.3 DISCHARGE OF METALS TO WATER FROM THE COPPER-SMELTER IN RÖNNSKÄR ON THE BOTHNIAN BAY

ton/year	1974	1981
Copper	28	5
Lead	30	4
Zinc	70	7
Cadmium	3.3	1
Arsenic	1 037	96
Mercury	0.6	0.1

The discharge of metals to the atmosphere from the copper-smelter in Rönnskär is higher than the discharge to the water. The atmospheric emissions will to some extent be deposited in the water and thus influence the environment in the Bothnian Bay.

Besides the direct discharges to the Baltic there are also discharges from the streams and rivers. The discharges of organic material, nitrogen and phosphorus compounds from the rivers are higher than the direct discharges from onshore activities. The total amount of organic carbon is 880 000 tons, which corresponds to an oxygen consumption of more than 2 000 000 tons.

5.4 DISCHARGE FROM STREAMS AND RIVERS IN 1980

ton/year	Organic carbon[1)]	Total-P	Total-N
Bothnian Bay	250 000	930	14 000
Bothnian Sea	470 000	1 240	23 000
Baltic Proper	160 000	750	21 000
Total	880 000	2 920	58 000

1) Measured with $KMnO_4$

As can be seen from the presented facts about water protection measures in Sweden, the emission of organic material measured as BOD and the emission of suspended solids and nutrients from industry and sewage treatment plants have decreased considerably since 1974. The discharge of metals from the big metal works has also decreased and it is probable that the total discharge of metals has also decreased.

This is to some extent due to the structural changes described above. Small and old industrial plants have been shut down and production has been concentrated to bigger and more modern plants. The construction of those plants has been relatively easy to adapt to new concepts of pollution control.

After all, discharges are still too high and the work to make them smaller must continue. A problem is the difficulty to correlate the diminishing emissions with positive effects in the environment. Special consideration should be given to the effects in the coastal area.

On the whole, technical problems in reducing discharges from point sources has now been solved - at least when it comes to conventional discharges like degradable organic compounds and nutrient salts. A remaining problem area is the emission of pollutants with large effects in space and time, many of them not even known to us today. Probably the most difficult problem and a problem that will remain for a long time is the pollution load from non-point sources as agriculture and deposition from the atmosphere.

NATIONAL STATEMENT OF THE RESULTS ACHIEVED BY THE GERMAN DEMOCRATIC REPUBLIC IN APPLICATIONS OF TECHNOLOGIES OF WATER PROTECTION AFTER THE CONVENTION ON THE PROTECTION OF MARINE ENVIRONMENT OF THE BALTIC SEA AREA WAS SIGNED

Klaus Winkel
Ministry for Environmental Protection and Water Management
German Democratic Republic

The Convention on the Protection of the Marine Environment of the Baltic Sea Area siqned on March 22, 1974 was ratified by the Staatsrat of the German Democratic Republic on November 5, 1976.

On January 6, 1977 the ratification document was deposited with the government of Finland being the depositary of the Convention.

Keeping the Baltic Sea clean and its protection – these are inalienable prerequisites for ensuring further use of the Baltic Sea in recreation system, traffic, fishery and civil engineering as well as for the purpose of water managing.

In this connection the German Democratic Republic proceeds from the basic idea that any efforts must be made to preserve environment for the human being in order to ensure that also future generations may peacefully co-operate and live together in the Baltic Sea area.

At this place I wish to draw your attention to the booklet published under the headline "Baltic Sea protected", which was already handed over by me to all delegations.

The progress made in the activities to protect marine environment of the Baltic Sea area was laid down in legislation, when the Water Act was passed by parliament of the German Democratic Republic, the People's Chamber. The Water Act together with its implementing regulations defining the general conditions regulates any activities related to utilization of the water resources in national economy as well as in the private sphere of the population. These legal regulations replaced the Water Act of April 13, 1963.

Said Act covers implementation of all tasks related with water management beginning with preparation of long-term conceptions on utilization of water, water supply and treatment of sewage up to maintenance of waters, protection from flood and of coastline.

Above law, which is binding on the whole German Democratic Republic, also fully covers, therefore, the catchment area of the Baltic Sea and, of course, includes the inland sea waters and territorial waters in its operation.

All binding requirements raised to utilization of water and waters as well as to its protection, which are in line with the modern state of science, were fixed in said complete legal regulation. To fully cover the need of potable water and water for industrial use it is urgently necessary to make use of water several times and to ensure its capacity of self-cleaning. Multiple ***use*** of water necessitates its profound cleaning, before it is returned to the cycle of nature. The cleaner the water discharged is the less are the harms caused to waters and the lower are the costs to be spent for repeated treatment. The costs to be spent for treatment in order to produce incontestable industrial water out of polluted waters will rise immensely in line with increase of the degree of pollution.

From point-of-view of national economy profound cleaning of sewage, ***on*** the other hand, will cost less than recovery of water for industrial use from severely polluted waters, because very complicated procedures of treatment will be necessary to be applied for this purpose. On the other hand, waste endangers life of plants and fish living in our waters and severely effects possibilities of recreation.

Under the instructions given by the council of ministers in relation with efficient utilization of water load of waters shall be reduced during the period from 1981-1983 by means of profound cleaning of sewage to such dimension, which is equivalent, on an average, to the annual quantity of sewage produced by households of five million inhabitants.

The provisions of para 2 of above Act request to protect water and waters from influences, which may effect their utilization, endanger life and health of citizens, and lead to harms in national economy, flora and fauna or to other adverse consequences. Therefore, the principle is applicable that a ***consent*** will be necessary, if due to use of waters adverse effects may be caused.

The requirements of protection defined in para 24 of above Act generally request to deal with solid matter, liquids or gases in such a manner that water of water supply plants as well as waters will not be exposed to adverse effects.

Under the provisions of the Water Act the polluter having caused spillage of noxious substances is responsible to combat it.

To increase effectiveness of the provisions relating to protection of water and waters dealing with highly hazardous substances noxious to water as well as long distance pipe lines which are to be established for carriage of any kind of substances noxious to water shall be notified under para 26 of said Act. Under those provisions storage of definite quantities of poisons as well as of mineral oils and their products, which may be different due to the degree of their noxiousness, must be notified to the National Water Inspection Board.

Legal powers of the National Water Inspection Board relating to their influence on harmless storage of substances noxious to water were much extended. Hereunder the National Water Inspection Board was empowered to check observance of the ligal obligation to deal with substances noxious to water in a not harming manner. As far as measures will arise there from, which are to be taken to protect waters, the National Water Inspection Board is authorized to impose appropriate injunctions. In this connection restriction, time-limit or prohibition of the activities notified is possible.

Since discharge of sewage may endanger or effect waters in many respects, necessary provisions were included in Article V of above Act referring to fixation and application of limit values. Thus quality of the term "limit value" which was applied so far in connection with use of water only was raised to a higher level.

The regulation which proved to be good will furtheron rule as main principle that sewage is allowed to be discharged within the limit values only fixed by the National Water Inspection Board.

The provisions of this regulation ensure that effects on the water will be restricted to an acceptable or unavoidable extent and will not lead to any adverse consequences.

The limit values fixed for the ingredients of the sewage were defined to be maximum values. Hereunder strict observance of those values is definitely requested at any time, otherwise material responsibility will be applicable. Enterprises are legally obliged to make any efforts to keep below those limit values. Hereunder they are induced not to make full use of the load of waters allowed to them for discharge of sewage. Rather they are requested to decrease sewage load by optimal operation and maintenance of the plants, improvement of efficiency, reduction of quantity of sewage, recovery of valuable substances out of sewage or by other possibilities.

Further progress was made, when the regulation to combat spillages of noxious substances in the Baltic Sea was adopted on March 11, 1982. Under the provisions of said regulation it is definitely fixed, what are the activities to be conducted by authorities and competent establishments for combatting spillages of noxious substances in the Baltic Sea. The preamble of the law explicitly refers to the Baltic Sea convention. The provisions of said law fix among others to form a commanding centre for combatting spillages of noxious substances at the Baltic Sea under the suspices of the Board of Navigation of the German Democratic Republic, where responsible members of all competent authorities are represented to co-ordinate the work. Two marine bases forming the material basis of the combatting activities are being equipped at Rostock and Sassnitz. Those marine bases will be able to comply with the time periods requested for initiating combatting activities in the coastal area of the German Democratic Republic. Under said regulation the legal principles are laid down for conducting efficient combatting activities.

The administrative tasks to implement the legal regulations are being fulfilled by the National Water Inspection Board of the German Democratic Republic for many years. They are the national body to regulate among others use of waters and check observance of the legal regulations pertaining to use and protection of waters and water. They enjoy extended legal powers to impose binding injunctions for use of water as well as use and protection of waters. Those injuctions may be enforced by sanctions. The tasks of the National Water Inspection Board are being executed by the Directorate of Water Management Coast. The very extended checking activities lead among others to an effective reduction of discharge of noxious substances into the water from land bases and thus also into the Baltic Sea.

After the Baltic Sea Convention was put into force on May 3, 1980 check of the degree of pollution and thus of further reduction of sewage load became a forcing necessity for all the coastal states of the Baltic Sea.

The Baltic Sea Convention is being implemented in the German Democratic Republic by means of the programme devised to keep the Baltic Sea clean. Said programme is being prepared and accounted for for a period which is identical with the period of the five-years-plan.

Such programme includes a number of activities referring to supervision and decrease of land-bases pollution as well as requirements directed against pollution of the marine area from ships trading there.

Below picture can be obtained from the analysis of the results achieved so far:

By establishing sewage treatment plants in areas, where waters are, in particular, endangered by discharges of sewage major improvements were attained in cleaning of domestic, industrial, and agricultural sewage.

During the period from 1976 to 1980 the sewage load was reduced – which also was due to the activities conducted at the Oder and Neisse rivers as well as on board the vessels and at ports – for 540 000 population equivalents. This is equal to a reduction of the load of sewage discharged for about 16 p.c.

To implement those measures a total amount of about 270 million marks was spent.

Those objectives were achieved among others due to construction of sewage treatment plants at Sassnitz, Barth, Wismar, Bützow, Schwerin, Neubrandenburg and Pasewalk.

In the catchment area of Oder/Neisse there the planned activities *were* continued at Eberswalde, Zittau and Görlitz.

In the field of marine and port service a bilge and ballast water treatment plant was put into operation at the Rostock sea port, which is an essential prerequisite for dealing with oily water.

In consequence of implementing the technical results achieved during research and development activities for treatment of oily waste water a total quantity of nearly 177 000 t of such waste water could be treated by means of the bilge and ballast water treatment plant and in this connection more than 14 000 t of oil were recovered.

By operating port cleaning boats at the Rostock and Wismar ports as well as at the Stralsund Volkswerft prerequisites were simultaneously created to clean the port water from oil and other pollutants discharged into the water.

As far as possible, the vessels of the fleets of fish industry as well as of shipping and port industry were equipped respectively additionally equipped with sewage treatment plants, bilge water de-oilers, faeces tanks, garbage containers and incineration plants for garbage. Such activities are being continued and prerequisites created to produce those plants.

The German Democratic Republic fulfilled their programme referring to monitoring cruises by operating 5 cruises per year, which cover a period from 2 to 4 weeks. During those cruises all monitoring stations existing in the appropriate trading area between the South of Kattegat and the Gulf of Finland are being called at and operated.

Standard regulations to classify quality of surface water were drafted for the inland waters and put into operation.

In this connection should be mentioned:

- Standard No. 22764 "Classification of quality of running water", binding as from March 1, 1982 as well as instructions for application of Standard No. 22764, binding as from April 1, 1983.

- Standard No. 27885/01 "Classification of still inland water", binding as from January 1, 1983.

- Instruction by the Directorate of Water Management Coast for classification of quality of sea waters of the German Democratic Republic, binding as from April 1, 1983.

By means of classification of surface waters a profound total idea of the quality of water can be obtained in consequence of comparative assessment of different criterions of graded concentration intervals. At the same time, the bases are hereby formed to take measures for protection of water and improvement of quality of water. The target to be achieved in this connection is among others to reduce discharges of noxious substances of high priority, viz. Cu, Pb, Hg, Zn, Cd, and oil.

FUNDAMENTAL TRENDS FOR THE DEVELOPMENT OF WATER PROTECTION ACTIVITY IN THE SOVIET UNION FROM THE MOMENT OF SIGNING THE CONVENTION OF THE PROTECTION OF THE MARINE ENVIRONMENT OF THE BALTIC SEA AREA

Leonid Soumin
The USSR Ministry of Land Reclamation
and Water Management
Union of Soviet Socialist Republics

The Convention on the Protection of the Marine Environment of the Baltic Sea Area, signed in Helsinki, had a wholesome effect on the implementation of the work in the Soviet Union aimed at marine environment pollution prevention.

A wide scope of measures on the fulfilment of this Convention was envisaged by the decree on intensification of pollution control measures in the Baltic Sea basin, adopted in 1976 by the Council of Ministers of the USSR.

In accordance with this State act the governing body of the ministries and organizations were obliged to take all necessary actions for implementation of a complex of measures ensuring by 1985 complete halt of untreated industrial and municipal water discharges into the rivers and other water bodies in the Baltic Sea basin.

In compliance with the program developed for the prevention of water pollution in the Baltic Sea, the construction of water pollution control works was developed in large scale in the cities, at enterprises and organizations situated in the Baltic Sea region, controlled by the Soviet government bodies of Union Republics and Water Inspections in the system of the Ministry of Land Reclamation and Water Management of the USSR.

As the Soviet side transferred to the Helsinki Commission Secretariat the USSR National Report for the 5th Meeting, which contained data on pollution loading in the Baltic Sea, in this paper there are only fundamental trends for the development of water protection of the Baltic Sea area since the Convention was signed.

In the Estonian Soviet Socialist Republic within the period from 1976 to 1982 over 580 municipal and industrial water treatment plants were constructed. The largest sewage treatment systems were constructed in the cities of Tallin, Narva, Kohtla-Järve, Pärnu, etc.

Considerable amount of work was completed on the construction of local treatment plants in the Kohtla-Järve industrial region. Local biological treatment plants with capacity of 55 000 m^3/day and a number of local treatment plants at the industrial enterprises of the region were built.

Besides, on the basis of the Soviet-Finland Working Group recommendations on water protection in the basin of Gulf of Finland, projects for construction of low capacity biological treatment plants with extended aeration and capacity of 25-1000 m^3/day were elaborated. During the period up to 1982 over 950 treatment plants were built and put into operation in the Republic in agricultural areas, which allowed to reduce the organic and biogenic loading into the sea from the catchment territory essentially.

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For the mentioned period in the cities, at working enterprises and organizations on the territory of the Lithuanian Soviet Socialist Republic 686 local water treatment systems were constructed.

Within the last years alone biological treatment plants were built in some cities and at 30 enterprises of milk and food industry and other branches of industry of the Republic, sewage treatment plants are being constructed in Vilnius, Klaipeda and other cities and at a number of enterprises.

When implementing water protection measures during the period from the moment of signing the Convention over 1 000 municipal sewage treatment plants mostly of low capacity were constructed in the Latvian Soviet Socialist Republic. Biological treatment plants are being constructed in Riga, Liepaja and other cities.

On the territory of the Russian Soviet Federative Socialist Republic in the Baltic Sea area water treatment plants were constructed at 17 industrial enterprises. Construction of such plants is being carried out in some cities and at 37 enterprises. In Leningrad a chemical-biological sewage purification plant is being constructed and the first stage with the capacity of 750 000 m^3/day is already under operation, the second stage of the same capacity will be put into operation in the near future.

Thus, during 1976-1982 in the cities and at operating enterprises located in the Baltic Sea area over 2 500 treatment plants and other water protection facilities were built, including 1 800 biological purification plants with total capacity of up to 4 000 000 m^3/day, that is about 60 per cent of all waste water.

Substantial work on marine environment protection was carried out on the ships of passenger, cargo and fishing fleet of the USSR in the Baltic Sea area.

All ships registered to home ports of the USSR zone are equipped with oily-water separators and filters, providing treatment of oily-water up to permissible limits (15 mg/l) or with accumulating reservoirs and systems, delivering oily-water to floating or coastal reception facilities. The ships are to be soon equipped with similar facilities for domestic sewage. Reception devices and facilities available in ports completely meet requirements for discharging sewage and garbage from ships.

Port operation service provides a twenty-four-hour control over aquatorium purity and effective guidance on elimination of accidental oil spills of small scale in the aquatoria of ports. For this purpose the Baltic Sea ports are equipped with appropriate technical facilities (skimmers, booms and other ships of service and accessory fleet).

Thus, due to timely taken measures with use of various technical means the accidental spillage of fuel oil from the tanker "Globe Assimi" in November of 1981 in the port of Klaipeda was combatted and the results are considered to be successful.

One of the principal tasks in the field of water bodies pollution prevention, brought forward before the industry by the directive documents is the development and promotion of waterless technologies and water management systems of industrial enterprises with maximum water use in recirculating water supply eliminating wastewater discharge into water bodies.

Significant progress in this respect is achieved in oil-shale industry where use in the recirculating water supply amounts to 70-80 8 of total water consumption: pollution load on treatment plants at starch and treacle enterprises is reduces due to improvement of technology up to 80 %, pollution load in meat and milk industry is reduced by 20-30 %, etc.

Within ten years which passed from the moment of the adoption of the Convention the country gained some experience in scientific studies on creation of new more effective technological processes and designs of facilities and equipment for wastewater treatment, ensuring protection of water bodies against pollution, and succesfully introduced at enterprises, organizations and municipal facilities.

To prevent eutrophication of water bodies we need a chemical precipitation of biologically treated sewages. This is under investigation in the USSR.

Thus, in Radvilishkis city in the Lithuanian Soviet Socialist Republic a pilot plant for chemical-biological treatment of municipal sewages with capacity of 10 000 m^3/day was put into operation. Ferrous(green) vitriol and polyacrylamide are used as reagents. Clarification of wastewater is carried out in radial-flow clarifiers on two-layer filters and advanced waste treatment in aerated oxidation ponds. In Tallin a chemical-biological sewage treatment plant with total capacity of 370 000 m^3/day is under construction. Biological treatment is to be carried out in aeration tanks with simultaneous precipitation with aluminium sulfate. The first stage comprises mechanical-chemical purification and a 3 km long sea outlet. Sludge treatment is made on centrifuges with subsequent drying in driers with countercurrent gas jets.

However, as practice shows, separate efforts on implementation of local water protection measures inspite of considerable expenditures do not always give a desirable effect. Further increase of water protection activity efficiency is possible on the basis of a water planning programme: creation and realization of complex water planning programmes representing the aggregate of measures aimed at achievement of a certain goal, that is standard water quality in water consumption places, and linked among themselves by terms of implementation and availability of resources.

The important element for further regulating of water protection planning is the rating of maximum allowable discharges (emission standards) of harmful substances entering water bodies with wastewater taking into account ecological criteria of water bodies. With observance of the established maximum allowable discharges the water quality in streams and water bodies will correspond to ecological standard indices stipulated by the Rules of surface water protection against pollution by wastewater (imission standards).

Ascertainment of maximum allowable discharges is such a planned index by means of which the volume of water protection measures is defined. The realization of these measures should envisage stage by stage reduction of wastewater discharge volumes on the basis of available resources.

Great work is carried out in the Soviet Union on implementation of the provisions of international agreements, including the Convention on the Protection of Marine Environment of the Baltic Sea Area aimed at sea water pollution prevention.

At present, new rules of coastal sea water protection against pollution are under preparation. They will increase demands for sewage water discharges quality.

Apart from the sections containing rather strict requirements to the order of marine water use for discharge of industrial, sewage, drainage and other types of wastewater, these Rules will contain also the List of substances harmful for the public health or living resources of the sea, the discharge of which is prohibited (DDT, PCB). The Rules will also indicate maximum allowable concentrations of harmful substances in water bodies used for domestic, public amenities and fishery purposes. This List includes about 800 denominations of various harmful substances, including the substances mentioned in the Convention on the Protection of Marine Environment of the Baltic Sea Area.

The above mentioned Rules will impose stringent demands upon the equipment of ports, terminals, ship-repairing yards, floating and stationary facilities for exploration and mining of the sea soil resources by technical means to prevent pollution of the sea.

Serious measures were taken for arrangement of service controlling the implementation of the national legislation and provisions of the Convention on the Protection of the Marine Environment of the Baltic Sea Area.

Such control of sewage discharges is now being exercised on the Baltic Sea by 8 basin (territorial) departments for water management and protection, belonging to the USSR Ministry of Land Reclamation and Water Management. The USSR State Committee for Hydrometeorology and Control of Environment exercises control of water bodies and airborne pollution.

Control authorities make systematic observations of the state of the sea surface with the help of special ships and aircraft.

Besides, chemical methods are applied to keep regular control over the quality of wastewater discharged into the sea by industrial, agricultural and other coastal enterprises.

All cases of sea pollution are thoroughly studied and the culprits recompense the State for the damage in complience with the laws of the USSR. The National "Procedure of Calculating the Damage Inflicted on the State through Violation of the Water Legislation" is being developed in the USSR for calculation of such damage.

Purposeful water protection activities including long-term planning, utilization of achievements in wastewater treatment, improvement of technologies and arrangement of efficient control systems, present protection of water bodies, help improve their condition and create prerequisites for their normal functioning in future under the conditions of rapidly developing economy.

FEDERAL WASTEWATER DISCHARGE STANDARDS IN THE FEDERAL REPUBLIC OF GERMANY

Bernd Bayer
Federal Environmental Agency
Federal Republic of Germany

ABSTRACT

By the 4th amendment of the Federal Water Act of the Federal Republic of Germany in 1976 an Article 7 a has been inserted which enables the Federal Government to set uniform emission quality standards (Minimum Requirements) for the discharge of wastewater into waters. The Federal Government is authorized to enact with the approval of the Bundesrat general administrative regulations which clearly determinde what it means to purify wastewater according to the generally acknowleges rules of technology. About 50 Working groups were established in 1977 by the Federal Government to make proposals for minimum requirements on an industry-by-industry basis. The Federal Government is transferring these minimum requirements into General Administrative Regulations.

Up to now the Federal Government and the Bundesrat have passed 27 of these Regulations and 5 more are ready to be issued.

In connection with the Wastewater Charges Act which was enacted in 1976 the Federal Republic of Germany created an instrument to motivate dischargers to reduce the discharge of untreated wastewater.

In accordance with the basic law (constitution) for the Federal Republic of Germany the Federation has in the field of water management not the concurrent legislative power but only a general legislative competence. The authority of detailed legislation and implementation is assigned to the Laender (states).

To safeguard or restore the ecological balance of the waters the Federal Government enacted two general laws in 1976:

- the 4th Amendment of the Act of the Regulation on Matters relating to Water (Federal Water Act, WHG) (1) and
- the Act Pertaining to Charges Levied for Discharging Wastewater into Waters (Wastewater Charges Act, AbwAG) (2).

Making these laws, the Federal Government followed two principles, important for the environmental protection:

- the principle of precaution and
- the polluter pays principle.

By the 4th Amendment an Article 7a has been inserted into the Federal Water Act which enables the Federal Government to set uniform emission quality standards (Minimum Requirements) for the discharge of wastewater into waters.

The Wastewater Charges Act rules that a charge has to be paid discharging wastewater into waters. Both Acts are linked through Article 9, para 5 of the Wastewater Charge Act which rules that the charge to be paid may be reduced by 50 per cent if the Minimum Requirements are complied with.

Article 7a of the Federal Water Act prescribes the following:

"(1) A permit for discharging wastewater shall only be granted if quantity and nociousness of the wastewater is kept as low as is possible if the processes in question are carried out according to the generally acknowledged rules of technology. This shall not affect the provisions of Article 6. The Federal Government, with the consent of the Bundesrat, shall issue general administrative regulations concerning the minimum requirements to be met by effluent discharges in line with the generally acknowledged rules of tehchnology as stated in sentence 1.

(2) If existing effluent discharges do not comply with the requirements under the above para. 1, the Laender shall ensure that the necessary measures are taken. The Laender may set specific time limits within which these measures must be completed".

The minimum requirements apply to discharges into inland and coastal waters and are enforced by the responsible Laender authorities. The term "minimum requirements" and the term "generally acknowledged rules of technology" which is joined to it, imply that more stringent requirements may be imposed, both in individual cases and

- in the case of entire river basins or parts of river basins, e.g. on the basis of management plans pursuant to Article 36b of the Federal Water Act and
- in the case of specific pollutants, groups of pollutants or branches of industry, e.g. on the basis of clean water regulation pursuant to Article 27 of the Federal Water Act or EC directives or international agreements.

Such stricter requirements have been imposed in a number of cases. Moreover, it is prohibited to issue a discharge licence if the common good might be affected, especially if a hazard to the public water supply would have to be expected (Article 6, Federal Water Act).

Basically, the minimum requirements apply both to new and to existing effluent discharges. In the case of existing effluent discharges which do not yet meet the minimum requirements, the Laender have to see to it that the measures needed to improve the situation are taken within an appropriate time limit (Article 7a, para. 2 of the Federal Water Act).

To ensure the best possible implementation of the clause "if the processes in question are carried out according to the generally acknowledged rules of technology" (Article 7a, para. 1, first sentence of the Federal Water Act) for the various types of effluents and manufacturing activities, separate minimum requirements are laid down for municipal effluents and the various types of industrial effluents.

The general administrative regulations are being prepared in close cooperation between the Federal Republic of Germany and the Federal Laender and will, essentially, be completed by 1983. A total of about 40 general administrative regulations are to be expected. Twentyseven of these general administrative regulations had already been published by March 1983. (3)

The material needed in the preparation of these general administrative regulations was elaborated by representatives of public authorities, science and the individual branches of industry in about 50 working groups. Thorough consultations have yielded new insight in many areas and made waste water management, i.e. the effluent treatment conditions as well as the use of preventive measures during the production process, more transparent. They have, in particular, stimulated the discharges to use new preventive measures and also shown where this development should be enhanced, for example by supporting specific research and development projects. More advanced processes and equipment which prove to be useful will in many cases have to be introduced as "generally acknowledged rules of technology". The administrative provisions will in future have to be adapted to this development from time to time. In some areas where this development is already looming up, it is envisaged to up-date the minimum requirements in the near future.

To facilitate the practical application of these requirements, the information and experience which was gained in the working groups dealing with the individual sectors of production was summarized and published in individual reports. First reports are available as loose-leaf edition (4). The publications are introduced by a general part with chapters on general and comprehensive questions, e.g.:

- legal framework of the administrative provisions
- minimum requirements, monitoring result, maximum permissible concentration, normal concentration, reference value
- evaluation of measurement results
- irrigation techniques (flush and spray irrigation)

The above-mentioned reports of the working groups (4) contain supplementary or explanatory information on the scope of application and on the wastewater treatment methods used in the individual sectors as well as on the preventive measures that may be taken by the operator. If in the individual case a discharge does not clearly fall under one of the general administrative, regulations, comparable cases falling under specific regulations may be used in the enforcement practice or mixed calculations may be carried out on the basis of more than one administrative regulation.

The effluent situation is also considerably improved by the fact that, in addition to the new requirements pursuant to Article 7a of the Federal Water Act, the Wastewater Charges Act (AbwAG)(2) provides further motivation. Dischargers complying with the minimum reguirements (provided that no stricter requirements are applicable) enjoy a 50 per cent reduction on the usual rates (Article 9, para 5 of the Wastewater Charges Act). The charges levied on the residual noxiousness of the wastes in question are low - for correspondingly purified municipal sewage they are generally less than 10 per cent of the charges levied for untreated sewage.

Finally a few remarks are added to explain structure and contents of our general administrative regulations laid down there:

The administrative regulations are structured according to the following uniform scheme:

1. Scope of application
2. Minimum requirements
2.1 Individual values
2.2 Analytical methods
2.3 Method of evaluation.

A regulation according to Article 7a, Federal Water Act consists of two parts - the scope of application and - the minimum requirements.

The scope of application is defined by a positive and by a negative statement. The positive statement defines the scope of application, the negative statement has to delimit the regulation against others.

The following quotation from the Second Administrative Regulation may be an example for the positive statement of the scope of application:

"This general administrative regulation applies for the discharge of wastewater, the pollutants of which essentially derive from the production of lignite briquets, including linked power stations or which are obtained in connection with the production".

The word **"essentially"** is included for pragmatic reasons. It shall establish the application of the regulation even in the case of small quantities of other types of wastewater which can be treated together with the main stream.

The following quotation from the administrative regulation on the processing of potatoes may be an example for a negative statement:

"This general administrative regulation does not apply to discharge of wastewater

- deriving from distilleries, strach factories, factories working on the dehydration of vegetable products for the production of fodder and plants for the production of fruit and vegetable products,
  deriving from cooling systems (once through - and circulation system) and industrial water preparation".

The second part of an administrative regulation is entitled "Minimum Requirements". In this second part, first the minimum requirements are quantitatively listed, that is to say - parameters, limit values and the modalities of the sampling are assigned to each other. The limit values are fixed in terms of concentrations and/or load of pollutants specific of products and in special cases additionally as amount of wastewater specific of products (see Annex 1, list of Minimum Requirements pursuant to Article 7a, WHG of 27 branches).

Secondly the analysis procedures underlying to the minimum requirement are stated; thirdly the monitoring method concerning the control of the minimum requirement follows.

Looking at recent standards, it should be taken into account that analytical methods and evaluation methods played a far more important role than hitherto. A more prudent assessment was necessary in particular with regard to the new parameters that were introduced into practice only now (chemical oxygen demand and toxicity to fish), taking into account that the definition of the minimum requirements is indirectly affecting the wastewater charges to be paid or the 50 per cent reduction of the normal rates envisaged in Article 9, para. 5 of the Wastewater Charges Act for cases in which the minimum requirements are met.

The future implementation of the new regulatory (Federal Water Act) and levying (Wastewater Charges Act) provisions was harmonized and further improved by the establishment of these minimum requirements.

In this context the fact is also of particular importance that the relevant analytical measures are being adapted to the technological development and to the requirements of practical implementation. This task is carried out by the German Standards Institute (DIN) in close co-operation with representatives of authorities, science and industry. This work has been completed for the parameters of the Wastewater Charges Act, and the corresponding analytical methods have already been published: they will be published in the near future for the other relevant parameters (5).

The provision under 2.3 of the administrative regulations ensures that the administrative expenditure of the responsible water authorities will keep within limits. This implies that a specific figure must be complied with or that the minimum requirement is also considered to have been complied with if the arithmetic mean of the results from the last 5 tests carried out by the authority, as far they were made within the last 3 years, is not exceeded. In the case of the fish test, it is not the mean that counts but the question whether four out of five parameters have been complied with.

The authorities responsible for implementation will in many individual cases, as appropriate, conduct more frequent tests or charge the operator with additional self-monitoring.

The most important pollutants/parameters for which minimum requirements are to be fixed are those for which wastewater charge has to be paid.

– Settleable soils, COD, Cd, Hg, Toxicity for fish –

Besides these parameters in certain branches minimum requirements will be set for the following pollutants/parameters: BOD, Hydrocarbons, Phenols, Cyanide, Heavy Metals, Halogenated Hydrocarbons, Sulfide, Ammonia, Fluoride, Phosphorus, TSS.

On the other hand there will be no minimum requirement fixed for **pH-value** and temperature because limitations for those parameters will be set by the state authorities in accordance with the need of the receiving water.

In cases where industrial wastewater of different origin is treated jointly in one municipal **waste**water treatment plant there may be more than one minimum requirement competent. In those cases a proportional addition of the competent minimum requirements will be applied (mixing calculation).

For wastewater from large chemical factories with numerous productions and even for wastewater from municipalities which contain a high amount of different industrial wastewater it is at present not possible ***on*** the basis of "generally acknowledged rules of technology" to fix minimum requirements for the discharge in terms of fixed concentrations and/or load of pollutants and/or specific of products. In those cases the Federal Government sets only minimum requirements in term of reduction rates for COD, leaving the responsibility to limit concentrations to the state authorities. It was shown, that most of these discharges can reach a reduction rate of 75 per cent of the COD raw load when applying biological treatment in connection with special pretreatments.

The Wastewater Charges Act rules, that a charge has to be paid for discharging wastewater into water bodies. The amount of the wastewater charge depends of the noxiounsness of the wastewater which shall be determined on the basis of the volume of wastewater and the parameters

- (1) settleable solids,
- (2) oxidizable substances measured as chemical oxygen demand,

- (3) toxicity, expressed as toxicity for fish and
- (4) content of mercury and cadmium.

The number of units of noxiounsness may be infered from Table 1.

Table 1. Wastewater Charges Act – units of noxiousness

Pollutants and groups of pollutants assessed	Number of units of noxiousness for each full measuring unit	
	Unit of noxiousness	Measuring unit (s)
1. settleable solids containing at least 10 per cent organic matter	1	Annual volume in cubic metres or, respectively, in tons should Article 3, para 4 be applicable
2. settleable solids containing less than 10 per cent organic matter	0.1	Annual volume in cubic metres or, respectively, in tons should Article 3, para 4 be applicable
3. oxidizable substances expressed as Chemical Oxygen Demand (COD)	2.2	Annual volume of 100 kilograms
4. Mercury an its compounds	5	Annual volume of 100 grams of mercury
5. Cadmium and its compounds	1	Annual volume of 100 grams of cadmium
6. Toxicity for fish	0.3 G_F +)	Annual wastewater volume of 1 000 cubic metres

+) G_F represents the dilution factor at which wastewater loses its toxic effect on fish. When G_F = 2, the figure applied shall be 0.

Methods of analysis:

- (1) The volume of settleable solids shall be determined after a two-hour settling period.
- (2) The chemical oxygen demand shall be determined in accordance with the dichromate procedure, silver sulphate being applied as a catalyst.
- (3) The effect in fish tests is determined by using the species orfe (Leuciscus idus melanotus) as a test fish and applying various degrees of wastewater dilution.
- (4) Mercury and Cadmium shall be determined by way of atomic absorption spectrometry.

The liability to pay wastewater charges became effective on January 1, 1981. The revenue accruing from wastewater charges can only be used for specific purposes connected with measures for maintaining or improving water quality. The annual rate levied per unit of noxiousness started with 12 DEM in 1981 and steadily rise to 40 DEM in 1986.

An important point of this Act is, that the discharger has not to pay for the actual load which he discharges but for the load he is permitted to discharge by his licence. This way has been chosen, because it is too difficult and costly to determine the actual load.

Except in the case of rain water the wastewater charge shall be reduced by 50 per cent for those units of noxiousness which cannot be avoided despite compliance with the minimum requirement resp. the more stringent requirements set by the state authority.

Minimum requirements pursuant to Article 7a Federal Water Act are Emission Standards on a technical-related base which have no connection to quality objectives in regard to the receiving water body. More stringent requirements based on Immission Objectives may be enforced by the states (Laender) pursuant to Article 36b Federal Water Act.

During the extensive work done in the preparation of minimum requirements to be met by effluent discharges it became evident that the new provisions of the Federal Water Act and of the Wastewater Charges Act are suited to effectively improve the effluent situation. All effluent discharges will in the near future comply with the new requirements: this will further improve the quality of our waters in large areas.

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(2) Waste Water Charges Act of September 13, 1976 (Federal Law Gazette I, p. 2721)

(3) Gemeinsames Ministerialblatt, GMBl., (Joint Ministerial Gazette) issued by the Federal Minister of the Interior, Carl Heymann Verlag KG, Albert-Stifter-Str. 15, D-5300 Bonn 1

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* 1. Abwasser VwV of December 16, 1982, GMBl. p. 744 (municipal sewage)

* 2. Abwasser VwV of January 10, 1980,
GMBl. p. 111
(lignite briquetting)

* 3. Abwasser VwV of March 17, 1981,
GMBl. p. 183
(dairy wastes)

* 4. Abwasser VwV of March 17, 1981,
GMBl. p. 139
(processing of oil seeds, edible fat and oil refining processes)

* 5. Abwasser VwV of March 17, 1981,
GMBl. p. 140
(fruit and vegetable processing)

* 6. Abwasser VwV of March 17, 1981,
GMBl. p. 141
(manufacture of refreshing drinks, filling stations)

* 7. Abwasser VwV of March 17, 1981,
GMBl. p. 142
(fish processing)

* 8. Abwasser VwV of March 17, 1981,
GMBl. p. 143
(potatoe processing)

* 9. Abwasser VwV of March 17, 1981,
GMBl. p. 144
(manufacture of paints and varnishes)

* 10. Abwasser VwV of March 17, 1981,
GMBl. p. 145
(meat and meat products)

* 11. Abwasser VwV of March 17, 1981,
GMBl. p. 146
(breweries)

* 12. Abwasser VwV of March 17, 1981,
GMBl. p. 147
(production of alcohol and alcoholic beverages)

* 13. Abwasser VwV of March 17, 1981,
GMBl. p. 148
(compressed wood-fibre board production)

* 14. Abwasser VwV of March 17, 1981,
GMBl. p. 149
(drying of vegetable products in
feedstuffs production)

* 15. Abwasser VwV of March 17, 1981,
GMBl. p. 150
(skin glue, gelatine and bone glue)

* 16. Abwasser VwV of February 5, 1982,
GMBL. p. 56
(hard-coal processing and hard-coal
briquetting)

* 17. Abwasser VwV of February 5, 1982,
GMBl. p. 57
(pottery and ceramics)

* 18. Abwasser VwV of February 5, 1982,
GMBl. p. 58
(sugar production)

* 19. Abwasser VwV of February 5, 1982,
GMBL. p. 59
(cellulose, pulp and paper production)

20. Abwasser VwV of May 19, 1982,
GMBl. p. 293
(rendering plant)

21. Abwasser VwV of May 19, 1982,
GMBL. p. 294
(malt houses)

22. Abwasser VwV of March 19, 1982,
GMBl. p. 295
(mixed sewage)

23. Abwasser VwV of May 19, 1982
GMBl. p. 296
(calcium carbide production)

24. Abwasser VwV of May 19, 1982,
GMBl. p. 297
(iron and steel production)

25. Abwasser VwV of March 3, 1983,
GMBL. p. 140
(leather and leather fibrin production,
refinement of furs)

26. Abwasser VwV of March 3, 1983,
GMBl. p. 142
(stones and earth)
27. Abwasser VwV of March 3, 1983,
GMBl. p. 145
(ore dressing)

* The reports of the various working groups on the administrative regulations marked by * have already been published (4).

(4) Reports of the working groups relating to the general administrative regulations pursuant to Article 7a of the Federal Water Act, issued by the Federal Minister of the Interior and the Landerarbeitsgemeinschaft Wasser, Wasserwirtschaftsamt Bremen, Schlauchthausstr. 24, D - 2800 Bremen 1

(5) Deutsche Einheitsverfahren zur Wasser-, Abwasser- und Schlammuntersuchung (German standard methods for the examination of water, wastewater and sludges), Normenausschuss Wasserwesen (NAW) in the German Standards Institute (DIN) e. V., Beuth-Verlag GmbH, D - 1000 Berlin 30, Burggrafenstr. 4-10

(6) HORNEF, H. and KANOWSKI, S.: New Federal wastewater discharge standards in Germany. Effluent and Water Treatment Journal, Nov. 1981, P. 510-514.

Minimum Requirements pursuant to Article 7 a federal **Water** Act (**WHG**)

Regulation	Discharger / Branche of Industrie	Parameter St ≙ Random Sample (Sample)	Wastewater m³/t	Settleable Solids ml/l	Suspendid Solids mg/l	COD mg/l	BOD_5 mg/l			Extractable Substances mg/l							Toxicity for fish G_F	Remarks
1	unicipal Sewage until 31.12.1984 ndbegin of plant construction cforr 31.12.1978	St		0,5		200+	45+											+ plants with retention tire 'of more than 24 h
		2h				200	45											
		24h				150	30											
	uniciprl sewage after 1.1.1985 nd begin of plant-construction fter 1.1.1979 :60 kg/d BOD_5 (untreated)	St		0,5		180+	45+											+ "
		2h				180	45											
		24h				120	30											
		St		0,5		160+	35+											+ "
		2h				160	35											
	mad:) - 600 kg/d BOD_5 (untreated)	24h				110	25											
		St		0.5		140+	30+											+ "
		2h				140	30											
	Lord: > 600 kg/d BOD_5 (untreated)	24h				100	20											
2	lignite briauetting	2h	0,6	0,3	50+	60												+ resp. 18 g/t Load
3	Dairy wastes	St		0,5														
		2h				170	35											
		24h				160	30											
4	Processing of oil reeds	St		0,3														
		2h				200				30								
	Wastewater < 10 m³/t	24h				170				20								

Annex 1

Minimum Requirements pursuant to Article 7 a federal Water Act (WHG)

Administrative Regulation	Discharger / Branche of Industrie	Parameter St ≙ Random Sample	Wastewater	Settleable Solids	Suspendid Solids	COD	BOD_5			Extractable Substances							Toxicity for fish	Remarks
		Sample	m^3/t	ml/l	mg/l												G_F	
4 to be cont.	Edible fat and oil refining processes Wastewater < $10m^3/t$	St		0,3														
		2h				250				50								
		24h				230				40								
	Wastewater 10 - $25m^3/t$	St		0,3														
		2h				200				30								
		24h				170				20								
5	Fruit and vegetable processing	St		0,3														
		2h				250	60											
		24h				200	45											
6	Manufacture of refreshing drinks, filling stations	St		0,3														
		2h				160	35											
		24h				110	25											
7	Fish processing	St		0,3														
		2h				300	35											
		24h				250	25											
8	Potatoe processing	St		0,5		200	40											
		24h				160	30											
9	Manufacture of paints and varnishes	St		0,3														
		2h				155	30											
		24h				115	20											

Minimum Requirements pursuant to **Article 7 a Federal Water** Act **(WHG)**

Administrative Regulation	Discharger / Branche of Industrie	Parameter St ≙ Random Sample / Sample	Wastewater m^3/t	Settleable Solids ml/l	Suspendid Solids mg/l	COD mg/l	BOD_5 mg/l										Toxicity for fish G_F	Remarks
10	Meat rnd meat product&	St		0,3														
		2h				160	35											
11	Breweries	St		0,3														
	Wastewater per 100 l boor production (annual average):	2h				95	25											
	0,8 m^3	24h				85	20											
		St		0,3														
		2h				120	30											
	0,6 m^3	24h				100	25											
		St		0,3														
		2h				175	35											
	≤ 0,4 m^3	24h				150	30											
12	Production of alcohol and alcoholic beverages	St		0,3														
		2h				200	30											
13	compressed wood-fibre board production	St		0,5														
		2h				8*	2*											*kg/t fibre board (absolutly dry)
14	Drying of vegetable products in feedstuffs production	St		0,3														
		2h				160	30											
15	Skinglue, gelatine and bono glue	St		0,5														
		2h				140	25											

Minimum Requirements pursuant to Article 7 a Federal Water Act (WHG)

Administrative Regulation	Discharger / Branche of Industrie	Parameter St ≙ Random Sample	Wastewater	Settleable Solids	Suspendid Solids	COD	BOD_5			Cadmium	Lead						Toxicity for fish	Remarks
		Sample	m^3/t	ml/l	mg/l												G_F	
16	Hard-coal processing	St		0,5	100													
		2h				100												
	Hard-coal processing and hard-coal briquetting	St		0,5	100													
		2h				200												
17	Pottery and ceramics	St		0,5														
		2h			100	80				0,1	1							
18	Sugar production exept water of condensation and seal water (pumps)	St		0,5													4	
		2h				500	50											
		24h				450	40											
	Water of condensation and seal water (pumps)	St		0,3														
		2h				60	30											
19	Cellulose*	St		3														* all values in kg/t
	half -	24h	100		5	80	30										8	
		St		4,5														
	not bleached	24h	150		7,5	120	40										8	
		St		6														
	bleached	24h	200		10	220	70										8	
		St		7														
	refined, of leaf-wood	24h	230		11,5	350	120										8	
		St		7														
	refined, of conifers	24h	230		11,5	350	80										8	

Minimum Requirements pursuant to Article 7 a federal Water Act (WHG)

Administrative Regulation	Discharger / Branche of Industrie	Parameter St ≙ Random Sample	Wastewater	Settleable Solids	Suspendid Solids	COD	BOD_5										Toxicity for fish	Remarks
		Sample	m^3/t	ml/l	mg/l												G_F	
19	Pulp and paper production *	St		0,5														* 24h - measurements in kg/t
to be cont.	not sized, wood-free	24h				6	3											
		St		0,5														
	sized, wood-free	24h				8	3											
		St		0,5														
	highly extracted	24h				15	6											
		St		0,5														
	coated	24h				2*	0,7°											*5, if > 50% thermomechanical, pulp
		St		0,5														°resp. 25 mg/l Concentration
	ligneous	24h				5	0,8*											*resp. 25 mg/l "
		St		0,5														
	from recycling-paptr	24h				6	1,2											
		St		0,5														
	parchment	24h				12	6											
20	Rendering plant	St		0,5														
		2h				300*	40										8	*400, if > 50% blood
21	Malt houses	St		0,3														
		2h				140	30											
22	Mixed sewage	St		0,5														
		2h																*75% Reduction rate

Minimum Requirements pursuant to Article 7 a Federal Water Act (WHG)

Administrative Regulation	Discharger / Branche of Industrie	Parameter St ≙ Random Sample	Wastewater	Settleable Solids	Suspendid Solids	COD	BOD_5	free chlorine	free cyanide	Sulphide	Hydrocarbons	total chromium	chromium VI	Lead	Zinc	Iron	Toxicity for fish	Remarks
		Sample	m^3/t	ml/l	mg/l												G_F	
23	Calcium carbide production	St		0,3				0,5*										* if detoxicated with hypochlorite
		2h							4*								2	* g/t
24	Iron and steelproduction	St		0,5														
	general	2h				100					10			0,5	4	20		
		St		0,8														
	foundries	2h				200					10			0,5	4	20		
		St		0,5														
	production of tubes	2h				200					10			0,5	4	20		
		St		0,5														
	tinplate	2h				200					10			0,5	4	20		
		St		0,5														
	leading and patenting	2h				100					10			2	4	20		
25	Leather and leather fibrin production, refinement of furs	St		0,3														
		2h				250	25			1		2					4*	*only for refinement of furs
	general	24h				200	20			1		1					4*	* -"- .
	before treatment COD > 2500mg/l	2h				*												*not under 90% reduction rate
	" " BOD_5 > 1000mg/l	24h					*											* -"- 97,5% -"- -"-
26	Stones and earth	St		0,3*														*0,5 for kaolin and blanch earth
		2h			100*						10**		0,3***					*not valid for clay,kaolin,feldspar; **only for asbestos cement, concrete,natural stone; ***only for asbestos cement

Minimum Requirements pursuant to Article 7 a Federal Water Act (WHG)

Administrative Regulation	Discharger / Branche of Industrie	Parameter St ≙ Random Sample (Sample)	Wastewater (m^3/t)	Settleable Solids (ml/l)	Suspendid Solids	COD	BOD_5	total cyanide	Lead	Zinc	Iron						Toxicity for fish (G_F)	Remarks
					mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l							
27	Ore dressing	St		0,3	70													
	Non - ferrous (gangue ore)	2h				40		0,1	0,5	3	3							
	- metal - ore	St		0,3	70													
	(submarine, hydrothermal)	2h				150		0,1	0,5	3	3						4	
		St		0,3	70													
	fluorspar	2h				80					3							
		St		0,3	70													
	heavy spar	2h				80												
		St		0,3	70													
	graphite	2h				65					10							

PHOSPHORUS IN AQUEOUS ENVIRONMENT AND METHODS FOR REDUCING THE LOAD ON WATER-BODIES

Harald Velner
Tallinn Polytechnical Institute
Union of Soviet Socialist Republics

Enn Loigu
Baltic Branch of Institute of Applied Geophysics
Union of Soviet Socialist Republics

Ain Lääne
The USSR State Committee of Hydrometeorology
and Environmental Control
Union of Soviet Socialist Republics

In resent years in the Estonian S.S.R. the use of phosphorus compounds has considerabely increased and first of all, on the account of the usage of pesticides, detergents, fertilizers as well as development of phosphorus consuming industry. This has given rise to eutrophication processes in small rivers and lakes (l-4).

Investigations on the marine environment of the Bays of Tallinn, Narva and the Gulf of Riga have indicated an increase in the concentration of phosphorus compounds in the near costal waters, which has lead to their eutrophication. In the inner part of the Matsalu Bay of the Gulf of Riga a belt of about 30 km^2 overgrown with reed is formed. During the last 13 years (1962-1975) the mean density of bottom fauna in the bay has increased about 5 times (from 3 100 sp/m^2 to 15 000 sp/m^2) (4).

Pollution of water-bodies with phosphorus compunds is a result of concentrated discharges of sewage (point sources) or discharges from the whole river catchment area (non-point sources). Phosphorus pollution from point sources is easily stated, controlled and regulated. The existing treatment methods and technological measures enable to reduce the pollution load. The estimation and limiting of diffuce pollution loads from non-point sources **is** a rather complicated task since it depends on complicated and rapidly changing natural conditions. Balance calculations elaborated for the Estonian S.S.R. have shown, that the main amount of phosphorus, 85 8, is introduced to water-bodies with sewage waters, in municipal effluents phosphorus of detergent origin makes up to 43 % of the total amount of phosphorus (Table 1). Table 2 presents the load of organic substances and nutrients to the Gulf of Finland, convyed from the Soviet Union near to the sea by rivers and municipal effluents having a direct impact on the quality of the sea water near coastal area. The effluents from Leningrad and small communities, primarily treated in biological purification plants (750 000 m^3/day) are discharged to the River Neva.

Table 1. Amounts of nitrogen and phosphorus conveyd to Estonian water-bodies from main pollution sources

Pollution source	Phosphorus t/a	%	Nitrogen t/a	%
Municipal effluents	550+	56	2 900	13
Industrial effluents (food industry etc.)	280	29	1 500	7
Effluents from arable land area	150	15	18 000	80
Total	980	100	22 400	100

+Including 235 t detergents used

Table 2. Load of organic and phosphorus compunds to the Gulf of Finland in 1978-1980

Source	BOD_7 t/a	'total t/a
River Neva	165 500	2 460
River Narva	27 100	570
River Luga	7 460	240
River Jägala	1 630	43
River Pärnu	3 600	120
Kohtla-Järve	500	140
Tallinn	36 800	360
Total amount	242 590	3 933

The signing of the Convention on the Protection of the Marine Environment of the Baltic Sea Area in 1974 has given rise for creating and reconstructing sewage treatment plants for towns and industrial enterprises in the Baltic Soviet Republics. The building of the sewer system of Tallinn is under way. Till 1978 before the first stage of treatment plant was put into operation 360 tons of phosphorus and 36 800 tons of organic substances (expressed as BOD_7) were introduced to the sea. The mean concentration of phosphorus in municipal sewage does not exceed 4 mg/l, e.g. less than usual. After the mechanical treatment plants and the deep sea outlet were put into operation, the pollution load to the Bay of Tallinn has decreased about 15-20 8, but in 1985, when the chemical after-purification complex will be completed a reduction of phosphorus load by about 80-85 % can be achieved. In 1988 when the II stage, the biological treatment plant, is to be completed no harmful substances will be introduced to the Bay of Tallinn. It must be empasized that planning and construction of sewage purification plants is based on long-term thorough research and design studies. The advanced experiences of the countries of the Baltic Sea Basin are also appreciated (Fig. 1).

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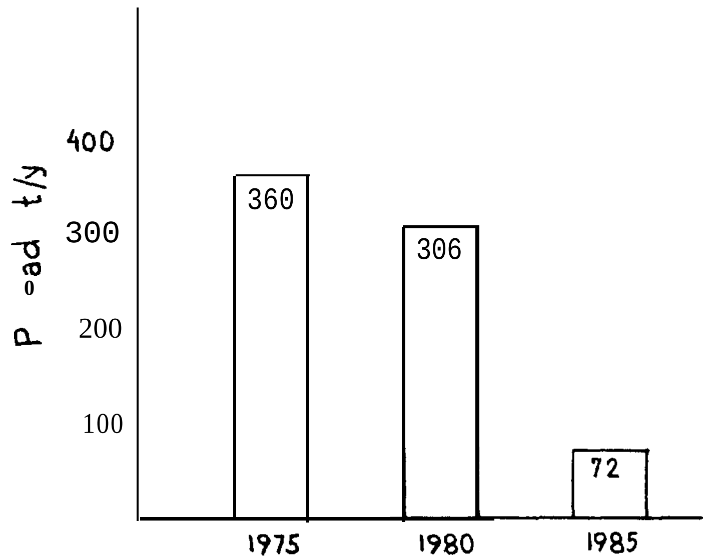

Fig. 1 Dynamics of the decrease of phosphorus load to the mar.ne environment from towns of the Estonian S.S.R.

The first stage of the all-town sewer system of the reconstructed sewarage network of Pärnu is put into operation and the construction of chemical precipitation units providing the purification efficiency of about 80 % has been started.

The expansion of biochemical treatment plants of the town Narva and the completion of local treatment plants for the industrial region of Kohtla-Järve reduces the pollution load by 80-85 % in the nearest future. Further investigations are aimed at the reduction of the pollution load to the Baltic Sea by the improvement of the operation of great treatment plants and creation of automatic management systems for municipal sewerage networks to equalize the flows of storm water and snow melting.

The studies of the load of phosphorus compounds entering the sea with river discharges have shown that the main pollution sources of phosphorus are small towns and communities as well as farming. Within 15 years in the Estonian S.S.R. about 1 000 small biological treatment plants with extended aeration have been put into operation. Domestic and foreign studies have shown that the purification efficiency of phosphorus is strongly dependent on the influent load and in the treatment plants with extended aeration does not exceed 10-20 %. In the 1970's large scale laboratory and field investigations were conducted in order to obtain a better efficiency of phosphorus removal. For phosphorus removal in the biological treatment process it was proposed to use lime instead of ferrous sulphate in batch treatment plant. An electrochemical method for phosphorus removal from sewage in treatment plants of the type BIO raises the anticorrosive properties of metallic constructions of the plant.

Non-point sources of phosphorus are of various kinds (atmospheric precipitation, discharges from arable land, effluents from municipal areas etc.). Intensive use of land contribute to the increase of phosphorus wash-off from the soil. The wash-off of phosphorus from arable land is varying, depending on the climate, intensity of erosion processes, season and quantity of fertilizers applied etc. As a rule phosphorus is washed-off to a minor extent from the soil since phosphates are easily absorbed by soil complexes and losses in phosphorus may be considerable due to erosion only. The wash-off of phosphorus from the catchment area depends on the intensive development of catchment (Fig. 2) and may be characterized by the following dependence

$$y = 11.85 \lg (x + 1) + 1.76,$$

where y = wash-off of total phosphorus from the catchment area $kg/km^2/year$

x = percentage of arable land in the catchment.

Thus, the wash-off of phosphorus even at complete development of the catchment area is unconsiderable and makes up no more than 1 8 of the applied amount of fertilizers. From the view-point of eutrophication, nitrogen compounds constitute considerable danger.

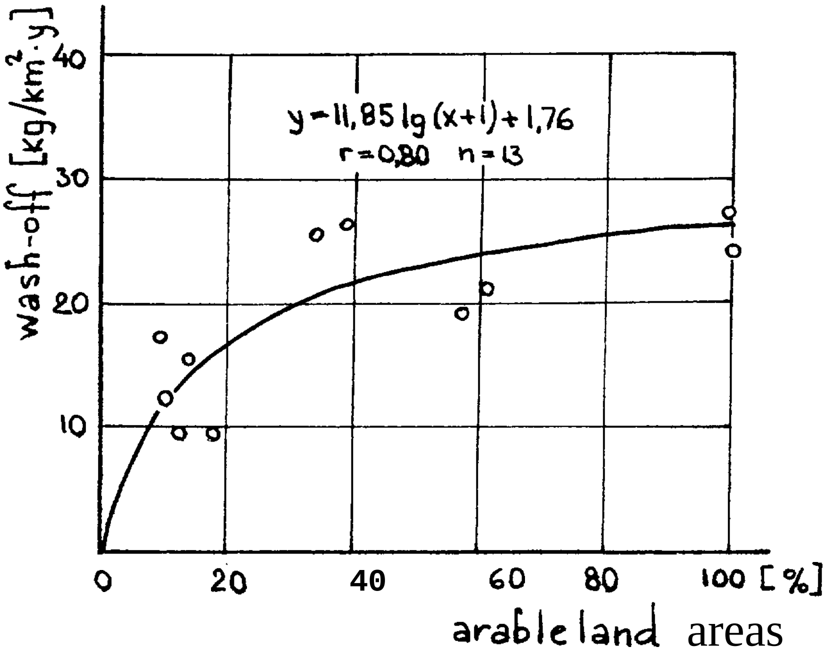

Fig. 2 Dependence of wash-off of phosphorus of the percentage of arable land area in the catchment

Table 3. The wash-off of nitrogen and phosphorus from intensively cultivated catchment areas

Watercourse	Catchment area km^2	Phosphorus PO_4^{3-}-P kg/ha.a	Phosphorus Tot.P kg/ha.a	Nitrogen NO_3^--N kg/ha.a	Nitrogen Tot.N kg/ha.a	Wash-off, % from applied fertilizer P	Wash-off, % from applied fertilizer N
Pilot section I	22.7::	0.14	0.25	24.9	30.0	0.95	31.6
Pilot section II	6.43	0.10	0.24	25.2	30.1	0.75	25.1

Conclusion

1. The completion of the building of chemical-biological treatment plants for the towns Leningrad, Tallinn, Pärnu, Kohtla-Järve and the reconstruction of municipal sewer system of the town Narva provides the reduction of 80-90 % of the direct load of phosphorus compounds to the Baltic Sea.

2. The subsequent work is directed to the elaboration of an automatic management system for sewerage networks and improvement of technology of industrial enterprises permitting the decrease in the amount of phosphorus compounds entering municipal sewerage network.

3. Chemical after-treatment is needed in small treatment plants to reduce the load of phosphorus in effluents discharged to the sea by rivers and operation of the treatment plants needs to be improved.

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UTILIZATION OF DOMESTIC AND INDUSTRIAL SEWAGE IN AGRICULTURE

Klaus Winkel
Ministry of Environmental Protection and Water Management
German Democratic Republic

The method of sewage treatment by the soil is gaining more and more importance.

This feature is due to below aspects:

- improvement of protection of waters by developing the sewage cleaning effect:
- multiple use of water, also and in particular, for irrigation purposes;
- use of the nutrients contained in sewage as secendary raw material in the sense of economy of material.

According to assessments, the annual quantity of sewage presently available in the G.D.R. is 6.2 billions of cubic meters. Out of this quantity 14 % originates from population, 84 % from industry and 2 % from agriculture (liquid manure is not included). By the year 2 000 above quantities will increase as to population to approximately 180 %, as to agriculture to 230 %, but as to industry to 116 % only. Altogether, the quantities will increase by 28 %. On the other hand, the volume of extended treatment of sewage by the soil will increase for 230 % during the same period and will cover approximately 556 millions of cubic meters per year spread on an area of 139 000 ha. In compliance with this calculation 7 % of the quantity of sewage available in 2 000 will be treated by the soil.

Presently about 3.7 % are being used in agriculture.

According to assessments, the potentially usable proportion complying with the requirements set to quality of the irrigation water is approximately 45 % of the total quantity of untreated sewage, respectively 58 % of domestic sewage and not more than 40 % of industrial sewage.

Also when considering the limiting local conditions considerable reservations for using sewage are evident.

The cleaning effect of different methods of sewage treatment is mentioned in Table 1.

Table 1. Comparison of the cleaning effect (%) of different sewage treatment methods

Substance contained	Local artificial-biological method	Sewage treatment by the soil	Domectic sewage from sugar factories artificial-biological method	treatment of sewage by the soil
N	24 to 28	90	36	90
P	20 to 25	100	63	89
K	4	90	18	36
BSB_5	70 to 95	100	26 to 99	85

In general, a better cleaning effect can be achieved when applying the method of sewage treatment by the soil instead of using the artificial-biological cleaning method, which shall be taken into account when making any further respective decisions in the future.

For domestic and industrial sewage, to which the mentioned method may be applied, rates of elimination of phosphorus and of organic substances of 100 % and of nitrogen of more than 90 % are possible according to the structure of operation – harmonization of irrigation level, kind of the soil and use. Those high rates of elimination and the increased absolute cleaning effects arising therefrom through the processes of seepage of water into the ground are appearing mainly indipendent of the concentration of substances in the sewage so that the method of sewage treatment by the soil is more qualified for sewage of a higher content of substances than other alternative methods.

Furthermore, one should take into account that all kinds of costs and expenditures arising in connection with treatment of sewage by the soil refer to its quantity and not to concentration.

The pollution potential of domestic and industrial sewage of the G.D.R. is approximately 60 millions of inhabitant equivalents.

By the method of sewage treatment by the soil the waste load is being reduced presently to approximately 3.6 millions of inhabitant equivalents, i.e. a proportion of 5.3 % only. This fact again is demonstrating the necessity to extend treatment of the sewage by the soil. Investigations prove that an increase in yield of 10.6 cereal units per ha was achieved on average during several years by using the method of sewage treatment by the soil instead of sprinkling treated water (29.9 cereal units per ha instead of 19.3 cereal units per ha).

In general it may be stated that treatment of sewage by the soil up to 50 000 inhabitant equivalents requires less investments than the artificial-biological method. As far as this characteristic is concerned, this method may be recommended, in particular, for this size of facilities.

The question of "treating ***or not*** treating sewage by the soil" may be answered only, when all conditions of water management, hygiene and other conditions prevailing at the respective locality were assessed in their complexity. The water monitoring authority will decide, what cleaning goal must be achieved. The higher the cleaning effect to be achieved will be, the higher will be the costs and material expenditure for the artificial-biological method, which is in contrast to the method of sewage treatment by the soil.

Basic decisions on the reception and utilization regime covering the whole year and including the discharge operation shall be prepared, in the course of which the requirements of protection and, in particular, of protection of the waters as well as the respective operational and organizational conditions of the parties (supplier, user of sewage) shall be fully taken into account. Those parties shall decisively participate in preparing the mentioned decisions. The degree of necessary pre-treatment must be determined. To comply with the provisions of the standard TGL 26567 referring to "Sewage treatment, sewage treatment by the soil" and to secure a nationally high effectiveness mechanical pre-treatment of domestic sewage without the subsequent artificial-biological stage for limit values below 100 000 inhabitant equivalents as well as application of a reception regime by the sewage users during the whole year are to recommend.

In future time reception and utilization of sewage shall be controlled in compliance with the present hydrological regime – quantity of discharge and temperature of the water. Those values are mainly influencing the degree of contamination, concentration and intensity of transformation processes of substances (analysis).

The following kinds of treatment shall be taken into account:

I The method of sewage treatment during the whole year by the soil is to be preferably used in agricultural areas, in the course of which discharge areas for 60 days in winter time shall be included.

II The method of sewage treatment during the whole year by the soil is to be used in agricultural areas, in the course of which discharge areas during the period outside vegetation up to approximately 130 days shall be increasingly included.

III The method of sewage treatment by the soil during the vegetation period is to be applied in agricultural areas, in the course of which discharge areas during approximately 30 days are to be included. This method is to be combined with other cleaning methods to discharge sewage treatment by the soil and to secure sewage treatment outside the vegetation period.

Above alternatives shall be preferably applied:

Alternative I:	In case of groups of inhabitants up to 25 000;
Alternative III:	In case of difficult or missing areas available for utilization of sewage, mainly for groups above 75 000 inhabitants.

Approximate values of the total load levels per year referring to various species of crops are grouped in Table 2 according to the conditions of the soil.

On industrial conditions of production the arable land conditions recommended in Table 3 should be realized for the main locations of sewage treatment by the soil together with proof of alternative and percentages.

The degree of concentration of species of crops necessitating irrigation as well as their most favourable load during the whole year determine the size of the sprinkling areas necessary for sewage treatment by the soil as well as of the necessary discharge facilities. The size of the area to be opened up for an extended sewage treatment by the soil shall be calculated by means of the following formula:

$$F_B = \frac{Q_A}{q_B} \; .$$

F_B – area opened up (sprinkled area) in ha:
Q_A – available quantity of sewage in m^3/d;
q_B – load of the area in $m^3/ha \times d$.

Table 2. Approximate values of total load levels per year in mn

crop species	Conditions of the soil					
	light soil		madiumsoil		heavy soil	
	vegeta- tion period	vegeta- tion rest	vegeta- tion period	vegeta- tion rest	vegeta- tion period	vegeta- tion rest
cereals	60	60	60	30	60	30
maize	60	60	60	60	60	60
potatoes						
RG *) I & II	60	60	30	60	30	60
RG III to v	90	60	90	60	60	60
sugar-beets	300	180	180	180	120	180
tumips	300	180	180	180	120	180
silo-maize	90	90	90	90	60	90
field-ass	200	300	360	300	300	300
clover	300		240		210	
clover-grass	360		300		240	
lucern	240		180		150	
intensely used pasture	500	300	360	300	300	300
intermediate summer crop	180		120		90	
intermediate winter crop	120	-	60		60	

*) = ripeness group

Table 3. Alternatives for conditions of arable land arcas in %

Group of crop species	Light soil			medium soil		heavy soil	
	A	B	C	A	B	A	B
field food	50	80	35	50	66.7	40	66.7
root crops	30	20	35	30	33.3	30	33.3
cereals	20	-	30	20	-	30	-
interm. crops	10	-	20	10	-	20	-

Some examples specifying the areas required as a function of the limit values are mentioned in Table 4. In this connection the following values were used for specifying the load levels:

light soil	1.4 mm/d
medium soil	1.0 mm/d
heavy soil	0.9 mm/d

Table 4. Examples specifying the size of areas required for extended sewage treatment by the soil

Number, of inhabitants connected	Quantity of available sewage m^3/d	Necessary area to be opened up (F_B) in ha		
		light soil	medium soil	heavy soil
10 000	1 200	85	120	135
20 000	2 400	170	240	270
50 000	7 500	535	750	835
100 000	20 000	1 430	2 000	2 220

In addition there to discharge areas will be necessary for the frosty period. Basic data referring to size and operation are laid down in Table 5. Organization of work specified in the cultivation as well as irrigation programme shall comply with that of the sewage reception programme.

During the vegetation rest the areas are to be sprinkled or irrigated up to the moment, when severe frost will set in.

Table 5. Examples specifying requirement of discharge areas during 60 days

Number of inhabitants connected	Quantity of sewage available m^3/d	Necessary discharge areas in ha at a load of 33 mm/d light soil	25 mm/d medium soil	20 mm/d heavy soil
10 000	1 200	3.6	4.8	6.0
20 000	2 400	7.3	9.6	12.0
50 000	7 500	23.0	30.0	37.5
100 000	20 000	61.0	80.0	100.0

Appliability of industrial sewage and of sewage from production of farms for being treated by the soil is to be defined in compliance with the provisions of the standard TGL 6466/01.

See Table 6 for assessment of applicability.

Table 6. Assessment of applicability of industrial sewage and of sewage from production of farms for being treated by the soil

Kind of sewage	Classification	Characteristic factories and farms	Remarks concerning pre-treatment
mainly loaded by organic substances and/or nutrients	well suited	sugar factories, breweries, starch flower factories, dairies, slaughterhouses, farms, animal production establishments	in general mechanical cleaning only, intermediate storage for continuous discharge for treatment by the soil is possible.
	suited	coking plants, gas works, textile, cellulose, paper factories	frequently factory-owned facilities are necessary for chemical and artificial-biological pre-treatment
mainly loaded by unorganic substances	well suited	agrochemical centres	depends on the ratio of components, additional methods, e.g. dilution, precipitation, to reduce toxic substances (biocides) or their concentration are necessary
	suited in a limited way	chemical works, metal working factories	for taking decisions expert opinion will be necessary; in general, sewage treatment by the soil will be possible, if the sewage concerned is being cleaned directly or mixed with water by the artificial-biological cleaning method

The method of sewage treatment by the soil is applicable to clean domestic and industrial sewage in compliance with the provisions of the standard TGL 6466/01, in case the sewage concerned does not contain any components of toxic concentration being harmful to plants. The above method shall be preferably used for sewage originating from food industry and sewage produced by production of farms.

To comply with technology of operation the sewage doses under the meteorological conditions prevailing in the G.D.R. shall be determined differently by approximation as follows (Table 7):

Table 7.
Sewage doses

Method	Mean value mm	Maximum value mm
Annual doses:		
– sprinkling including discharge	375	800
– among the areas sprinkle discharge areas during the vegetation rest	800	2 000
– irrigation	1 000	4 000
Individual doses:		
– sprinkling	40	60
– discharge	100	500
– irrigation	200	500

The annual dose applied to discharge areas of light soil may be increased for maximum 500 mm to cover the requirement of irrigation during summer time.

The method of sewage treatment by the soil is not applicable for widespreed distribution to areas having a ground water level below 1 m and for discharge areas having a ground water level below 2 m.

Geographic as well as meteorological factors such as:

levels (from the sea level)	above	350 m
mean annual rainfalls	above	700 mm
mean annual temperatures	below	7°C

restrict the application of the method of sewage treatment by the soil in some locations of G.D.R.

REPORT ON METHODS AND TECHNOLOGIES FOR IMPROVEMENT OF COASTAL WATER QUALITY PRESENTING THE EXAMPLE OF THE GULF OF PUCK

Marek Kamieniecki
Voivodeship Bureau in Gdansk
Poland

The Gulf of Puck constitutes the western part of the Gulf of Gdańsk delimited from the West and South - West by the abrasive-accumulative sea-coast on the stretch from Gdynia to Władysławowo and by the accumulative form of the Peninsula of Hel from the North-East.

From the point of view of morphometry and morphology of the sea bottom and the existing oceanographic conditions the Gulf of Puck presents a distinctly dual form. The eastern part - the Great Gulf of Puck - has a character of declining asymmetric syncline of the axis running in the direction NW - SE and at the depth below 20 m (max. 50 m). In geomorphological, hydrological and biooceanographic sense the Gulf of Puck is monoaqueous with the other part of the Gulf of Gdańsk.

The other fragment of the Gulf of Puck located in NE part - the Small Gulf of Puck - shall be the subject of further considerations of the present report. The reason for taking this water body into consideration is its particular character both in morphological as well as in oceanographic sense and far progressed degradation of that valuable ecosystem in the scale of the Baltic Sea.

The Small Gulf of Puck has the surface of approx. 103 25 km^2 and the water volume approx. 0.3 km^3. That is a shallow water body of differentiated depth, averagely 3 m and max. 9.4 m. The form and depth differentiation is a result of post glacial origin of this water body (9, 10). The system of overdeepenings, gullies and ridges creating the bottom is an extension of geomorphological forms of sea-shores, modified by lithodynamic processes on the contact line of the sea-coast and the coastal zone. The south-western and western sea-coast consists of alternate abrasive-cliff shores, created on the edges of Pleistocene holms formed from ground undulating moraine and accumulative formations occuring on the contact line with the system of proglacial stream valleys. The proglacial stream valley system of Pleistocene drainage found its continuation in the area of the present small Gulf of Puck forming the depth differentiations of that water body.

The north-eastern boundary of the small Gulf of Puck constitutes the Peninsula of Hel formed mainly of sandbank formations, and the shores of the Peninsula from the side of the small Gulf of Puck easily turn into a shallow submerged platform of the Peninsula ground course. The small Gulf of Puck is separated from the Great Gulf of Puck by the shoal of the Sea Swallow Shelf periodically emerging to the surface. In those situations the water exchange between those two water bodies is limited to the two artificially dredged water courses at the apposite shores (2, 9, 18). The water body of the Small Gulf of Puck consists of greater depths called Chałupska, Kuźnicka and Rzucewska hollows, which are separated by the shelf shoals. Those general formations are covered by merescale subaquatic morphological shallow-water formations of insufficiently known genesis (9, 10, 18). At the part of accumulative sea-shores occur trough systems and at the Peninsula of Hel – a wide sandy platform. On the platforms at the holms occur gravels and post-glacial boulders as an abrasive residuum (9, 18). The primary character of bottoms resulted from the structure and lithology of post-glacial formations, and was characteristic for almost exclusive occurence of fine grain sands and silty sands (11, 18, 20, 24, 25). At present in connection with progressing eutrophication of deep sea the character of the surface bottoms has also changed (13, 18). As a result of the above, particularly in the hollows and at the river estuaries silts and loams as well as organic loams occur. The morphology of the Small Gulf of Puck conditioning its significant isolation from the other water bodies has caused, inclusive external impacts from the land (rivers, sewage, atmosphere, surface run-off), formation of a specific ecosystem and its further complex evolution.

In connection with the genesis of the Small Gulf of Puck the organisms living in that water body are both marine and brackish species as well as freshwater organisms (22, 24, 25). The catchment of the Small Gulf of Puck has the surface of 774.3 km^2 (14). The surfaces of particular catchments and the structure of the land use are presented in Tables 1 and 2. It is necessary to point out that 55.4 % of the area are arable lands and green grounds, and 37.8 % – forests. Thus, the spatial and linear discharge of pollutions, and in particular biogenic compounds is connected with agricultural utilization of the catchment (6, 8, 18).

Table 1. Surface of drainage area in SGP*) catchment acc. to (14)

River or water - course	Surface of drainage area in km^2
Reda	496.7
Zagórska Struga	128
Płutnica	80
Gizdepka	31.7
Błądzikowski	26.8
in the region of Władysławowo	11.1

Table 2. Forms of land use in drainage area of SGP*) (share in %) acc. to (14)

Type of land use	Share in %
Arable land	34.8
Green grounds	20.6
Forests	37.8
Water tanks	
Others	6.0

*) SGP - the Small Gulf of Puck

Since the annual inflow of river water into the Small Gulf of Puck amounts to 180-200 x 10^6 m^3, when the volume of the water body is of the order 300 x 10^6 m^3, the Gulf is under a significant influence of fresh waters. In connection with the above the average salinity of the Small Gulf of Puck oscylates around 5.5-6.5 $^o/_{oo}$ reaching in the estuary regions the value approx. 2-3 $^o/_{oo}$ (2, 3, 9, 18). The effect of the above is the necessity of living of the majority of organisms, both marine brackish species as well as fresh water organisms, in extreme ecological conditions. Since the rivers and effluents transport into the Gulf considerable amounts of pollutions, its ecosystem has been under the conditions of continuous impact.

Table 3. Average concentrations in mg/dm^3 of tot. N and tot.P and COD in runoff waters from areas of various land use acc.to (8)

Index	Arable land		Land use pasture		Green ground	
	season with snow	season with rain	season with snow	season with rain	season with snow	season with rain
tot. P	0.44	1.05	0.67	0.49	0.43	0.35
tot. N met. Kejdakla	2.1	2.6	3.3	1.7	2.8	0.8
COD	49	148	69	49	62	22

The primary compositions and the state of waters and living organisms was highly oligotrophic.

The vulnerability of the water body to pollutions is increased by practically annually occurring ice cover in winter season and impeded water exchange (9, 10, 18).

In result of the above the increased input of pollution, and in particular of biogenic origin has brought about considerable changes in chemical composition and encroachment of elements circulation cycles in the environment. Particularly drastic effects are to be observed in the range of water eutrophication and its biocoenotic consequences (Tables 3-8) (2, 3, 11, 13, 14, 16, 17, 18, 22, 24). The max. concentration of NH^+_4 in that water body amounted even 13 $ugat/dm^3$ (2). The quantity of biogenetic substances discharged into the water body is sufficiently great so that in the regions of river estuaries and sewage inputs the phenomena of biogenic exhaustion into phyto-plankton development do not occur.

Table 4. Discharge of certain pollutions into SGP*) acc.to (6, 14) in kg/a

Index	SGP*) (rivers a. sewers) without the Reda river for period V. 1982-IV 1983	Reda river for 1982	Total
BOD_5	381 629	882 000	1 263 629
tot.N	161 708	345 800	507 508
Ammonia nitrogen	72 905	92 300	165 205
Nitrite nitrogen	1 530	6 610	8 140
Nitrate nitrogen	26 915	32 100	59 015
tot.P	17 763	24 700	42 463

Table 5. Average daily volumes of river waters and sewage discharged into SGP*) in m^3 acc.to (6, 14)

Name of water couse or sewer	Liquid volume in m^3
Sewers in Władysławowo	917
Płutnica	54 740
Bładzikowski Sewer	8 468
Gizdepka	29 130
Sewer at Reda	6 127
Zagórska Struga	116 813
Rewa Sewer	3 823
Reda river	315 000
Total of water courses	535 078
Mechanical Plant in Puck	580
Town Puck	2 000
Rzucewo	84
Total of sewage	2 664

*) SGP - the Small Gulf of Puck

In the period of recent dozens of years great changes in quantitative and qualitative state of bioceonosis in the Gulf have occurred. The general trend is typical for water bodies under degradating impacts, i.e. increasing quantitative and qualitative domination of microphytoplankton and zooplankton and simultaneous regression of plants and higher animals.

Table 6. Indices of approach intensity of N and P by rivers and in waste water to certain water bodies

Water body	Quantity		Intensity t/km^3xa		Intensity t/km^2xa	
	N (t/r)	P (t/r)	N	P	N	P
Baltic Sea $V=21.7\cdot10^3 km^3$ $S=415\cdot10^3 km^2$		53 000		2.44		0.128
Baltic proper $V=13.1\cdot10^3 km^3$ $S=212\cdot10^3 km^2$	1 000 000		76.34		4.72	
SGP *)	507.508	42.463	1695	141.54	4.92	0.41

Calculations by the author acc.to morphometric data and pollution loads acc.to (1, 6, 14).

Table 7. Extremal and average concentrations of COD, tot.N and tot. P in some water courses flowing into SGP *) in mg/dm^3 acc.to (6, 14)

Water course	Index	Concentration min.	max.	average
Sewer Władysławowo	COD	28.6	216.0	75.9
	tot.N	0.78	2.22	1.13
	tot.P	0.014	0.31	0.079
Płutnica river	COD	13.9	72.0	32.1
	tot.N	0.74	1.85	1.36
	tot.P	0.006	0.59	0.17
Sewer Błądzikowo	COD	9.8	98.1	45.5
	tot.N	2.1	40.0	9.34
	tot.P	0.021	3.0	0.81
Gizdepka river	COD	10.3	46.0	20.4
	tot.N	0.91	2.62	1.66
	tot.P	0.03	0.73	0.23
Zagórska Struga river	COD	7.2	47.8	17.7
	tot.N	0.94	2.48	1.67
	tot.P	0.06	0.42	0.15
Reda river	COD	9.2	31.0	22.3
	tot.N	0.5	1.686	0.341
	tot.P	0.026	0.205	0.083

*) SGP - the Small Gulf of Puck

In the period 1947-1978 the number of taxons in phytoplankton was reduced from 260 to 210, and simultaneously the number of taxons of Diatoma was stabile, whereas the number of taxons of the algae Cyanophyceae increased by 10 units (17). A greater domination by Diatoma approx. 75 % of taxons has been determined in the Small Gulf of Puck, however, the quantitative samples are poorer than from open waters of the Gulf of Gdansk (17). The reduction of phytoplankton in the Small Gulf of Puck and progressing development of zooplankton is dealt with in the elaboration (18).

Table 8. Concentration of phosphates and ammonia in surface and bottom layers of SGP*) in period 1975-1978 in particular seasons of the year acc.to Falkowska (13)

			Surface	Bottom
PO4 - P ($u\ gat/dm^3$)	spring	av.	0.32	0.32
		max.	1.13	0.91
		min.	0.06	0.12
	summer	av.	0.51	0.53
		max.	2.13	2.81
		min.	0.05	0.05
	autumn	av.	0.96	1.08
		max.	7.04	7.04
		min.	0.22	0.12
	winter	av.	1.12	1.25
		max.	1.16	3.08
		min.	0.42	0.47
NH^+_4 - N ($u\ gat/dm^3$)	spring	av.	1.00	1.06
		max.	5.98	2.59
		min.	0.06	0.14
	summer	av.	1.00	1.10
		max.	21.60	6.43
		min.	0.07	0.10
	autumn	av.	2.80	3.20
		max.	11.68	10.54
		min.	0.30	0.13
	winter	av.	4.31	2.10
		max.	22.80	7.19
		min.	0.79	0.71

*) SGP - the Small Gulf of Puck

The work (18) points out 10 times greater quantity of zooplankton in the Small Gulf of Puck than in the Southern Baltic Sea and 6 times greater than in the Gulf of Gdańsk, and simultanously the reduction of phytoplankton of the number $21-91 \cdot 10^3$ units/m^3 in the Small Gulf of Puck in comparison with $21-238 \cdot 10^3$ units/m^3 in the Gulf of Gdańsk and approx. 1.10^6 in the Southern Baltic Sea (19). The data mentioned above indicate a highly advanced degradation and transition of the water body into the state of saprotrophy (18). Based on

METHODS FOR REMOVAL OF NUTRIENTS FROM WASTEWATER

Erik Bundgaard
Akvadan Division
Denmark

1. INTRODUCTION

In Denmark the developments regarding wastewater treatment have been substantially different from those in other Scandinavian countries! Full biological treatment, BOD removal and nitrification have been required for all discharge of treated wastewater to fresh waters, as the basic philosophy has been to minimize the immediate oxygen demand in the streams as much as possible. These regulations have resulted in the construction of more than 400 extended aeration activated sludge plants in Denmark, mainly of the oxidation ditch type.

Within the last 10 years, processes for nutrient removal, i.e. nitrogen and phosphorus removal, suitable for extended aeration systems have been developed. The developments as regards nitrogen removal have their background in comprehensive research activities carried out by the Department of Sanitary Engineering, Technical University of Denmark, and Akvadan A/S. These activities were started in the early 1970's. A process – the Bio-Denitro process – was developed (1) and research still takes place for further development.

Phosphorus removal has mainly been carried out by the simultaneous precipitation process with ferrous salts used as precipitant, for economic reasons. Recently a new method for biological phosphorus removal has been developed. The process is now being tested in pilot plant studies and a full scale plant is in construction.

In result of the eutrophication of waters and bottoms a number of characteristic species reduced their range of occurrence, and some fragments of the sea bottom covered with organic detritus (Kuźnicka Hollow, region near Puck and the estuary of the Reda river) are devoid of benthic flora (13, 16, 18).

A particular reduction of range, quantity and biomass of Fucus vsiculosus and Furcellaria fastigiata and simultaneous domination of Ectocarpaceae from the species Ectocarpus siliculosus and Pilayella litoralis have been observed (11, 16, 18).

The excess of organic value of thallophytic algae (Thallopyta) and the class Chlorophyceae (Enteromorpha sp.) causes that they occupy the coastal waters and the sea-shore creating sanitary hazards by toxins, and in particular mycotoxins and developing on them bacteria species. The changes in zoobenthos mainly mean reduction of mussel biomass (Mytilus edulis) by approx. 66 8, and simultaneous maintenance of the molluses domination in zoobenthos (21, 24).

A transition of max. productivity to deeper zones and a reduction of biomass of shellfish (Crustacea), being the food base for fish, and increase of function of molluscs - philanthropists has occurred.

The progressing euthrophication, changes of matter and energy circulation cause particular impacts for ichthyofauna.

In the years 1964-1979 the share of fresh-water fish in total catches in the Gulf of Puck increased from 25.5 % to 45.1 %, at the same time the share of

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volume from the number of inhabitants of the order 60 000-80 000 in the season and 15 000-25 000 out of summer season.

The total load of those sewage inputs has at present a direct or indirect influence of eutrophication and pollution of the Small Gulf of Puck (18). The first stage of construction of that sewage treatment plant "Swarzewo" for the towns Puck and Władysławowo shall be completed by 1986. In that year the pollution load discharged into the Small Gulf of Puck is expected to be radically reduced. Simultaneously, other measures aimed at reduction of the number of point and area pollution sources in the river catchments feeding the Gulf shall be undertaken.

In the light of those assumptions, starting from 1986 it should be possible to observe a set-back of the present degradating trends, a reduction of pollution concentrations and biogenic compounds as well as an actual elimination of bacteriological contamination of the greater part of waters. Simultaneously, it is expected that conditions favourable for augmenting self-regulation processes in biocoenosis shall occur. In result of the above the present treands of changes in quantitative and qualitative composition of flora and fauna should be restrained and then the trend mark of environmental processes should get changed. The present state of knowledge on the Small Gulf of Puck environment as well as a number of outcomes and observations in that water body incline to make a forecast for a positive trend in environmental changes, a trend for augmenting the self-regulation processes (2,3,4,6, 18,22,23,24). The effects of that trend should be a succession of the flora and fauna previously characteristic for that water body. The directions, scale and intensity of that succession as well as a probable degree of similarity to the "primary" conditions should become the subject of detailed investigations.

DISCUSSION

At Søholt wastewater treatment plant, an effective filtration pilot plant has been build up in pilot-scale. It was statistically proved that there are no scale effects between the full-scale filter and the pilot plant. The many results obtained in the experiments, of which only some are shown in this work, have been put into a database, and software to present the results has been developed.

One of the most important results in this work is the good survey, which the experimental apparatus gives of the head loss profiles. Not until the appearance of the experimental results was it known, that what was believed to be a deep bed filtration in reality is a surface filtration, with the resulting lacking solids capacity of the filter. The question remains, in how many other places the same applies.

Two solutions are given to the surface filtration problem. Either the uppermost filter media may be changed with a media with a greater grain size (and possibly a third filter media in the middle), or the working method may be changed, as the solids capacity can be better utilized by short termed air injections during operation.

The contact filtration experiments show that the content of dissolved phosphorus in the effluent may be reduced to a lower limit of 0.05 mg/l.

The experiments show that there is no distinct difference in the results of contact filtration, where $FeSO_4$ was used, or in cases where $FeCl_3$ was used. The content of the dissolved phosphorus in the effluent may be regulated with the molar the places of occurrence or by culture. That undertaking on the mass scale can involve only fish-culture, and it is implemented at present in the range of the family Salmonidae (13).

5. Cleaning of the bottoms of excess organic matter.
6. Culture of macroalgae and vascular plants as deentrophicators (7,16,20,25).
7. Aeration of bottom waters in the Kuźnicka Hollow (5).

On the basis of elaborations and investigations carried out hitherto (4,7,13,15,25) the methods ad 1°-4° may be applied on a wider scale for achieving effects in the area of the whole water body. The other methods may be applied in macroscale for obtaining detailed data on environmental and biocoenotic changes in small parts of the water body. The method of active bottoms elaborated and analysed also in some regions of the Small Gulf of Puck (4,15) consists in putting up old fishing-nets for facilitating the development of periphyton.

The selected organisms from the epiphyte system analysed from the point of view of productivity yield significant biomass (Table 9) (4).

Table 9. Wet biomass of some more important taxons of epiphyte system from nets investigated in various seasons in g/m^2 of net surface. Acc. to (4)

Taxon season	July	September	November	max.
Gammarus	11.9	12.5	65	179.7
Idothea	2.2	29.5	4.6	48.4
Sphaeroma	0.4	4.3	not found	13.2
Mytilus	not found	24.8	36.0	47.3
Balanus	not found	39.1	76.9	133.9

The results from the experiments show that a "safe" typical concentration of suspended-phosphorus after the contact filtration will be 0.2 mg/l.

In the two examples, the required effluent qualities are for total-phosphorus concentration after filtration: ex. 1: 0.7 mg tot-P/l and ex. 2: 0.4 mg tot-P/l. With these requirements the concentration of dissolved-phosphorus after filtration will be 0.5 mg diss.-P/l, respectively 0.2 mg diss.-P/l. The results are summarized in Table 5 and 6, which clearly shows the advantage of the two stage process. The stricter requirements, the greater savings in chemicals.

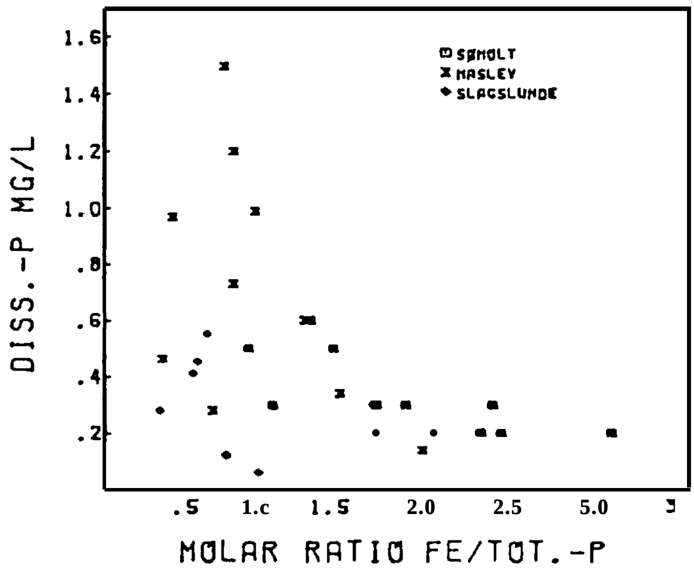

Fig. 11. Results from 3 simultaneous precipitation plants using ferroussulphate as precipitation chemical.

The application of methods ad 1°-4°, parallely besides a great amount of information on ecosystem reaction and its particular components, shall probably enable the acceleration of self-cleaning and self-regulation of the matter and energy circulation in biocoenosis of the Small Gulf of Puck. The other methods shall enable obtaining interesting investigation outcomes which may be utilized in the future in practice for recultivation of the coastal water bodies of lower ecological value.

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Table 4 shows removal of suspended solids, total phosphorus, and dissolved phosphorus from 3 simultaneous precipitation plants with subsequent contact filtration with iron. In all three plants the results are mean values. The mean values from Søholt are based on experiments with both Fe (II) and Fe (III), while the mean values from the two other plants are experiments with adding of Fe (III). (1, 2) use, besides adding of iron, also a non ionic polyelectrolyte (Meyprofloc P-3) in a concentration of 0.1 mg/l.

Table 4. Results from contact filtration. Values before and after filtration.

		Søholt	Boller et al.	Peterson & Var
ss (mg/l)	before filtration	15	12	
	after filtration	1	3	
tot. -P (mg/l)	before filtration	0.87	1.43	1.55
	after filtration	0.22	0.38	0.34
	% removal	75	73	78
Diss-P (mg/l)	before filtration	0.47	0.74	
	after filtration	0.17	0.27	
	% removal	64	64	
Molar ratio	Fe/diss.-P	4.0	2.3	5.6*

*) Fe/tot.-P

It is seen that Søholt has the smallest concentration of phosphorus in the effluent, but at an expense of a higher molar ratio. It is also seen that the simultaneous precipitation works better at Søholt than at the other plants. The pro rata removal of phosphorus in the three cases is seen to be the same. The explanation to the fact that the molar ratio at Søholt is greater than in the experiment performed by (1, 2) at the same pro rata removal of phosphorus is, that the removal of phosphorus at Søholt happens at lower absolute concentrations. This is also illustrated in Fig. 10, where the content of dissolved phosphorus after the filtration is shown as a function of the molar ratio Fe/diss.-P. used.

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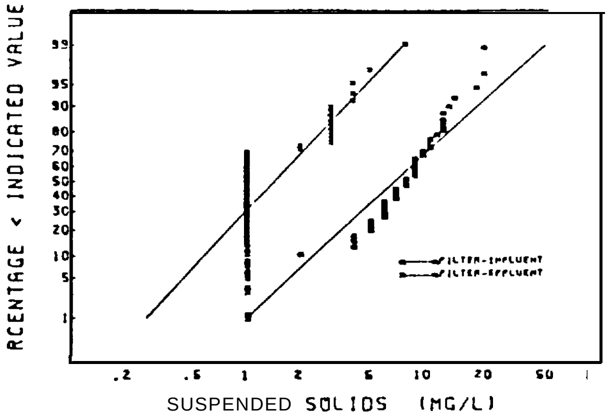
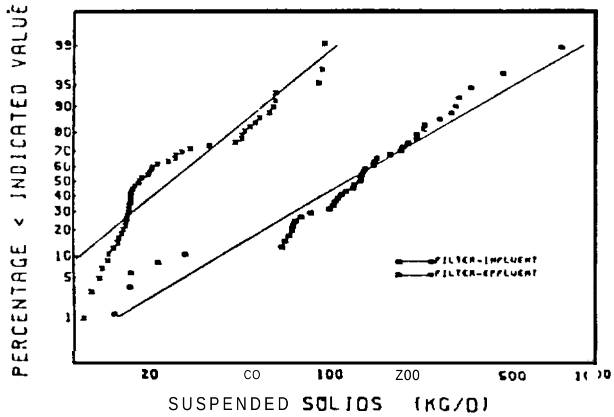


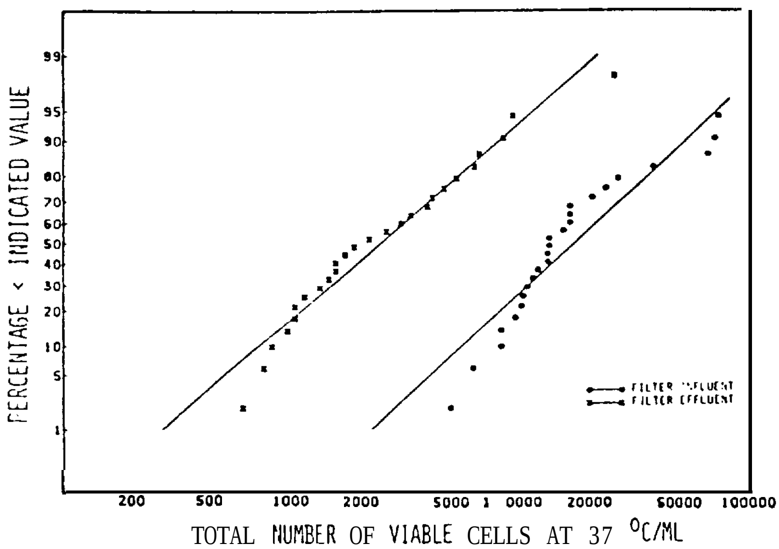
	Influent	Effluent
Number of samples	44	53
Mean	9.3	1.7
Standard deviation	8.5	1.1
Median	6.9	1.4
90%-quantile	20.1	3.6
10%-quantile	2.4	0.6
Correlation	0.93	0.81



	Influent	Effluent
Number of samples	44	53
Mean	166.3	28.5
Standard deviation	172.1	18.5
Median	115.6	24.0
90%-quantile	358.5	54.2
10%-quantile	37.3	10.6
Correlation	0.97	0.93

Fig. 7. Cumulative frequency distribution of Suspended Solids concentrations and daily loadings before and after filtration at Søholt.
Reduction (mean) 137.5 kg SS/d (83 %).

In Fig. 8 is shown a similar diagram for the content of total number of viable cells at 37 °C. The sample periods are distributed over 3 years, with the highest frequency in the summer periods.



	Influent	Effluent
Number of samples	26	26
Mean	19510	2820
Standard deviation	11275	1830
Median	16890	2365
90%-quantile	52265.	7910
10%-quantile	5460	710
Correlation	0.95	0.98

Fig. 8. Cumulative frequency distribution of total number of viable cell concentrations before and after filtration at Søholt.
Reduction (mean) 86 %.

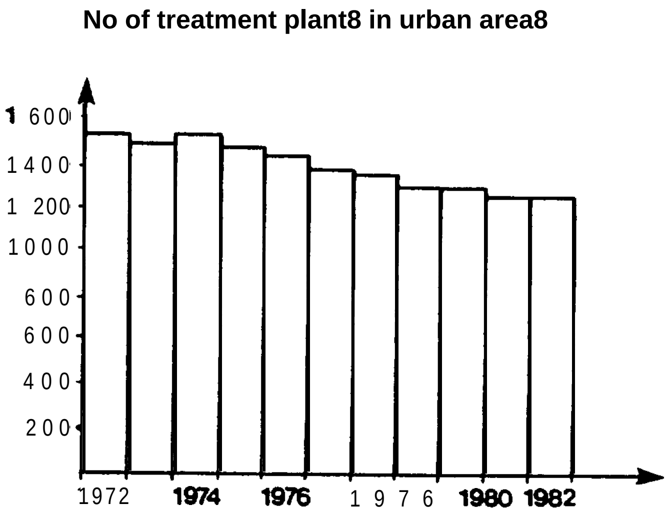


Fig. 1. Total No of municipal wastewater treatment plants in Sweden 1972-1982 (1)

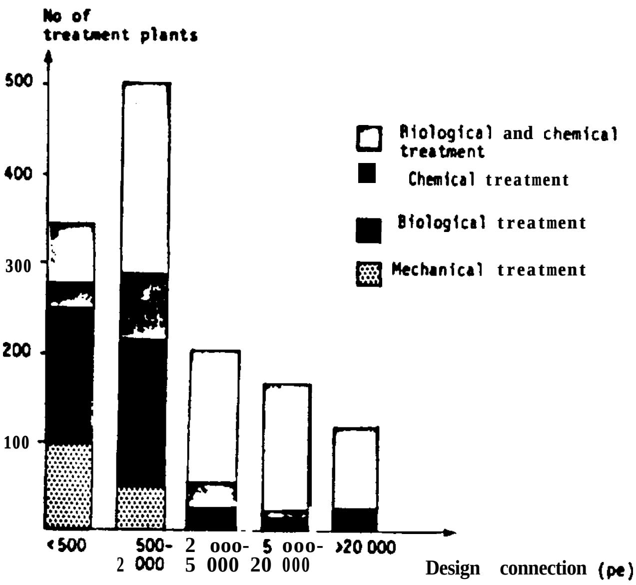
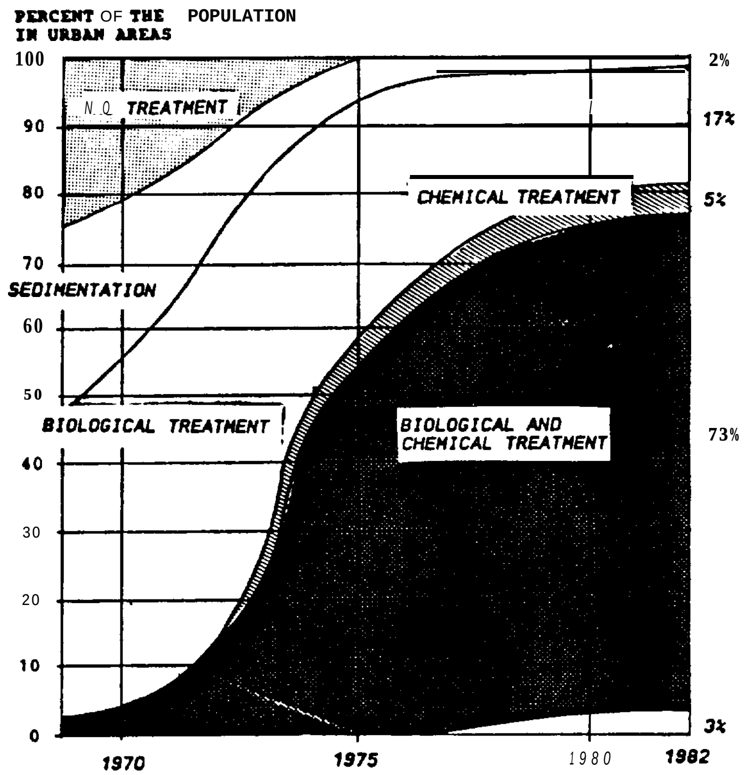


Fig. 2. No of treatment plants in Sweden 1 1979 according to size and treatment process



Type of sewage treatment	Number of treatment plants 1982-01-01	Number of persons served
No treatment		7 000
Sedimentation	109	138 000
Biological treatment	284	1 206 000
Chemical treatment	165	311 000
Bio. chemical treatment	711	5 262 000
	1 269	6 924 00

Urban areas with at least 200 inhabitants account for approximately 83% of the population in Sweden.

Fig. 3. Developmen of mun .cipal wastewater treatment in Sweden (1).

The effluents content of suspended solids and total phosphorus in the pilot scale experimental runs is shown in Table 3. The treatment plants investigated by (4) are biological plants, those investigated by (13,181 are simultaneous precipitation plants, whereas the filter investigated by (20) is filtrating secondary precipitated waste water. The table shows a removal of suspended solids of approx. 75 %, varying from 55 % to 85 %. The simultaneous precipitation plants show a removal of total phosphorus of approx. 55 % due to the filtration.

Table 3. Comparison of effluents. All values are average.

		Sohot	Fitzpatric et al.		Tholander	Latvala		Vtk
		all experiments	North	South	Märslet	Askola	Hyvinkää	Kjeller
Anthracite	(cm)	60	53	23	90			50
grain size	(mm)	1.6-2.5	2.7	1.7	1.3			0.8-1.2
Sand	(cm)	40	61	56	50	100	100	0.4-0.8
grain size	(mm)	0.8-1.2	1.4*	0.7*	0.6-0.9	-		0.4-0.8
Flow rate	(m/h)	5.6	9.3	5.1	7.7	- 7	- 7	11.3
SS before filter	(mg/l)	11	44	37	29	20	49	26
SS after filter	(mg/l)	2	7	9	13	5	7	6
Tot.-P before filter		0.64			0.50	0.5	1.3	0.34
Tot.-P after filter		0.34			0.34	0.2	0.4	0.06

* D_{50} (50 fractile in the grain size distribution)

In Fig. 5 to 7 are shown the results of the analyses for the reduction in three central parameters for the filtration. The sampling is based on weight by volume 24 hours samples and is evenly distributed over 2 years. The results are presumed to follow a logarithmic normal distribution and are presented in matching probability plots. Stable effluent qualities and good reductions are seen in all three parameters. The accumulation of dots in Fig. 7 is due to lacking accuracy in the analysis.

sedimentation. This had to be followed by a chemical step with flocculation and separation (sedimentation, flotation and/or filtration). Trickling filters were allowed without separate sludge separation before the flocculation basins.

2. CONTROL OF EFFLUENT CONCENTRATIONS

According to guidelines from the Environment Protection Board (4) effluents have to be monitored with respect to BOD,, COD and total phosphorus. Recently, suspended solids and pH have been added. The frequency is dependent on the size of the plant according to the design connection as is shown in Table 1.

Table 1. Monitoring of effluent concentrations for control purposes (4).

Parameter	Design connection, person-equivalents			
	200	200-2 000	2 000-20 0000	20 000
BOD_7	1 d/year	8 d/year	2 d/month	1 d/week
COD	1 d/year	4 d/year	1 d/month	1 w/every fortnight
P-tot	2 d/year	8 d/year	2 d/month	1 w/week
SS	2 d/year	8 d/year	2 d/month	1 d/week
pH	2 s/year	8 s/year	2 s/month	4 s/week

s = grab sample
d = 24 hours composite sample
w = 7 days composite sample

Surveys carried out by the Environment Protection Board show that a number of treatment plants do not meet their effluent conditions. A survey carried out in 1977 among 490 post precipitation plants showed that 20 % of the plants could not meet 15 mg/l BOD_7 and 35 8 could not meet 0.5 mg/l total phosphorus as the yearly average (1). The situation had improved in 1980 as was shown in a

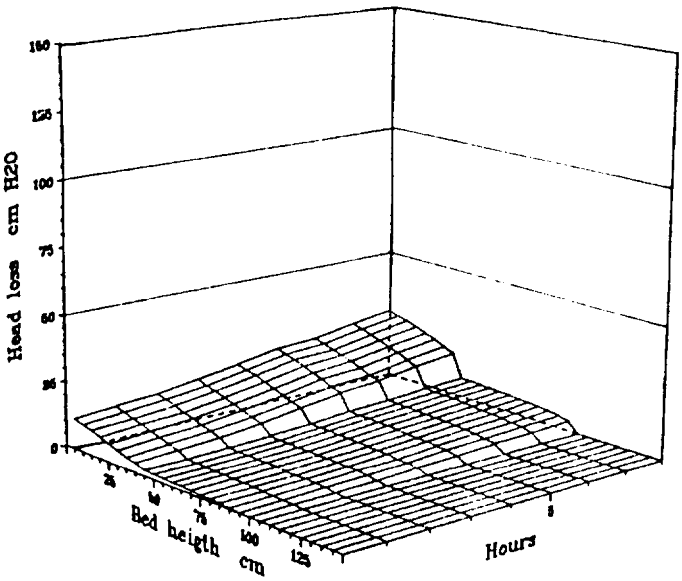


Fig. 3. Filtration cycle, 2-media-filter: Sand + plastic pellets. Period (10-2). Flow rate 6 m/h. SS: 113 mg/l. Solid loading: 648 $g/m^2 \cdot h$.

The lacking "effect of depth" in the filter manifests itself at most materials, and is a problem with the present materials at Soholt. In order to "ease" the materials and "turn" the filter cake down into these, a short air scour was tried (approx. 1 min.) after reaching half of the head loss permitted. The result is shown in Fig. 4. At t = 2.5 hour air is injected under the materials, and it is seen that the head loss is considerably decreased, because the surface filtration is changed to a deep bed filtration. It is furthermore seen that the materials pack somewhat closer.

Causes not discussed in this study but that might have a substansial impact on the operation costs and effluent quality are interest and knowledge of the operators, their capability to handle different situations and their willingness to adopt new ideas. Also poor management can be a factor of importance.

3. OPERATION MODES

Even if most of the treatment plants were designed for post-precipitation, different operation modes have been developed in practice over the past 10 years. Examples of process development that have proved to be advantageous in respect of costs or effluent concentrations are:

- nitrification
- recirculation of chemical sludge
- two point addition of precipitants

Chemical precipitants used in Sweden are AVR (a technical grade aluminium sulphate), ferric chloride, ferrous sulphate and in some small plants also lime.

In recent years a number of articles have been written describing advantages with different operation modes. Nitrification (6,7) causes a decrease in alcalinity which means that the chemical dose may be reduced drastically where post-precipitation is employed and AVR or lime are used as precipitants. Reduced amounts of precipitants also mean reduced amounts of chemical sludge to handle. Nitrification is **more energy consuming but this is outweighed by lower chemical costs and less sludge to handle.**

The recirculation **of chemical** sludge to the primary sedimentation (7,8), has proved to produce the same

When the filtration begins at t = 0, Fig. 1 shows the start head loss, which only is due to head loss because of the flow rate through the filter materials. Due to a.o. the smaller size of grain in the sand than in the anthracite layer, a more steep curve is seen at the bottom of the filter materials. As the filtration progresses this picture is blurred, and as the suspended material is accumulated in the filter materials, the greatest head loss is shifted against the top of these. The "flat plain" in front appears, because no filter materials exist at a height above 100 cm.

4. FILTRATION RESULTS

Fig. 2 shows a typical filtration cycle at the Søholt wastewater treatment plant. The total head loss measured as the function of time is more or less as expected, but the head loss profiles clearly disclose that the filter material used results in a surface filtration with a resulting lack of solids capacity in the materials, which may turn out disastrously at greater loadings.

The explanation for this surface filtration is, that the particle size distribution of the anthracite layer does not fit with the particle size distribution of the incoming suspended solids, but as will be shown later, this does not effect the removal efficiency of the filter.

periods to establish influence from factors like different weather conditions, load variations, flow, temperature, organic load etc.

The project also includes development of a computor-based datahandling and evulation system.

In Table 3 six of the treatment plants in the project are presented. Some of the results from the Eskilstuna treatment plant will be presented in more detail below.

Table 3. Treatment plants incorporated in the SWEP-project

Treatment plant	Actual loads		Tested operation modes
	Flow m^3/d	BOD, kg/d	
Eskilstuna	47 000	4 200	Post-precipitation with ferric chloride and recirculation of the sludge to the aeration basin.
	36 000	3 400	Two-stage precipitation with ferric chloride (combination of pre- and post-precipitation).
	48 000	3 800	Two-stage precipitation with ferric chloride and recirculation of the post-precipitated sludge to the influent.
	38 000	4 900	Two-stage precipitation with ferric sulphate as pre-precipitation agent and ferric-chloride as post-precipitation agent.
Linköping	42 000	8 600	Post-precrprtation with aluminium sulphate (AVR) and recirculation of the sludge to the aeration basin.
Hässleholm	11 300	1 500	Post-precipitation with ferric chloride, recirculation of the sludge to the Inflow.
	13 100	1 400	Post-precipitation with aluminium sulphate (AVR) and ferric chloride.
	12 800	1 600	Two-stage precipitation with ferric chloride (added to the grit chamber) and aluminium sulphate (AVR) (added to the post-precipitation step).
Borås	76 000	9 000	Post-precipitation with aluminium sulphate (AVR) and recirculation of the sludge to the influent. During certain periods sulphuric acid is dosed to the post-precipitation step.
Landskrona	12 400	2 700	Post-precipitation with aluminium sulphate (AVR).
	13 900	3 600	Two-stage precipitation with ferric chloride (added to the grit chamber) and aluminium sulphate (AVR) (added to the post-precipitation step).
	12 700	3 900	Two-stage precipitation with ferric chloride (combination of pre- and post-precipitation).
Sunne	3 600	1 300	Post-precipitation with lime

Anthracite 1 and anthracite 2 differ by particle size distribution, as type 2 is shifting towards higher values.

Table 2. Filter material qualities

		Søholt				Mörgeli & Ives				Boller et al.		
Material		Sand	Anthracite 1	Anthracite 2	Plastic pellets	Sand	Anthracite	Hydro-anthracite	Pumice	Sand	Anthracite	Pumice
Grain size	(mm)	0.8-1.2	1.6-2.5	1.6-2.5	3.5	0.9-1.2	1.2-2.5	1.6-2.5	1.5-2.5	0.7-1.2	1.5-2.5	1.5-2.5
Grain size (mean)	(mm)	0.9	1.3	1.4	3.5	-				0.9	2.2	2.2
Settling velocity	(m/s)	0.13	0.06	0.06	0.11	-				0.12	0.10	0.06
Density (g_s (kg/m^3))		2800	1400	1400	1200	2650	1450	1740	1180	2620	1640	1200
Hydraulic diameter	(mm)	0.7	0.9	0.9	3.0	-				0.7	1.1	1.4
Sphericity		0.78	0.67	0.63	0.86	0.70	0.65	0.65	0.75	0.78	0.50	0.64

The sphericity will be 1 for a ball and for decreasing values the material will become more and more "flaky". A "flaky" material will settle with the sides of the flakes aqainst each other and be closely packed, which gives a low permeability and thus a rapid build up of head loss. A lower limit for this sphericity is 0.6. (7). Below this limit the material will be too "flaky".

The effluent quality of the filter construction itself was followed in full-scale over a period of 2 years, independent of the tests described above. Approximately 40 samples, proportional to volumes and evenly spread over the period, were taken during a period of 24 hours before and after the filter. These were analysed for BOD_5, total phosphorus, and SS. Over a longer period of time also the hygienic effects of the full-scale filter were investigated.

Two-point addition of chemicals, $FeSO_4$ to the inflow and $FeCl_3$ in the post-precipitation step. Recirculation of chemical sludge from the post-precipitation step back to the inlet of the plant.

The monitoring programme includes analysis of SS, total phosphorus and alkalinity in the effluent on a daily basis and BOD and COD once a week. The influent as well as the primary and secondary effluents are, from time to time, analyzed less frequently.

5.1 PHOSPHORUS REDUCTION

Phosphorus concentrations throughout the plant are present in log-normal frequency-distribution diagrams for the four periods in Fig. 4,5,6 and 7.

From Fig. 4 it is obvious that most of the phosphorus is reduced in the post-precipitation step. With the introduction of two-point addition, the phosphorus will be reduced earlier in the plant as Fig. 5 and 6 show. With ferrous iron as a precipitation agent some suspended phosphorus is carried over in the primary effluent and separated in the secondary clarifiers after beeing oxidized in the aeration basins.

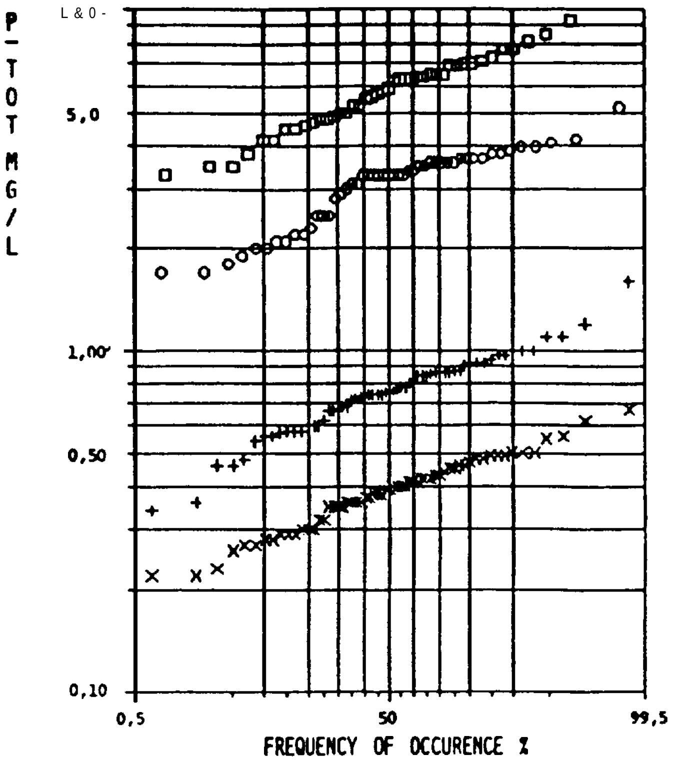
Fig. 4 and 5 show that very high phosphorus concentrations can appear in the secondary effluent. This is due to loss of suspended solids from the secondary clarifiers that appeared at high flows when post-precipitated sludge was recirculated back to the aeration basins. The activated sludge process was more stable when the recirculation of chemical sludge was changed to the primary clarifiers as can be seen in Fig. 6 and 7.

The amount of precipitants used are presented in Table 4 as avarage values for the four periods together with the mean value of total phosphorus in the effluent. The chemical dose is presented as mole of metal (Fe) added per mole of phosphorus reduced from influent fo effluent.

process at the Søholt wastewater treatment plant, which is located in Silkeborg, Denmark. The plant is a chemical biological treatment plant with nitrification and denitrification. The chemical phosphorus removal takes place by simultaneous precipitation with ferrous sulphate. The plant is designed to 105 000 persons and an average dry weather flow of 21 900 m^3/d. The filter is a two-media down stream gravitation filter, the principal data of which are described in Table 1. Besides the two filter materials described, the design of the filter allows for modification into a three-media-filter, where the third material e.g. could be plastic pellets.

The data of the full-scale filters are all, except for those relating to area, initiated in a pilot-scale filter column. The diameter of the column is 30 cm. The feeding- and backwash water to the column was taken from the same places as the supply to the full-scale filter. The column was also operated in a way closely following the programme of the full-scale filter. In the filter column tubes were mounted through the wall by every 5 cm of filter material (and 5 cm into it, in order to prevent wall effects). These 29 tubes were connected to water gauges, in which the head loss profile now could be immediately seen and was monitored automatically every hour.

Simultaneously with the head loss build up composite samples weighed by volume were taken in the inlet and outlet from the filter column. These samples were analysed for suspended solids (SS) volatile suspended solids (VSS) dissolved phosphorus (diss.-P) total phosphorus (tot.-P) alcalinity and pH.



		50% value	90% value	90%/50%	No of values
□	INFLU-ENT	5.90	7.90	1.34	43
○	PRIM EFFL	3.30	3.95	1.20	49
+	SEC EFFL	0.75	1.00	1.33	61
x	TERT EFFL	0.39	0.50	1.28	61

OPERATION MODE IV

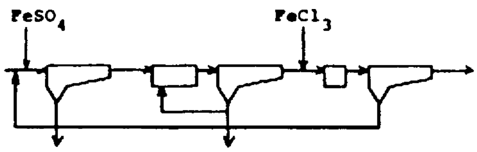
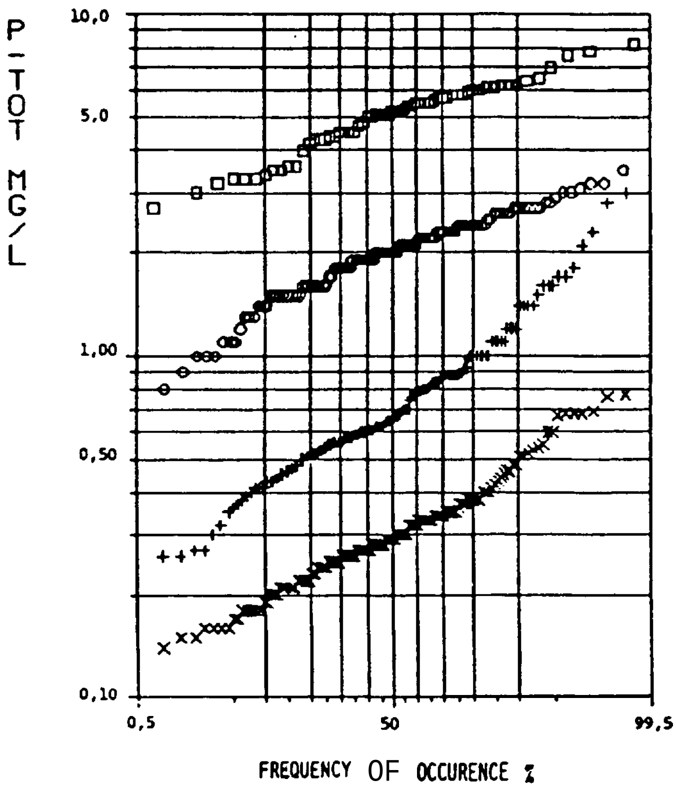


Fig. 6. Phosphorus concentrations during operation period 3



		50% value	90% value	90%/50%	No of values
□	INFLU-ENT	5.20	6.30	1.21	61
○	PRIM EFFL	2.00	2.70	1.35	143
+	SEC EFFL	0.65	1.40	2.15	151
x	TERT EFFL	0.29	0.51	1.76	151

OPERATION RODE III

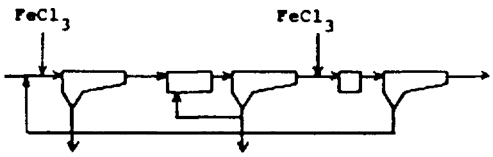


Fig. 7. Phosphorus concentrations during operation period 4

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9. Valve, M. 1983b. Typen ja fosforin poisto jätevedestä jaksottain toimivalla rinnakkaissaostusprosessilla (Summary: Removal of nitrogen and phosphorus in wastewater by a periodically operating simultaneous precipitation process) Vesitalous 3 (24) 1983, pp. 1-6.
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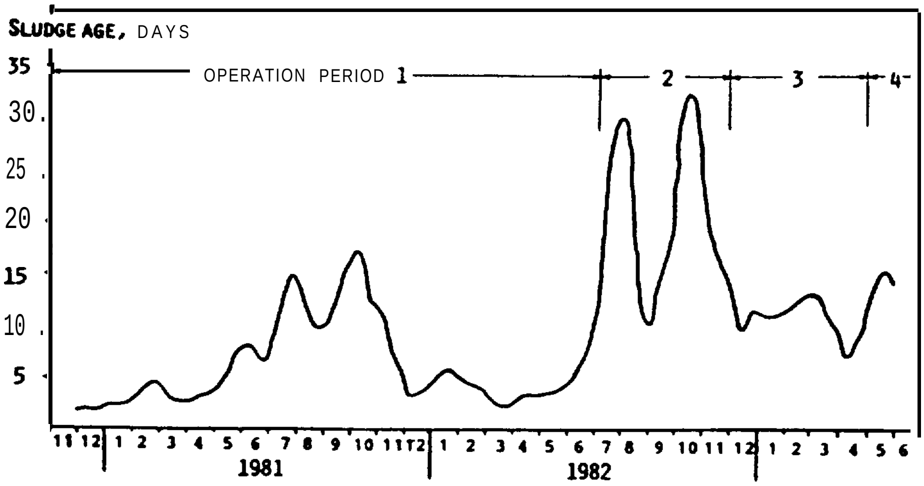


Fig. a Sludge age during the operation periods 1 to 4.

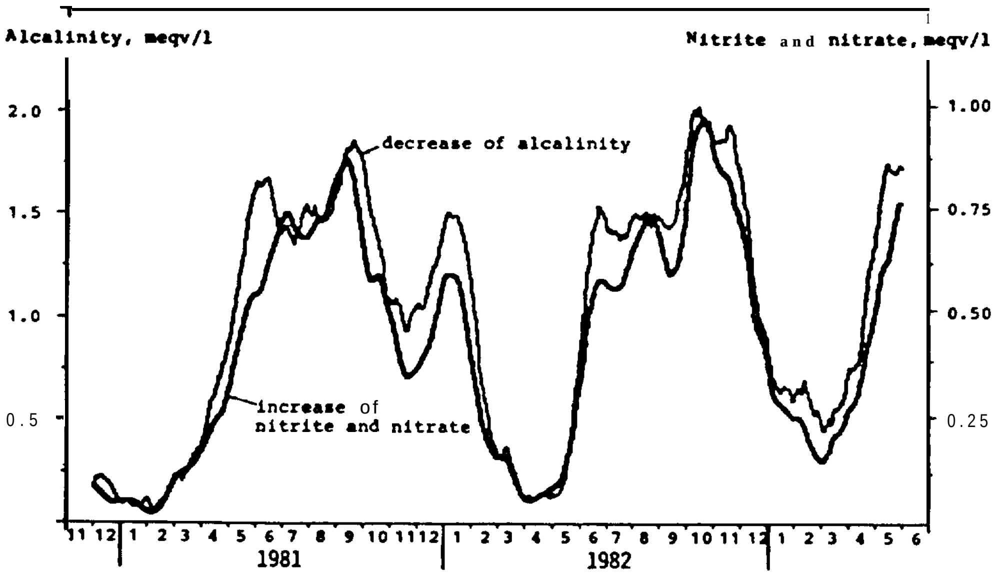


Fig. 9 Nitrification in the activated sludge system.

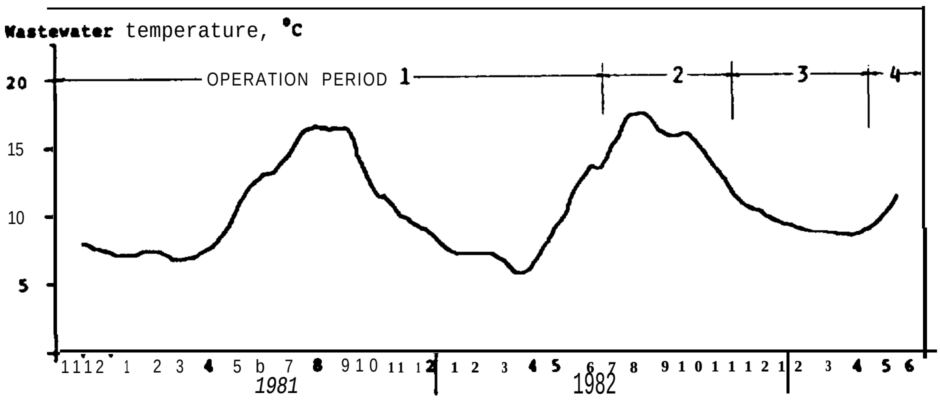


Fig. 10 Wastewater temperature.

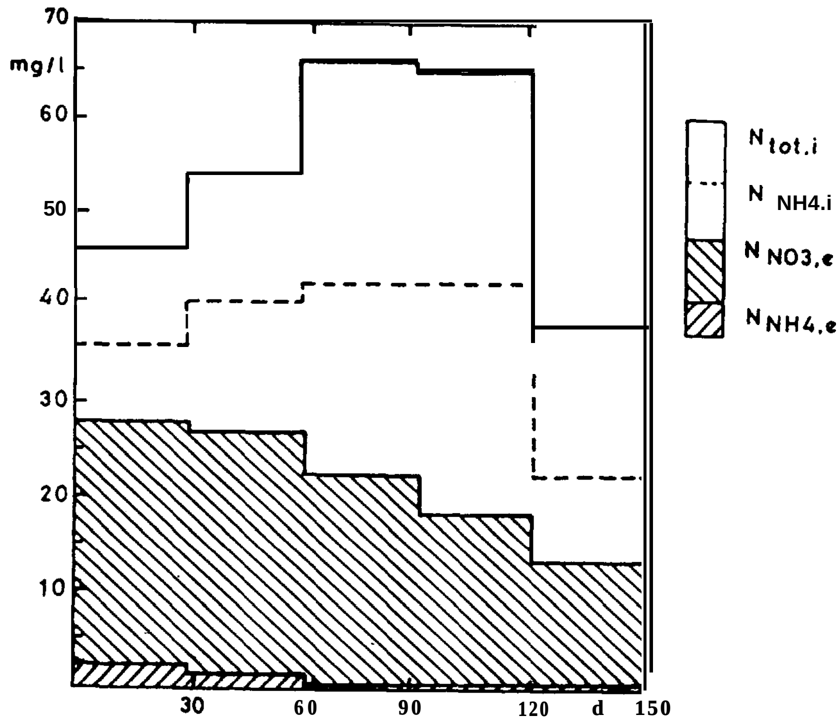


Fig. 12. Nitrogen components in full scale dn-process (Mikkeli)

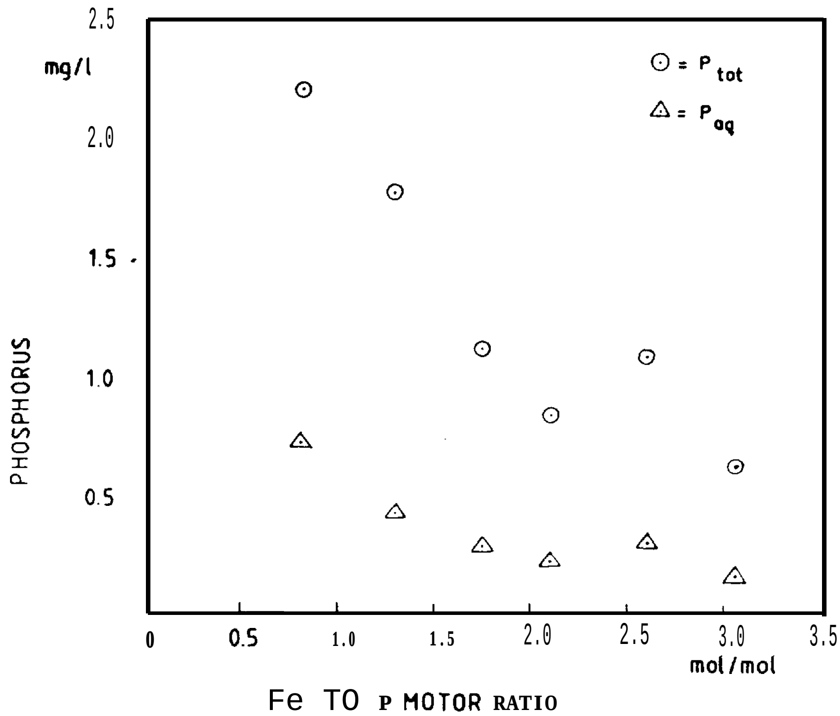


Fig. 13. Effluent phosphorus versus Fe to P molar ratio in full scale dn-process (Mikkeli)

5.3 SLUDGE PRODUCTION

The sludge production is presented in Table 5 together with the polymer consumption.

Table 5. Production of dewatered sludge and polymer consumption.

Period	Sludge production tons DS/day	Polymer kg/tons DS
1	5.24	1.62
2	5.14	1.34
3	5.6	*
4	4.8	*

*) Values yet not reported

The amount of sludge produced is influenced by weather conditions, the sludge age and nitrification and also by the dose of chemicals. At high flows a lot of suspended material, that used to be deposited in the transport system, is transported to the treatment plant. This is especially obvious during the spring time and results in one or two months with 6 tons of dry solids per day as a monthly average value. Periods with nitrification give low excess-sludge amounts from the activated sludge process. During the first operation period sludge production was to start with around 5.7 tons DS per day, which dropped to only 4.6 tons DS per day when nitrification began. The higher the chemical dose is the more chemical sludge is produced which explains the sludge amount produced during period 2 when nitrification was almost complete. Period 3 is run during a winter period with low nitrification and the following spring time with a high transport of deposits.

Polymer consumption is so far only reported during period 1 and 2 and it seems as if two-point addition gives a sludge that is more easily dewatered and demands smaller amounts of polymers.

be caused either by diffusion limitation due to the ferrous matrix surrounding the bacteria in the simultaneous precipitation flock or by competitive inhibition due to the sulphate ion. The true mechanism was not established.

The high phosphorus content was due to the rather high effluent suspended solids concentration which again is thought to be caused by the long sludge age.

The alcalinity and pH remained high enough so that no lime had to be added to the processes.

4.2 FULL SCALE STUDIES

Full scale experiments with the dn-process have been made at Mikkeli city wastewater treatment plant. It is an ordinary activated sludge plant with a U-shaped aeration basin and diffused aeration. The process was modified by turning off 30-50 % of the aerators in the first half of the aeration basin and by installing a recirculation pump in the second half.

The operating parameters during a five-month experimental period are given in Table 8.

Table 8. Parameters of full scale dn-process

Parameter	Period 1	2	3	4	5
Sludge load kg/kg.d	0.11	0.09	0.09	0.10	0.06
Sludge age d	9	9	9	9	9
Oxic retention time h	10.8	10.8	9.2	7.7	7.7
Anoxic retention time h	4.6	4.6	6.2	7.7	7.7
Temperature ^{o}C	10	10	9	10	9
Fe-feed g/m^3 Fe^{2+}	23	25	31	29	16
Lime feed g/m^3 $Ca(Oh)_2$	90	83	100	104	59
Recirculation rate %	200	200	200	200	200

useful. In addition to this there is a possibility of presenting the data in log-normal frequency distribution graphs and to calculate continuously moving average values for a specified time period.

An example of moving average technique is shown in Fig. 12 where the total phosphorus concentration in the secondary effluent from the Eskilstuna treatment plant is shown on a daily basis (curve A) and curve B shows the moving average values based on 30 days (15 days on each side of actual day). This has evened out the curve considerably. Curve C shows the residual variation around the moving average curve. As can be seen, there has been quite a dramatic change in both the concentration level and the variation since introduction of two-point addition of chemicals.

7. DISCUSSION

Results from the different operation periods that are evaluated up till now from the studied treatment plants, excluding Eskilstuna (see Table 4) and Sunne (data not yet evaluated), are summarized in Table 6.

Table 6. Results from different operation modes (10).

Treatment plant	Operational mode/ months	Precipitation agent	Dose mole/mole P removed	Effluent concentration in unfiltered samples, mg/l		
		pre/post		e-tot	BOD,	SS
Linköping	a/6	-/AVR	1.6	0.30	10	8
Hässleholm	c/7	-/$FeCl_3$	1.2	0.27	3	3
"	c/3	-/$FeCl_3$+AVR	1.9	0.06	2	2
"	b/7	aR	1.4	0.09	2	2.5
Borås	c/3	$FeCl_3$/A-/AVR	2.1	0.35	10	8
Landskrona	d/8	-/AVR	1.8	0.32	31	10
"	e/2	$FeCl_3$/AVR	2.5	0.14	11	13
"	e/1	$FeCl_3$/$FeCl_3$	1.6	0.19	15	12.5

a = post-precipitation and recirculation of the chemical sludge to the aeration basin.

b = two-point addition of chemicals (pre/post) and recirculation of chemical sludge to the inlet.

c = post-precipitation and recirculation of the chemical sludge to the inlet.

d = post-precipitation after trickling filters, no recirculation.

e = two-point addition of chemicals (pre/post) before and after trickling filters. no recirculation.

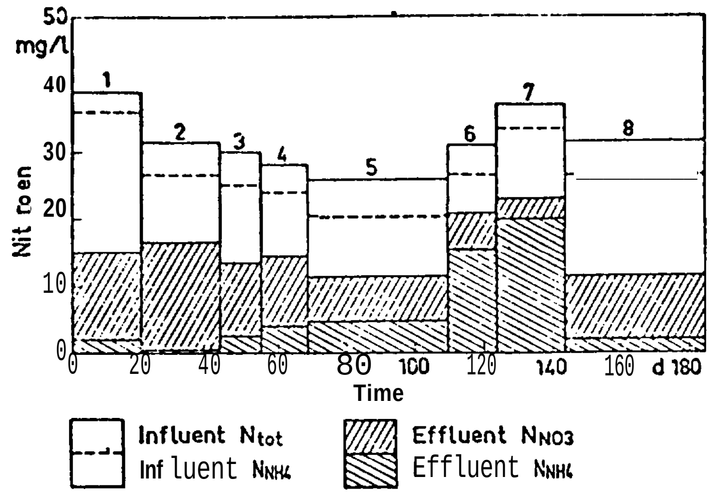
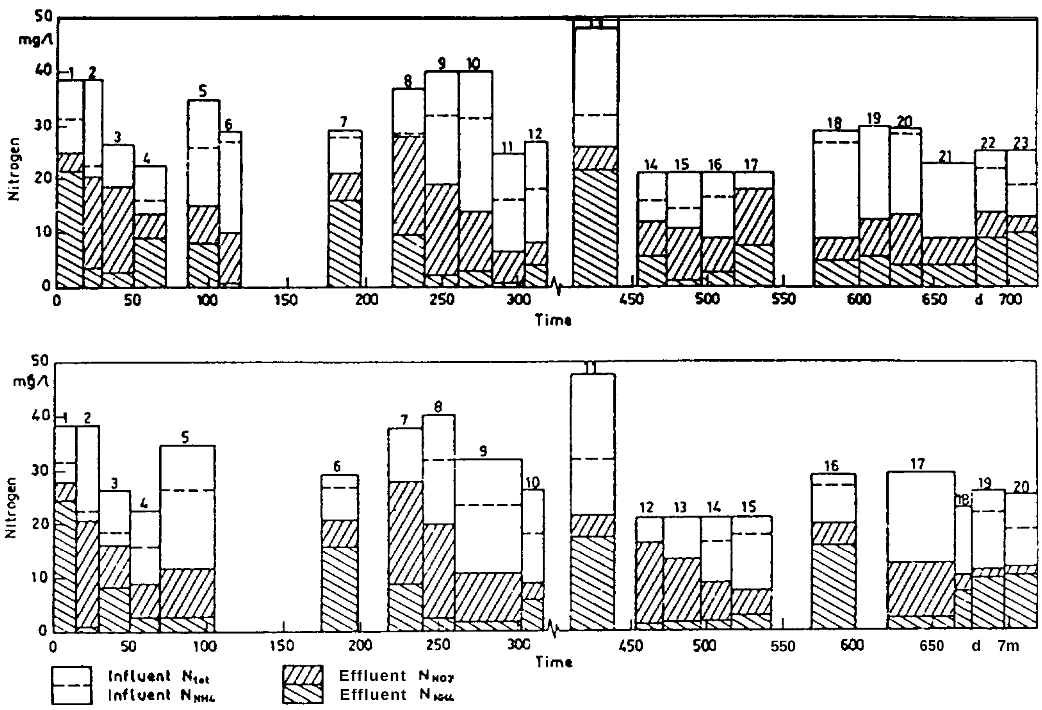


Fig. 9. Nitrogen components in dn-process during different experimental periods (8)



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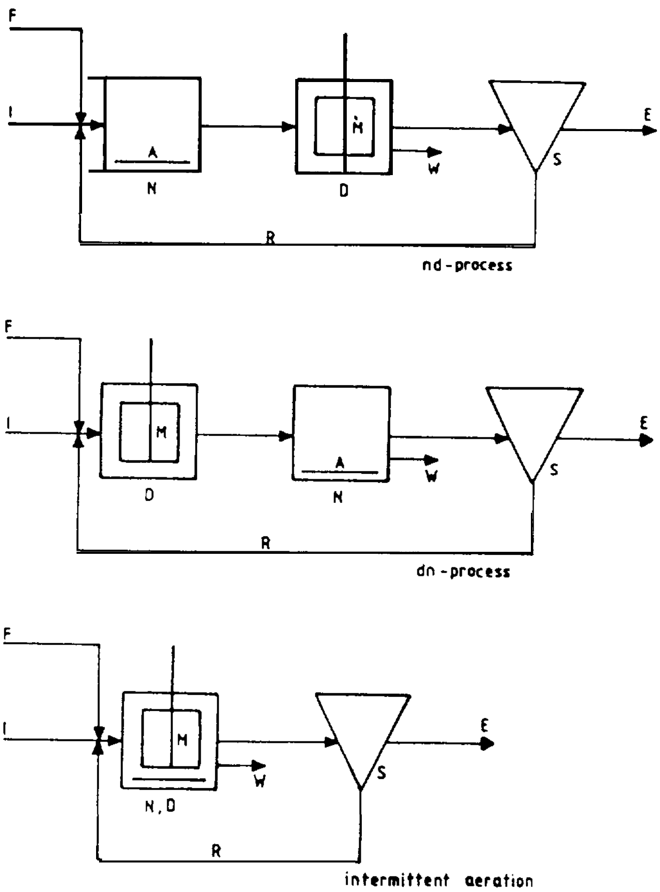

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Recirculation	%	100	400	100
Temperature range	^{o}C	10-12	10-17	10-17
Fe-feed	g/m^3 Fe^{2+}	o-13	0-26	16-26
Oxic time	h			0.5-2
Anoxic time	h			0.5-2

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G_{min} is the minimum sludge age to prevent wash out of nitrifiers.

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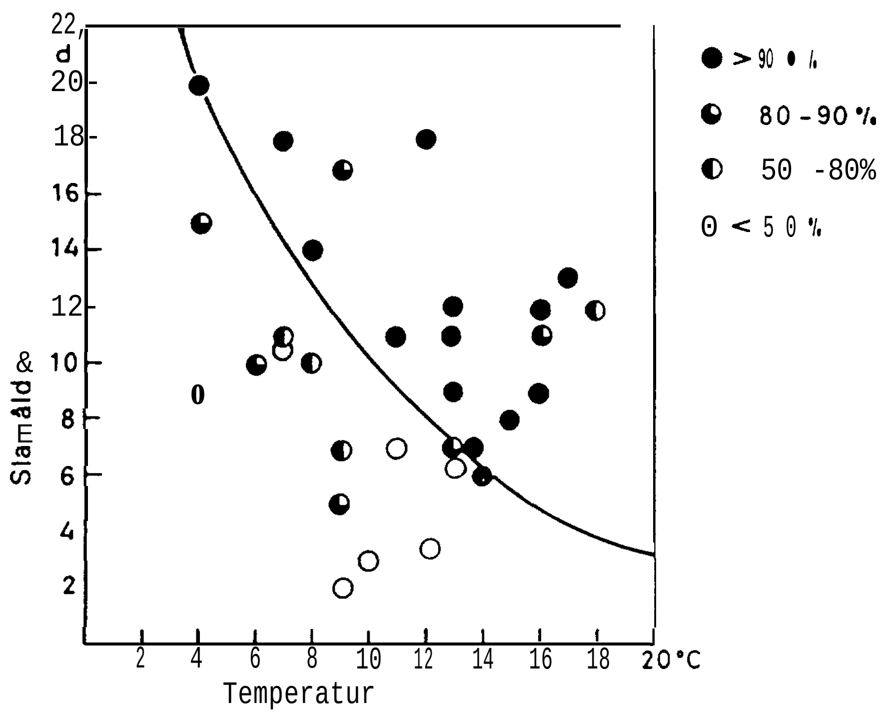

Fig. 6. Degree of nitrification at different temperatures and sludge ages in 10 treatment plants. The bold line indicates minimum sludge age versus temperature.

NUTRIENTS REMOVAL FROM WASTEWATER IN FINNISH EXPERIENCE

Matti Valve
National Board of Waters
Finland

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Several pilot-plant and full scale studies have been made in Finland in order to find out whether nitrification can be carried out in winter time and if it can be combined with simultaneous precipitation with ferrous sulphate. As the wastewaters in Finland are soft with a low alcalinity, reduction of the pH due to nitrification could also be expected with subsequent inhibition of nitrification and deflocculation of the activated sludge.

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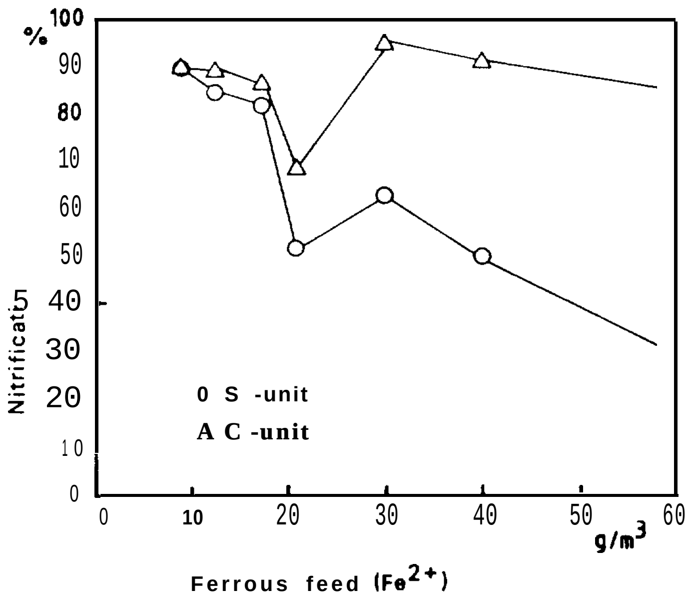

Fig. 5. Effect of ferrous sulphate on nitrification. (S=simultaneous precipitation, C=control) (6).

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Point sources		
Municipalities (Untreated/ treated)	4 200/ 800	19 600/ 13 600
Industry		
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Metal	10	1 150
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Food	39	350
Others	9	510
Fish Production	66	320

2.2 FULL SCALE STUDIES

Optimization of the simultaneous precipitation process was made at 4 treatment plants, which are situated at the river Vantaa. The optimization was accomplished by regulating the ferrous sulphate feed according to the effluent soluble phosphorus, which was set to 0.2 mg/l. The value was checked manually with a comparator. The sludge age was fixed according to the temperature and snow melting period. Four other plants were also observed as control. A summary of the results is present in Table 4.

Table 4. Summary of operating conditions and treatment efficiency at 8 treatment plants

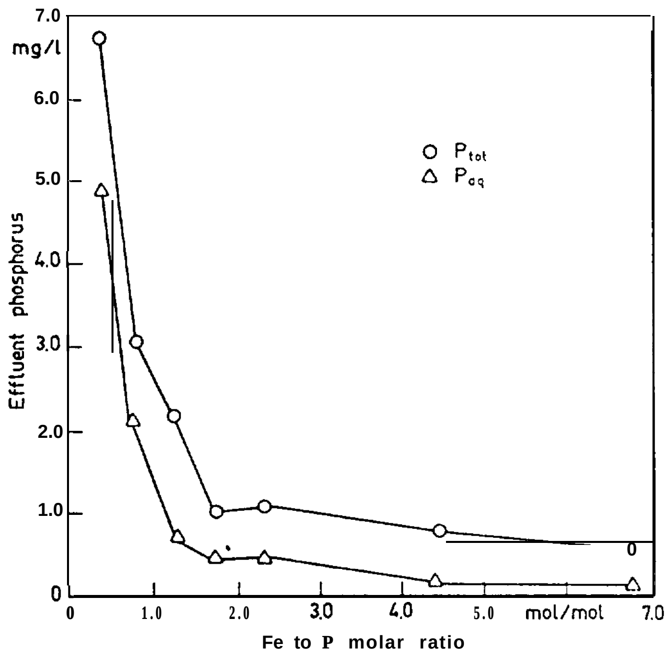
	Jokela	Nurmijärvi	Hyvinkää	Riihimäki	Lahti/Kariniemi	Suomenoja	Viikki	Seinäjoki
Flow, m^3/d	530	1800	6700	1990	10200	54500	19800	22900
Waste water composition*	D	D	D,T	D,F	D,F	D,C,M	D	D,F
Retention time, h	20	15	4	11.5	9	6.4	2.3	6.7
Sludge age, d	9-11	7-20	7	11	5-6	7-12	3	9-12
Sludge load, kg/kg·d (BOD_7/MLSS)	0.04-0.05	0.06-0.08	0.25-0.35	0.15-0.25	0.4-0.7	0.10-0.22	0.25-0.30	0.15-0.3
Fe-feed, g/m^3 Fe^{2+}/mol/mol	130/2.6	110/2.6	90/1.6	44/2.1	92/1.4	93/1.6	88/2.1	110/1.9
Temperature, °C	4-14	3-15	7-18	6.16	8-18	7-19	8-12	3-18
SVI, ml/g	SO-90	80-120	60-100	240-320	200-420	90-130	90-100	80-100
Influent Em,, mg/l	115	159	147	137	238	133	138	263
COD ($KMnO_4$), mg/l	163	228	174	133	417	210	218	337
P_{tot}, mg/l	6.0	6.2	6.2	2.5	7.5	6.6	5.4	7.6
Effluent BOD_7, mg/l	4	6	14	7	9	9	12	(20)**
COD, mg/l	34	36	46	36	67	46	58	50
P_{tot}, mg/l	0.50	0.90	0.77	0.22	0.48	0.48	0.74	0.40
P_{aq}, mg/l	0.36	0.38	0.32	0.13	0.22	0.24	0.29	0.12
SS, mg/l	5	16	11	4	6	6	14	9

* D = domestic wastewater, T = textile industry efflwts, F = food industry effluents, c = chemical industry effluents, '1 = metal industry effluents

It could be concluded that a very high efficiency could be achieved by controlling the sludge age. An example of the control strategy is given in Fig. 3.

The process parameters were: sludge load 0.1 kg/kg.d (BOD_7/MLSS), sludge age 10 d, temperature 10-17°C and hydraulic retention time 6 h. One plant acted as a control unit without ferrous sulphate. The Fe dosage in the simultaneous precipitation unit was 5-60 g/m^3 Fe^{2+} (25-300 g/m^3 $FeSO_4 \cdot 7H_2O$).

The total effluent phosphorus was 0.5-3.0 mg/l and soluble phosphorus 0.2-2.0 mg/l in the simultaneous precipitation unit depending on the Fe to P molar ratio and 4-6 mg/l in the control unit (Fig. 1).



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It was also shown that the ferrous compound bound to the sludge was still active after discontinuing of the ferrous sulphate feed: After two weeks of feeding 60 g/m^3 Fe^{2+} into the system, the feed was interrupted. The Fe content of the MLSS was then 25 %. The effluent phosphorus remained well below 1 mg/l during one week and reached 3 mg/l in

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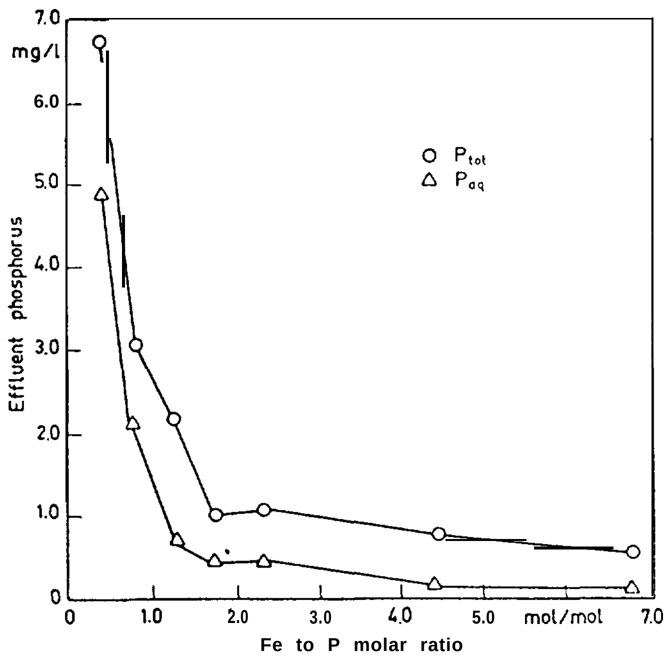

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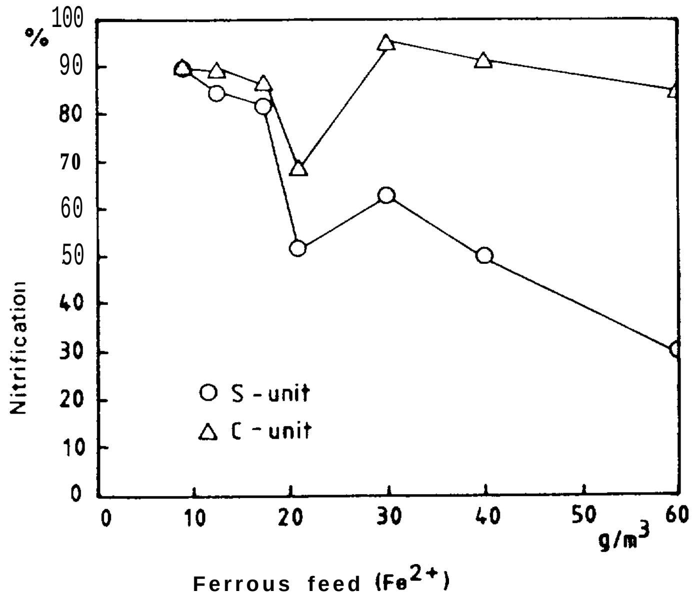

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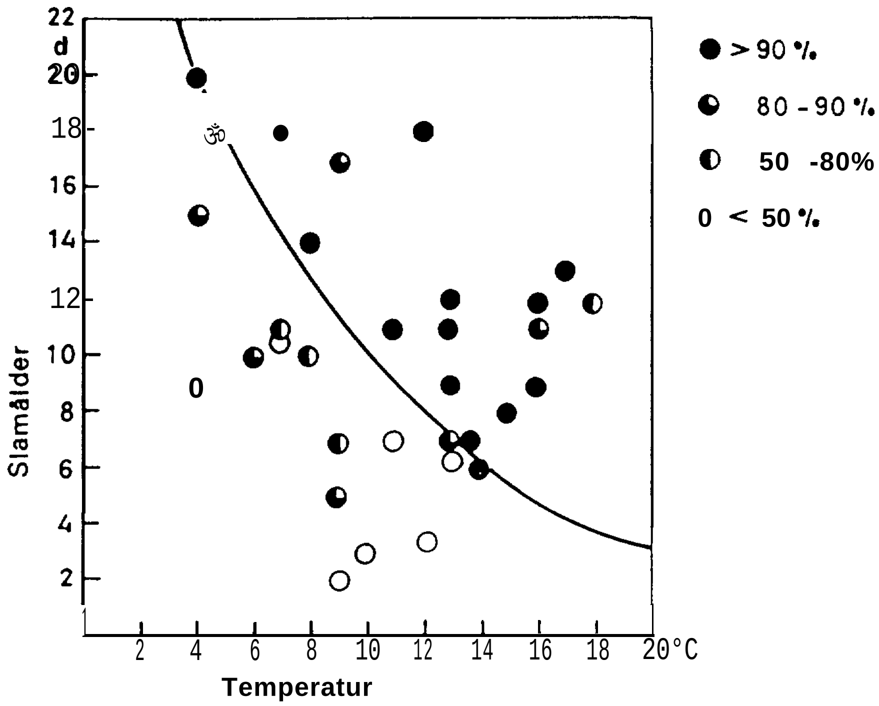

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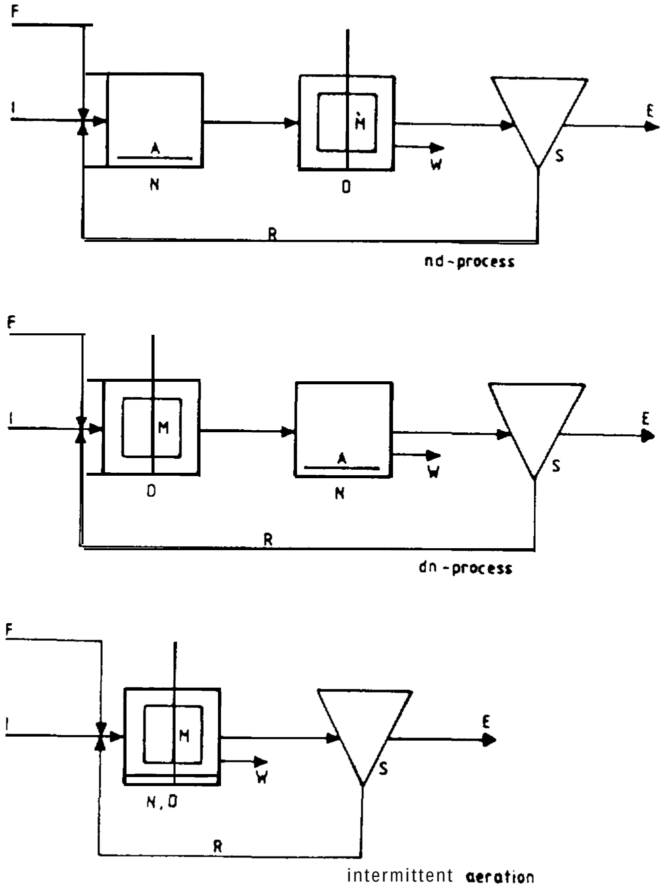

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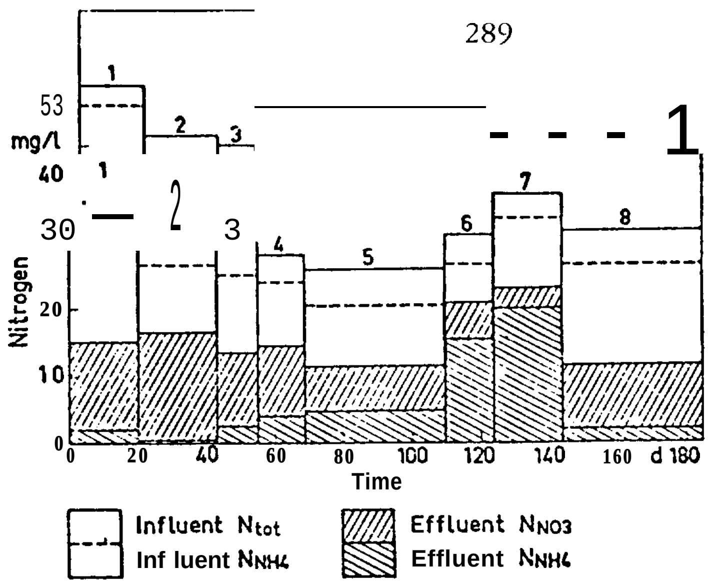

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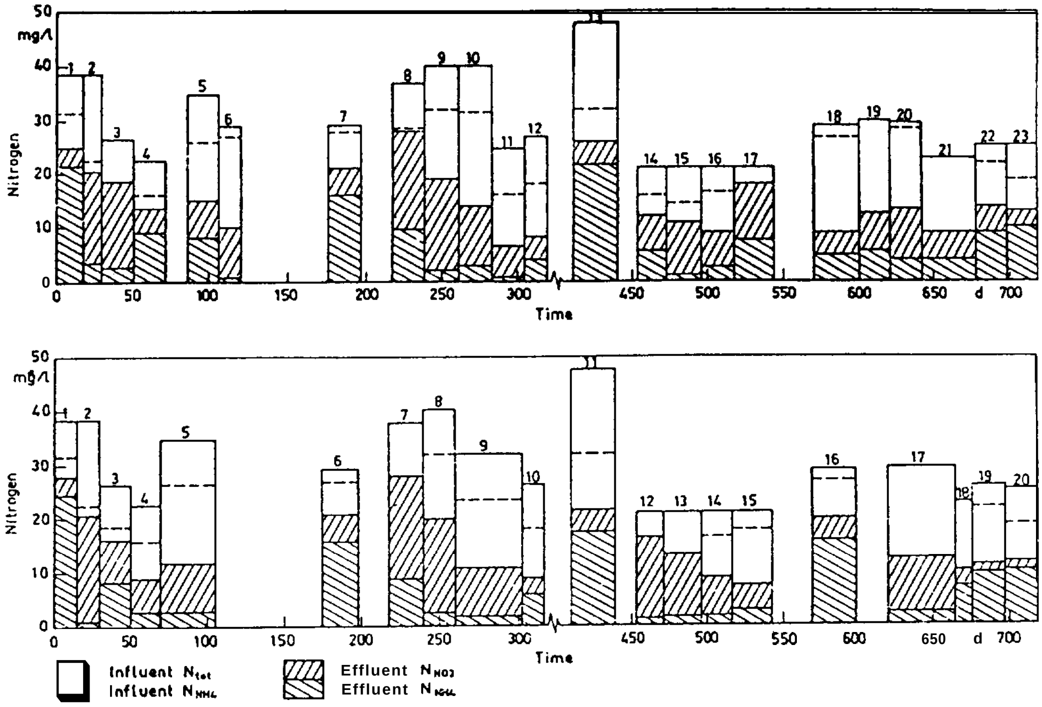

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useful. In addition to this there is a possibility of presenting the data in log-normal frequency distribution graphs and to calculate continuously moving average values for a specified time period.

An example of moving average technique is shown in Fig. 12 where the total phosphorus concentration in the secondary effluent from the Eskilstuna treatment plant is shown on a daily basis (curve A) and curve B shows the moving average values based on 30 days (15 days on each side of actual day). This has evened out the curve considerably. Curve C shows the residual variation around the moving average curve. As can be seen, there has been quite a dramatic change in both the concentration level and the variation since introduction of two-point addition of chemicals.

7. DISCUSSION

Results from the different operation periods that are evaluated up till now from the studied treatment plants, excluding Eskilstuna (see Table 4) and Sunne (data not yet evaluated), are summarized in Table 6.

Table 6. Results from different operation modes (10).

Treatment plant	Opera-tional mode/ months	Precipitation agent	Dose mole/mole P removed	Effluent concentra-tion in unfiltered samples, mg/l		
		pre/post		P-tot	BOD,	SS
Linköping	a/6	-/AVR	1.6	0.30	10	8
Hässleholm	c/7	-/$FeCl_3$	1.2	0.27	3	3
"	c/3	-/$FeCl_3$+AVR	1.9	0.06	2	2
"	b/7	$FeCl_3$/AaR	1.4	0.09	2	2.5
Borås	c/3	-/AVR	2.1	0.35	10	8
Landskrona	d/8	-/AVR	1.8	0.32	31	10
"	e/2	$FeCl_3$/AVR	2.5	0.14	11	13
"	e/1	$FeCl_3$/$FeCl_3$	1.6	0.19	15	12.5

a = post-precipitation and recirculation of the chemical sludge to the aeration basin.

b = two-point addition of chemicals (pre/post) and recirculation of chemical sludge to the inlet.

c = post-precipitatro” and recirculation of the chemical sludge to the inlet.

d = post-precipitation after trickling filters. no recirculation.

e = two-point addition of chemicals (pre/post) before and after trickling filters, no recirculation.

be caused either by diffusion limitation due to the ferrous matrix surrounding the bacteria in the simultaneous precipitation flock or by competitive inhibition due to the sulphate ion. The true mechanism was not established.

The high phosphorus content was due to the rather high effluent suspended solids concentration which again is thought to be caused by the long sludge age.

The alcalinity and pH remained high enough so that no lime had to be added to the processes.

4.2 FULL SCALE STUDIES

Full scale experiments with the dn-process have been made at Mikkeli city wastewater treatment plant. It is an ordinary activated sludge plant with a U-shaped aeration basin and diffused aeration. The process was modified by turning off 30-50 % of the aerators in the first half of the aeration basin and by installing a recirculation pump in the second half.

The operating parameters during a five-month experimental period are given in Table 8.

Table 8. Parameters of full scale dn-process

Parameter	Period 1	2	3	4	5
Sludge load kg/kg.d	0.11	0.09	0.09	0.10	0.06
Sludge age d	9	9	9	9	9
Oxic retention time h	10.8	10.8	9.2	7.7	7.7
Anoxic retention time h	4.6	4.6	6.2	7.7	7.7
Temperature ^oC	10	10	9	10	9
Fe-feed g/m^3 Fe^{2+}	23	25	31	29	16
Lime feed g/m^3 $Ca(Oh)_2$	90	83	100	104	59
Recirculation rate %	200	200	200	200	200

5.3 SLUDGE PRODUCTION

The sludge production is presented in Table 5 together with the polymer consumption.

Table 5. Production of dewatered sludge and polymer consumption.

Period	Sludge production tons DS/day	Polymer kg/tons DS
1	5.24	1.62
2	5.14	1.34
3	5.6	*
4	4.8	*

*) Values yet not reported

The amount of sludge produced is influenced by weather conditions, the sludge age and nitrification and also by the dose of chemicals. At high flows a lot of suspended material, that used to be deposited in the transport system, is transported to the treatment plant. This is especially obvious during the spring time and results in one or two months with 6 tons of dry solids per day as a monthly average value. Periods with nitrification give low excess-sludge amounts from the activated sludge process. During the first operation period sludge production was to start with around 5.7 tons DS per day, which dropped to only 4.6 tons DS per day when nitrification began. The higher the chemical dose is the more chemical sludge is produced which explains the sludge amount produced during period 2 when nitrification was almost complete. Period 3 is run during a winter period with low nitrification and the following spring time with a high transport of deposits.

Polymer consumption is so far only reported during period 1 and 2 and it seems as if two-point addition gives a sludge that is more easily dewatered and demands smaller amounts of polymers.

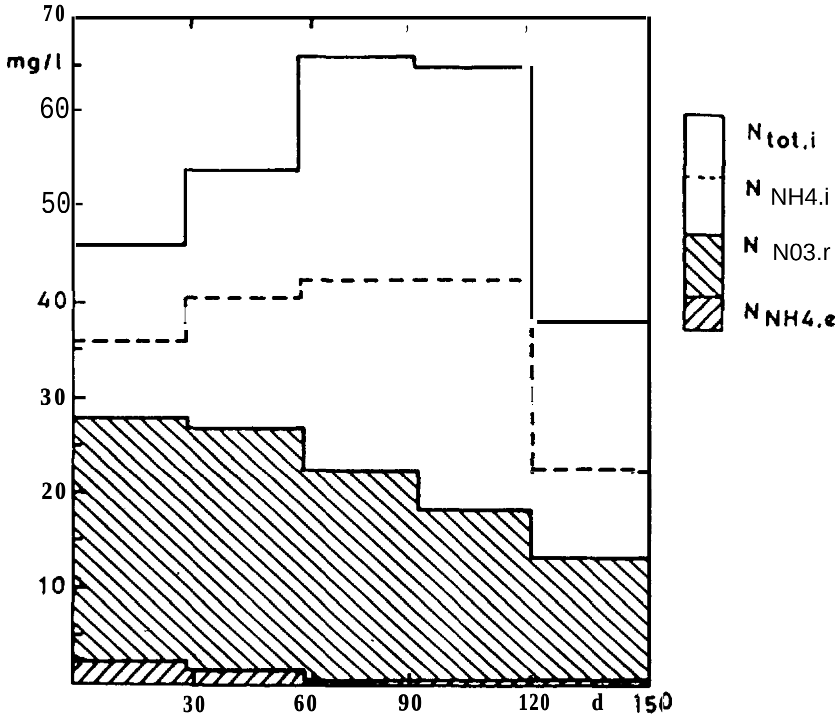

Fig. 12. Nitrogen components in full scale dn-process (Mikkeli)

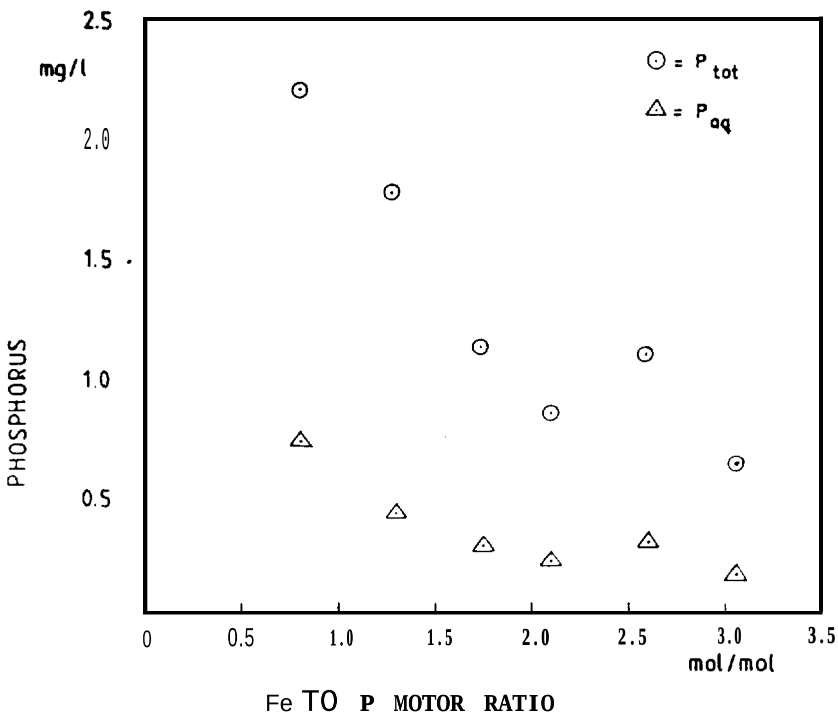

Fig. 13. Effluent phosphorus versus Fe to P molar ratio in full scale dn-process (Mikkeli)

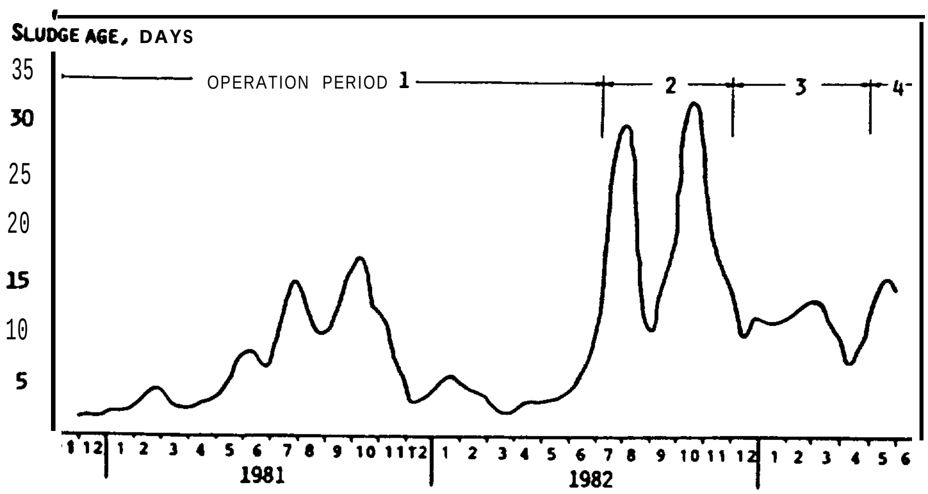

Fig. 8 Sludge age during the operation periods 1 to 4.

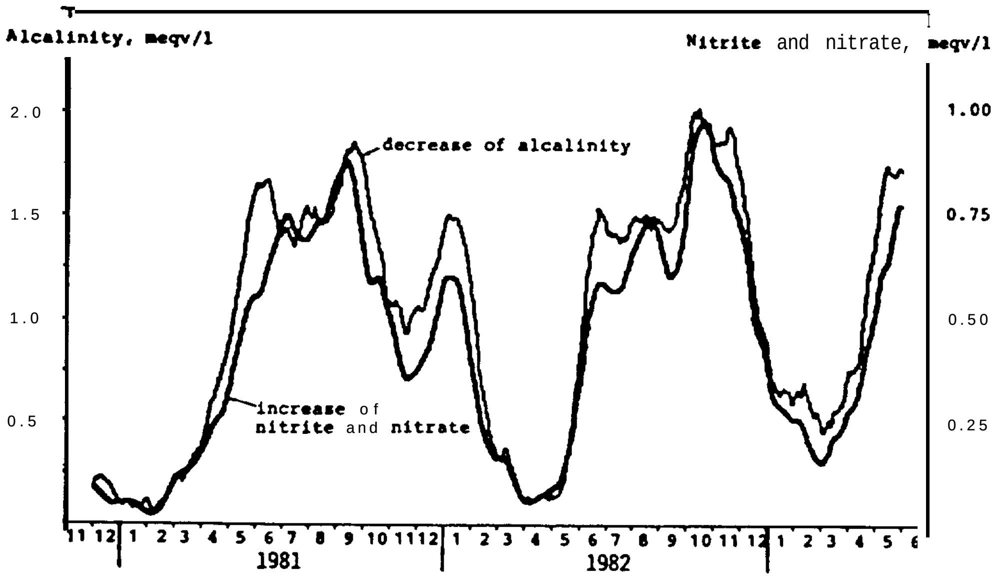

Fig. 9 Nitrification in the activated sludge system.

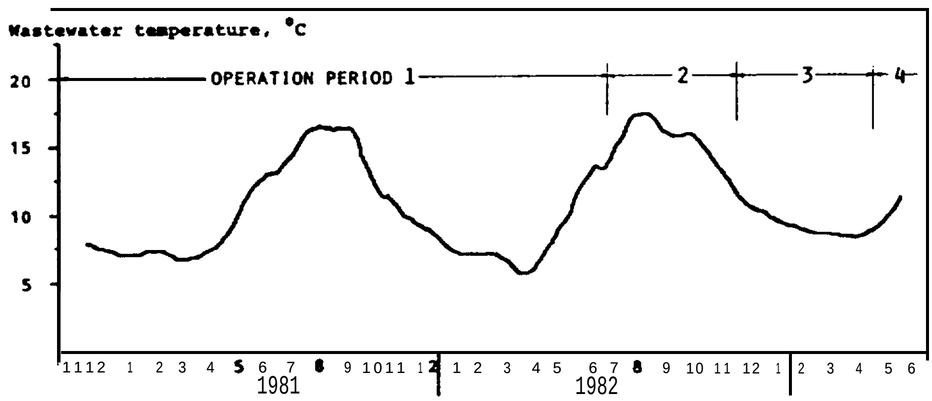

Fig. 10 Wastewater temperature.

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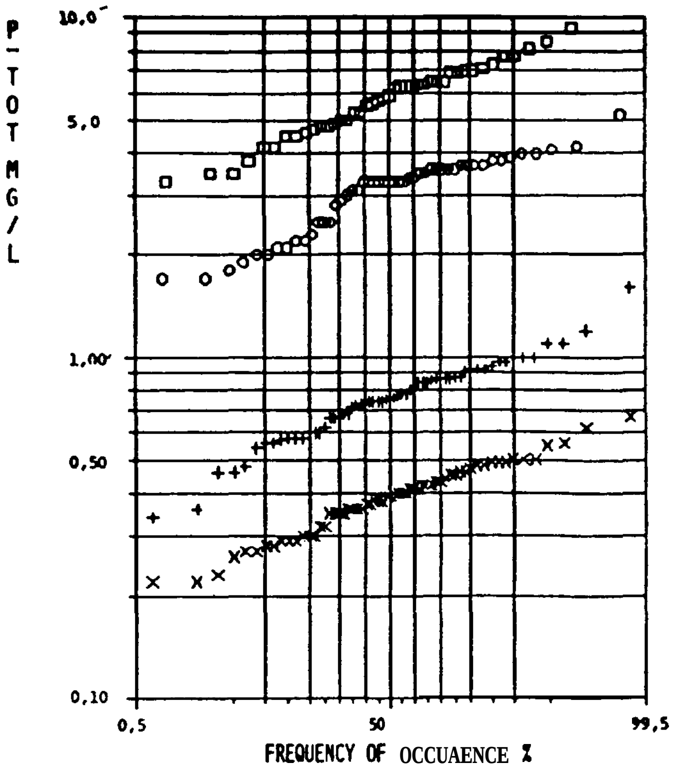


		50% value	90% value	90%/50%	No of values
□	INFLU-ENT	5.90	7.90	1.34	43
○	PRIM EFFL	3.30	3.95	1.20	49
+	SEC EFFL	0.75	1.00	1.33	61
×	TERT EFFL	0.39	0.50	1.28	61

OPERATION MODE IV

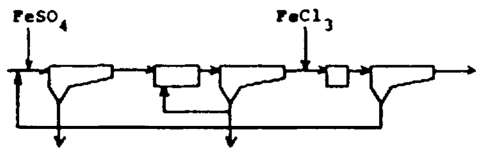
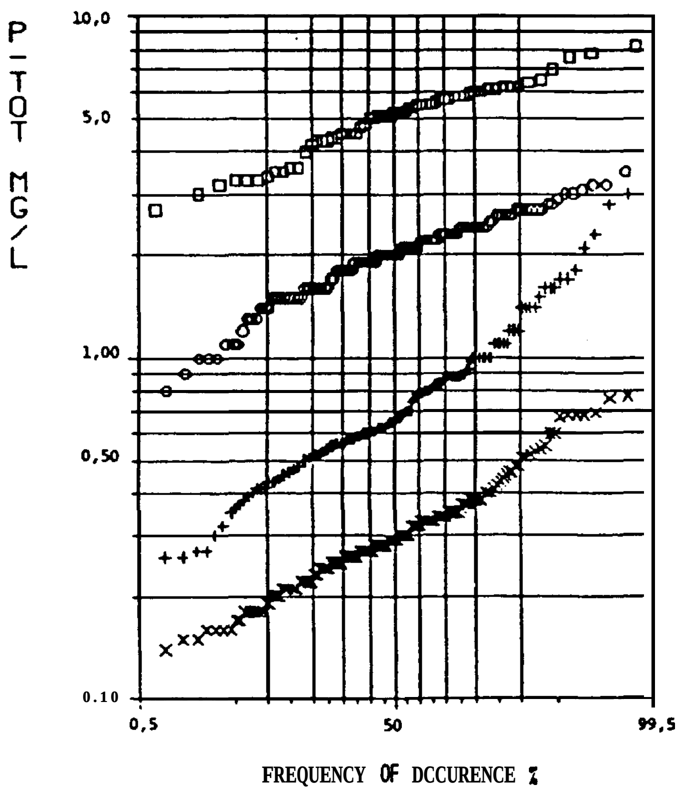


Fig. 6. Phosphorus concentrations during operation period 3



		50% value	90% value	90%/50%	No of values
□	INFLU-ENT	5.28	6.30	1.21	61
○	PRIM EFFL	2.80	2.70	1.35	143
+	SEC EFFL	0.65	1.40	2.15	151
×	TERT EFFL	0.29	0.51	1.76	151

OPERATION MODE III

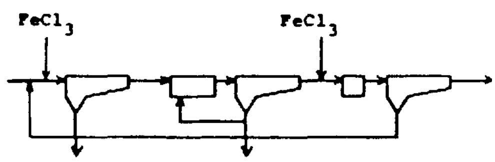


Fig. 7. Phosphorus concentrations during operation period 4

process at the Søholt wastewater treatment plant, which is located in Silkeborg, Denmark. The plant is a chemical biological treatment plant with nitrification and denitrification. The chemical phosphorus removal takes place by simultaneous precipitation with ferrous sulphate. The plant is designed to 105 000 persons and an average dry weather flow of 21 900 m^3/d. The filter is a two-media down stream gravitation filter, the principal data of which are described in Table 1. Besides the two filter materials described, the design of the filter allows for modification into a three-media-filter, where the third material e.g. could be plastic pellets.

The data of the full-scale filters are all, except for those relating to area, initiated in a pilot-scale filter column. The diameter of the column is 30 cm. The feeding- and backwash water to the column was taken from the same places as the supply to the full-scale filter. The column was also operated in a way closely following the programme of the full-scale filter. In the filter column tubes were mounted through the wall by every 5 cm of filter material (and 5 cm into it, in order to prevent wall effects). These 29 tubes were connected to water gauges, in which the head loss profile now could be immediately seen and was monitored automatically every hour.

Simultaneously with the head loss build up composite samples weighed by volume were taken in the inlet and outlet from the filter column. These samples were analysed for suspended solids (SS) volatile suspended solids (VSS) dissolved phosphorus (diss.-P) total phosphorus (tot.-P) alcalinity and pH.

Two-point addition of chemicals, $FeSO_4$ to the inflow and $FeCl_3$ in the post-precipitation step. Recirculation of chemical sludge from the post-precipitation step back to the inlet of the plant.

The monitoring programme includes analysis of SS, total phosphorus and alkalinity in the effluent on a daily basis and BOD and COD once a week. The influent as well as the primary and secondary effluents are, from time to time, analyzed less frequently.

5.1 PHOSPHORUS REDUCTION

Phosphorus concentrations throughout the plant are present in log-normal frequency-distribution diagrams for the four periods in Fig. 4,5,6 and 7.

From Fig. 4 it is obvious that most of the phosphorus is reduced in the post-precipitation step. With the introduction of two-point addition, the phosphorus will be reduced earlier in the plant as Fig. 5 and 6 show. With ferrous iron as a precipitation agent some suspended phosphorus is carried over in the primary effluent and separated in the secondary clarifiers after beeing oxidized in the aeration basins.

Fig. 4 and 5 show that very high phosphorus concentrations can appear in the secondary effluent. This is due to loss of suspended solids from the secondary clarifiers that appeared at high flows when post-precipitated sludge was recirculated back to the aeration basins. The activated sludge process was more stable when the recirculation of chemical sludge was changed to the primary clarifiers as can be seen in Fig. 6 and 7.

The amount of precipitants used are presented in Table 4 as avarage values for the four periods together with the mean value of total phosphorus in the effluent. The chemical dose is presented as mole of metal (Fe) added per mole of phosphorus reduced from influent fo effluent.

Anthracite 1 and anthracite 2 differ by particle size distribution, as type 2 is shifting towards higher values.

Table 2. Filter material qualities

Material		Søholt				Mörgeli & Ives				Boller et al.		
		Sand	Anthracite 1	Anthracite 2	Plastic pellets	Sand	Anthracite	Hydro-anthracite	Pumice	Sand	Anthracite	Pumice
Grain size	(mm)	0.8-1.2	1.6-2.5	1.6-2.5	3.5	0.8-1.2	1.2-2.5	1.6-2.5	1.5-2.5	0.7-1.2	1.5-2.5	1.5-2.5
Grain size (mean)	(mm)	0.9	1.3	1.4	3.5	-				0.9	2.2	2.2
Settling velocity	(m/s)	0.13	0.06	0.06	0.11	-				0.12	0.10	0.06
Density (g_s (kg/m^3))		2800	1400	1400	1200	2650	1450	1740	1180	2620	1640	1200
Hydraulic diameter	(mm)	0.7	0.9	0.9	3.0	-				0.7	1.1	1.4
Sphericity		0.78	0.67	0.63	0.86	0.70	0.65	0.65	0.75	0.78	0.50	0.64

The sphericity will be 1 for a ball and for decreasing values the material will become more and more "flaky". A "flaky" material will settle with the sides of the flakes aqainst each other and be closely packed, which gives a low permeability and thus a rapid build up of head loss. A lower limit for this sphericity is 0.6. (7). Below this limit the material will be too "flaky".

The effluent quality of the filter construction itself was followed in full-scale over a period of 2 years, independent of the tests described above. Approximately 40 samples, proportional to volumes and evenly spread over the period, were taken during a period of 24 hours before and after the filter. These were analysed for BOD_5, total phosphorus, and SS. Over a longer period of time also the hygienic effects of the full-scale filter were investigated.

periods to establish influence from factors like different weather conditions, load variations, flow, temperature, organic load etc.

The project also includes development of a computor-based datahandling and evulation system.

In Table 3 six of the treatment plants in the project are presented. Some of the results from the Eskilstuna treatment plant will be presented in more detail below.

Table 3. Treatment plants incorporated in the SWEP-project

Treatment plant	Actual loads		Tested operation modes
	Flow m^3/d	BOD_7 kg/d	
Eskilstuna	47 000	4 200	Post-precipitation with ferric chloride and recirculation of the sludge to the aeration basin.
	36 000	3 400	Two-stage precipitation with ferric chloride (combination of pre- and post-precipitation).
	48 000	3 800	Two-stage precipitation with ferric chloride and recirculation of the post-precipitated sludge to the influent.
	38 000	4 900	Two-stage precipitation with ferric sulphate as pre-precipitation agent and ferric-chloride as post-precipitation agent.
Linköping	42 000	8 600	Post-precipitation with aluminium sulphate (AVR) and recirculation of the sludge to the aeration basin.
Hässleholm	11 300	1 500	Post-precipitation with ferric chloride, recirculation of the sludge to the inflow.
	13 100	1 400	Post-precipitation with aluminium sulphate (AVR) and ferric chloride.
	12 800	1 600	Two-stage precipitation with ferric chloride (added to the grit chamber) and aluminium sulphate (AVR) (added to the post-precipitation step).
Borås	76 000	9 000	Post-precipitation with aluminium sulphate (AVR) and recirculation of the sludge to the influent. During certain periods sulphuric acid is dosed to the post-precipitation step.
Landskrona	12 400	2 700	Post-precipitation with aluminium sulphate (AVR).
	13 900	3 600	Two-stage precipitation with ferric chloride (added to the grit chamber) and aluminium sulphate (AVR) (added to the post-precipitation step).
	12 700	3 900	Two-stage precipitation with ferric chloride (combination of pre- and post-precipitation).
Sunne	3 600	1 300	Post-precipitation with lime.

When the filtration begins at t = 0, Fig. 1 shows the start head loss, which only is due to head loss because of the flow rate through the filter materials. Due to a.o. the smaller size of grain in the sand than in the anthracite layer, a more steep curve is seen at the bottom of the filter materials. As the filtration progresses this picture is blurred, and as the suspended material is accumulated in the filter materials, the greatest head loss is shifted against the top of these. The "flat plain" in front appears, because no filter materials exist at a height above 100 cm.

4. FILTRATION RESULTS

Fig. 2 shows a typical filtration cycle at the Søholt wastewater treatment plant. The total head loss measured as the function of time is more or less as expected, but the head loss profiles clearly disclose that the filter material used results in a surface filtration with a resulting lack of solids capacity in the materials, which may turn out disastrously at greater loadings.

The explanation for this surface filtration is, that the particle size distribution of the anthracite layer does not fit with the particle size distribution of the incoming suspended solids, but as will be shown later, this does not effect the removal efficiency of the filter.

Causes not discussed in this study but that might have a substansial impact on the operation costs and effluent quality are interest and knowledge of the operators, their capability to handle different situations and their willingness to adopt new ideas. Also poor management can be a factor of importance.

3. OPERATION MODES

Even if most of the treatment plants were designed for post-precipitation, different operation modes have been developed in practice over the past 10 years. Examples of process development that have proved to be advantageous in respect of costs or effluent concentrations are:

- nitrification
- recirculation of chemical sludge
- two point addition of precipitants

Chemical precipitants used in Sweden are AVR (a technical grade aluminium sulphate), ferric chloride, ferrous sulphate and in some small plants also lime.

In recent years a number of articles have been written describing advantages with different operation modes. Nitrification (6,7) causes a decrease in alcalinity which means that the chemical dose may be reduced drastically where post-precipitation is employed and AVR or lime are used as precipitants. Reduced amounts of precipitants also mean reduced amounts of chemical sludge to handle. Nitrification is more energy consuming but this is outweighed by lower chemical costs and less sludge to handle.

The recirculation of chemical sludge to the primary sedimentation (7,8), has proved to produce the same

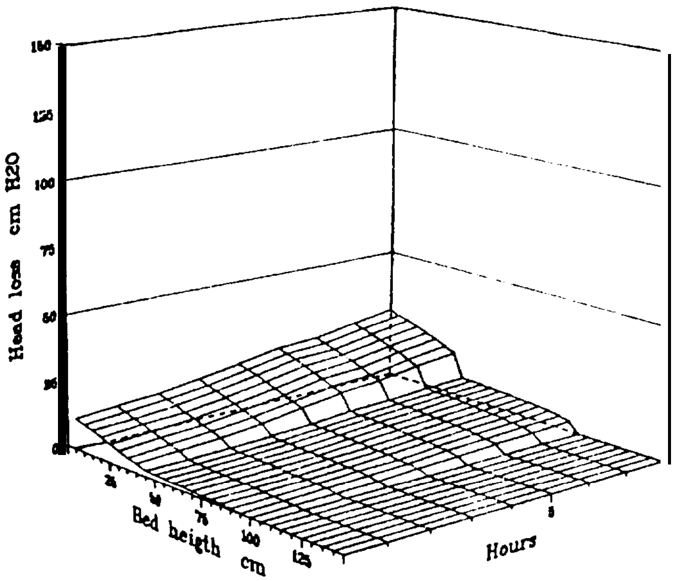


Fig. 3. Filtration cycle, 2-media-filter: Sand + plastic pellets. Period (10-2). Flow rate 6 m/h. SS: 113 mg/l. Solid loading: 648 g/ m^2 • h.

The lacking "effect of depth" in the filter manifests itself at most materials, and is a problem with the present materials at Soholt. In order to "ease" the materials and "turn" the filter cake down into these, a short air scour was tried (approx. 1 min.) after reaching half of the head loss permitted. The result is shown in Fig. 4. At t = 2.5 hour air is injected under the materials, and it is seen that the head loss is considerably decreased, because the surface filtration is changed to a deep bed filtration. It is furthermore seen that the materials pack somewhat closer.

sedimentation. This had to be followed by a chemical step with flocculation and separation (sedimentation, flotation and/or filtration). Trickling filters were allowed without separate sludge separation before the flocculation basins.

2. CONTROL OF EFFLUENT CONCENTRATIONS

According to guidelines from the Environment Protection Board (4) effluents have to be monitored with respect to BOD_7, COD and total phosphorus. Recently, suspended solids and pH have been added. The frequency is dependent on the size of the plant according to the design connection as is shown in Table 1.

Table 1. Monitoring of effluent concentrations for control purposes (4).

Parameter	Design connection, person-equivalents			
	200	200-2 000	2 000-20 0000	20 000
BOD_7	1 d/year	8 d/year	2 d/month	1 d/week
COD	1 d/year	4 d/year	1 d/month	1 w/every fortnight
P-tot	2 d/year	8 d/year	2 d/month	1 w/week
SS				
pH	2 2 d/year s/year	8 8 d/year s/year	2 2 d/month s/month	4 1 d/week s/week

s = grab sample
d = 24 hours composite sample
w = 7 days composite sample

Surveys carried out by the Environment Protection Board show that a number of treatment plants do not meet their effluent conditions. A survey carried out in 1977 among 490 post precipitation plants showed that 20 % of the plants could not meet 15 mg/l BOD_7 and 35 8 could not meet 0.5 mg/l total phosphorus as the yearly average (1). The situation had improved in 1980 as was shown in a

The effluents content of suspended solids and total phosphorus in the pilot scale experimental runs is shown in Table 3. The treatment plants investigated by (4) are biological plants, those investigated by (13,18) are simultaneous precipitation plants, whereas the filter investigated by (20) is filtrating secondary precipitated waste water. The table shows a removal of suspended solids of approx. 75 %, varying from 55 % to 85 %. The simultaneous precipitation plants show a removal of total phosphorus of approx. 55 % due to the filtration.

Table 3. Comparison of effluents. All values are average.

		Sohot	Fitzpatric et al.		Tholander	Latvala		Vik
		all experiments	North	South	Märslet	Askola	Hyvinkää	Kjeller
Anthracite	(cm)	60	53	23	80			50
grain size	(mm)	1.6-2.5	2.7	1.7	1.3			0.8-1.2
Sand	(cm)	40	61	56	50	100	100	0.4-0.8
grain size	(mm)	O.R-1.2	1.4’	0.7’	0.6-0.9			0.4-0.8
Flow rate	(m/h)	5.6	7.3	5.1	7.7	- 7	- 7	11.3
SS before filter	(mg/l)	11	44	37	29	20	48	26
SS after filter	(mg/l)	2	7	9	13	5	7	6
Tot.-P before filter		0.64			0.50	0.5	1.3	0.34
Tot.-P after filter		0.34			0.34	0.2	0.4	0.06

• D_{50} (50 fractile in the grain size distribution)

In Fig. 5 to 7 are shown the results of the analyses for the reduction in three central parameters for the filtration. The sampling is based on weight by volume 24 hours samples and is evenly distributed over 2 years. The results are presumed to follow a logarithmic normal distribution and are presented in matching probability plots. Stable effluent qualities and good reductions are seen in all three parameters. The accumulation of dots in Fig. 7 is due to lacking accuracy in the analysis.

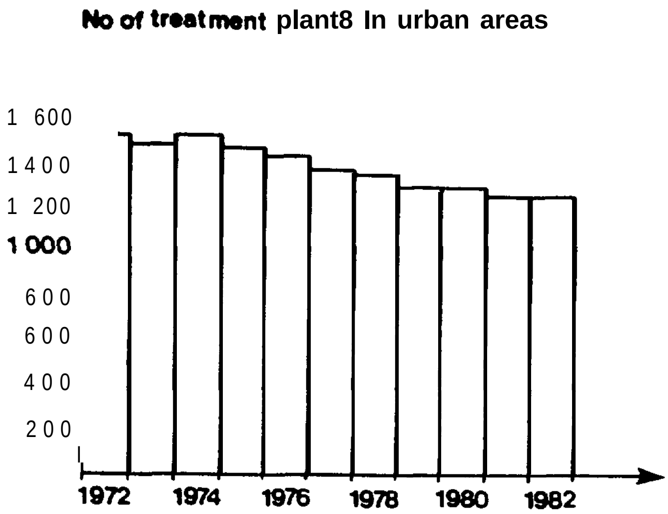


Fig. 1. Total No of municipal wastewater treatment plants in Sweden 1972-1982 (1)

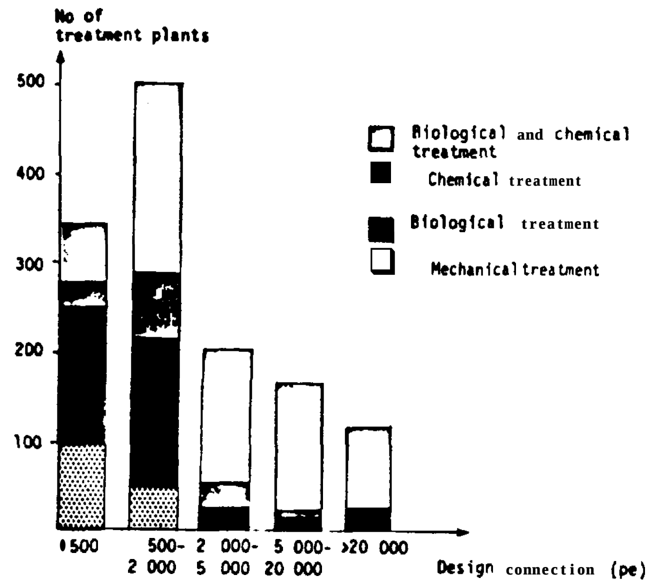
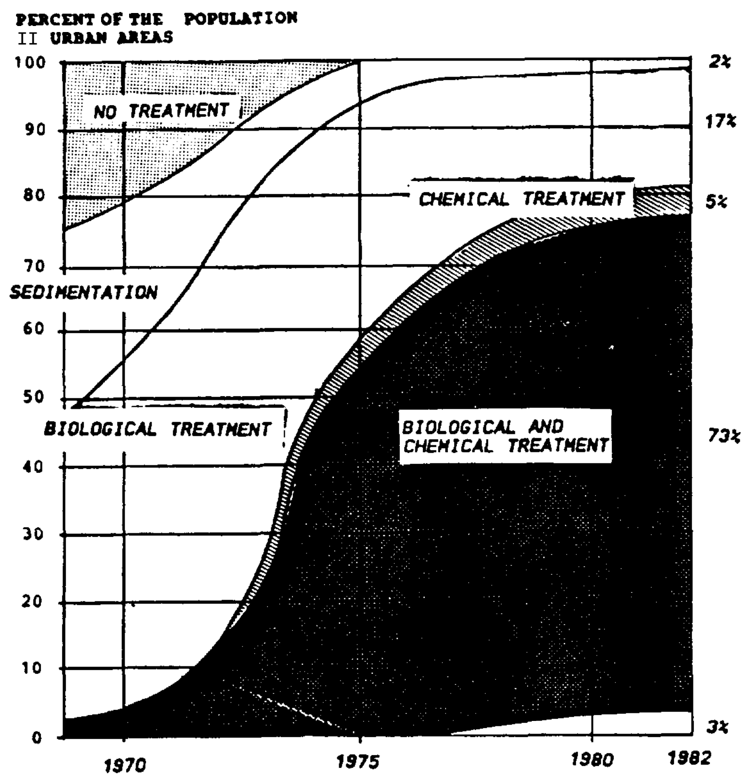


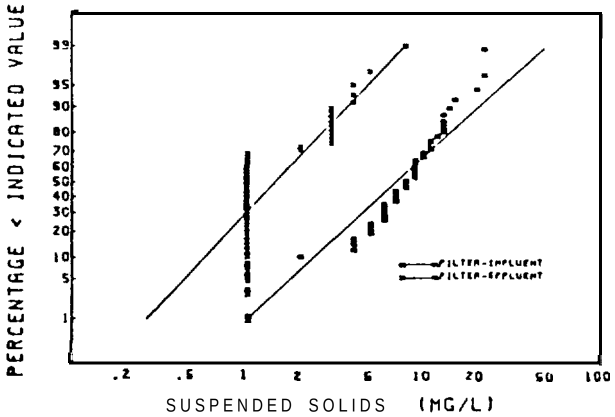
Fig. 2. No of treatment plants in Sweden 1 1979 according to size and treatment process

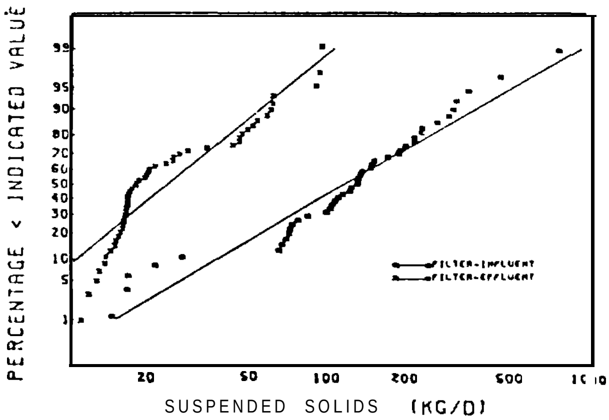


Type of sewage treatment	Number of treatment plants 1982-01-01	Number of persons served
No treatment		7 000
Sedimentation	109	138 000
Biological treatment	284	1 206 000
Chemical treatment	165	311 000
Bio. chemical treatment	711	5 262 000
	1 269	6 924 OO

Urban areas with at least 200 inhabitants account for approximately 83% of the population in Sweden.

Fig. 3. Deve.opment of municipal wastewater treatment in Sweden (1).



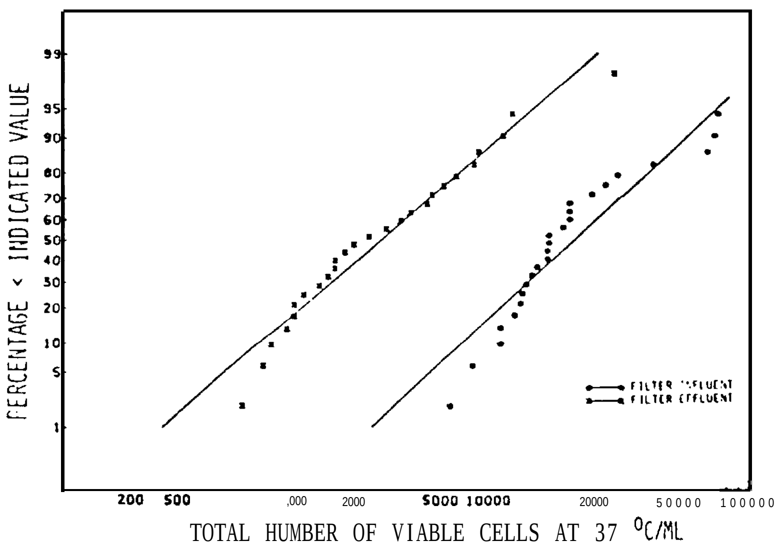


	Influent	Effluent
Number of samples	44	53
Mean	9.3	1.7
Standard deviation	8.5	1.1
Median	6.9	1.4
		3.6
10%-quantile	28.1	0.6
Correlation	0.93	0.81

	Influent	Effluent
Number of samples	44	53
Mean	166.3	28.5
Standard deviation	172.1	18.5
Median	115.6	24.0
90%-quantile	358.5	54.2
10%-quantile	37.3	10.6
Correlation	0.97	0.93

Fig. 7. Cumulative frequency distribution of Suspended Solids concentrations and daily loadings before and after filtration at Søholt.
Reduction (mean) 137.5 kg SS/d (83 %).

In Fig. 8 is shown a similar diagram for the content of total number of viable cells at 37 °C. The sample periods are distributed over 3 years, with the highest frequency in the summer periods.



	Influent	Effluent
Number of samples	26	26
Mean	19510	2820
Standard deviation	11275	1830
Median	16890	2365
90%-quantile	52265.	7910
10%-quantile	5460	710
Correlation	0.95	0.98

Fig. 8. Cumulative frequency distribution of total number of viable cell concentrations before and after filtration at Søholt.
Reduction (mean) 86 8.

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Table 4 shows removal of suspended solids, total phosphorus, and dissolved phosphorus from 3 simultaneous precipitation plants with subsequent contact filtration with iron. In all three plants the results are mean values. The mean values from Søholt are based on experiments with both Fe (II) and Fe (III), while the mean values from the two other plants are experiments with adding of Fe (III). (1, 2) use, besides adding of iron, also a non ionic polyelectrolyte (Meyprofloc P-3) in a concentration of 0.1 mg/l.

Table 4. Results from contact filtration. Values before and after filtration.

		Søholt	Boller et al	Peterson & Var
ss (mg/l)	before filtration	15	12	
	after filtration	1	3	
tot.-P (mg/l)	before filtration	0.87	1.43	1.55
	after filtration	0.22	0.38	0.34
	% removal	75	73	78
Diss-P (mg/l)	before filtration	0.47	0.74	
	after filtration	0.17	0.27	
	% removal	64	64	
Molar ratio	Fe/diss.-P	4.0	2.3	5.6*

*) Fe/tot.-P

It is seen that Søholt has the smallest concentration of phosphorus in the effluent, but at an expense of a higher molar ratio. It is also seen that the simultaneous precipitation works better at Søholt than at the other plants. The pro rata removal of phosphorus in the three cases is seen to be the same. The explanation to the fact that the molar ratio at Søholt is greater than in the experiment performed by (1, 2) at the same pro rata removal of phosphorus is, that the removal of phosphorus at Søholt happens at lower absolute concentrations. This is also illustrated in Fig. 10, where the content of dissolved phosphorus after the filtration is shown as a function of the molar ratio Fe/diss.-P. used.

The application of methods ad 1°-4°, parallely besides a great amount of information on ecosystem reaction and its particular components, shall probably enable the acceleration of self-cleaning and self-regulation of the matter and energy circulation in biocoenosis of the Small Gulf of Puck. The other methods shall enable obtaining interesting investigation outcomes which may be utilized in the future in practice for recultivation of the coastal water bodies of lower ecological value.

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The results from the experiments show that a "safe" typical concentration of suspended-phosphorus after the contact filtration will be 0.2 mg/l.

In the two examples, the required effluent qualities are for total-phosphorus concentration after filtration: ex. 1: 0.7 mg tot-P/l and ex. 2: 0.4 mg tot-P/l. With these requirements the concentration of dissolved-phosphorus after filtration will be 0.5 mg diss.-P/l, respectively 0.2 mg diss.-P/l. The results are summarized in Table 5 and 6, which clearly shows the advantage of the two stage process. The stricter requirements, the greater savings in chemicals.

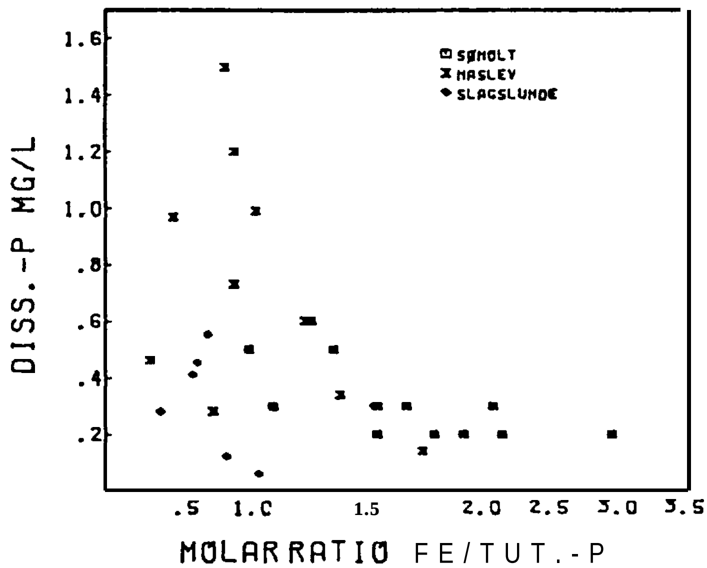

Fig. 11. Results from 3 simultaneous precipitation plants using ferroussulphate as precipitation chemical.

the places of occurrence or by culture. That undertaking on the mass scale can involve only fish-culture, and it is implemented at present in the range of the family Salmonidae (13).

5. Cleaning of the bottoms of excess organic matter.
6. Culture of macroalgae and vascular plants as deentrophicators (7,16,20,25).
7. Aeration of bottom waters in the Kuźnicka Hollow (5).

On the basis of elaborations and investigations carried out hitherto (4,7,13,15,25) the methods ad 1°–4° may be applied on a wider scale for achieving effects in the area of the whole water body. The other methods may be applied in macroscale for obtaining detailed data on environmental and biocoenotic changes in small parts of the water body. The method of active bottoms elaborated and analysed also in some regions of the Small Gulf of Puck (4,15) consists in putting up old fishing-nets for facilitating the development of periphyton.

The selected organisms from the epiphyte system analysed from the point of view of productivity yield significant biomass (Table 9) (4).

Table 9. Wet biomass of some more important taxons of epiphyte system from nets investigated in various seasons in g/m^2 of net surface. Acc. to (4)

Taxon season	July	September	November	max.
Gammarus	11.9	12.5	65	179.7
Idothea	2.2	29.5	4.6	48.4
Sphaeroma	0.4	4.3	not found	13.2
Mytilus	not found	24.8	36.0	47.3
Balanus	not found	39.1	76.9	133.9

DISCUSSION

At Søholt wastewater treatment plant, an effective filtration pilot plant has been build up in pilot-scale. It was statistically proved that there are no scale effects between the full-scale filter and the pilot plant. The many results obtained in the experiments, of which only some are shown in this work, have been put into a database, and software to present the results has been developed.

One of the most important results in this work is the good survey, which the experimental apparatus gives of the head loss profiles. Not until the appearance of the experimental results was it known, that what was believed to be a deep bed filtration in reality is a surface filtration, with the resulting lacking solids capacity of the filter. The question remains, in how many other places the same applies.

Two solutions are given to the surface filtration problem. Either the uppermost filter media may be changed with a media with a greater grain size (and possibly a third filter media in the middle), or the working method may be changed, as the solids capacity can be better utilized by short termed air injections during operation.

The contact filtration experiments show that the content of dissolved phosphorus in the effluent may be reduced to a lower limit of 0.05 mg/l.

The experiments show that there is no distinct difference in the results of contact filtration, where $FeSO_4$ was used, or in cases where $FeCl_3$ was used. The content of the dissolved phosphorus in the effluent may be regulated with the molar volume from the number of inhabitants of the order 60 000-80 000 in the season and 15 000-25 000 out of summer season.

The total load of those sewage inputs has at present a direct or indirect influence of eutrophication and pollution of the Small Gulf of Puck (18). The first stage of construction of that sewage treatment plant "Swarzewo" for the towns Puck and Władysławowo shall be completed by 1986. In that year the pollution load discharged into the Small Gulf of Puck is expected to be radically reduced. Simultaneously, other measures aimed at reduction of the number of point and area pollution sources in the river catchments feeding the Gulf shall be undertaken.

In the light of those assumptions, starting from 1986 it should be possible to observe a set-back of the present degradating trends, a reduction of pollution concentrations and biogenic compounds as well as an actual elimination of bacteriological contamination of the greater part of waters. Simultaneously, it is expected that conditions favourable for augmenting self-regulation processes in biocoenosis shall occur. In result of the above the present treands of changes in quantitative and qualitative composition of flora and fauna should be restrained and then the trend mark of environmental processes should get changed. The present state of knowledge on the Small Gulf of Puck environment as well as a number of outcomes and observations in that water body incline to make a forecast for a positive trend in environmental changes, a trend for augmenting the self-regulation processes (2,3,4,6, 18,22,23,24). The effects of that trend should be a succession of the flora and fauna previously characteristic for that water body. The directions, scale and intensity of that succession as well as a probable degree of similarity to the "primary" conditions should become the subject of detailed investigations.

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In result of the eutrophication of waters and bottoms a number of characteristic species reduced their range of occurrence, and some fragments of the sea bottom covered with organic detritus (Kuźnicka Hollow, region near Puck and the estuary of the Reda river) are devoid of benthic flora (13, 16, 18).

A particular reduction of range, quantity and biomass of Fucus vsiculosus and Furcellaria fastigiata and simultaneous domination of Ectocarpaceae from the species Ectocarpus siliculosus and Pilayella litoralis have been observed (11, 16, 18).

The excess of organic value of thallophytic algae (Thallopyta) and the class Chlorophyceae (Enteromorpha sp.) causes that they occupy the coastal waters and the sea-shore creating sanitary hazards by toxins, and in particular mycotoxins and developing on them bacteria species. The changes in zoobenthos mainly mean reduction of mussel biomass (Mytilus edulis) by approx. 66 %, and simultaneous maintenance of the molluses domination in zoobenthos (21, 24).

A transition of max. productivity to deeper zones and a reduction of biomass of shellfish (Crustacea), being the food base for fish, and increase of function of molluscs - philanthropists has occurred.

The progressing euthrophication, changes of matter and energy circulation cause particular impacts for ichthyofauna.

In the years 1964-1979 the share of fresh-water fish in total catches in the Gulf of Puck increased from 25.5 % to 45.1 %, at the same time the share of

METHODS FOR REMOVAL OF NUTRIENTS FROM WASTEWATER

Erik Bundgaard
Akvadan Division
Denmark

1. INTRODUCTION

In Denmark the developments regarding wastewater treatment have been substantially different from those in other Scandinavian countries! Full biological treatment, BOD removal and nitrification have been required for all discharge of treated wastewater to fresh waters, as the basic philosophy has been to minimize the immediate oxygen demand in the streams as much as possible. These regulations have resulted in the construction of more than 400 extended aeration activated sludge plants in Denmark, mainly of the oxidation ditch type.

Within the last 10 years, processes for nutrient removal, i.e. nitrogen and phosphorus removal, suitable for extended aeration systems have been developed. The developments as regards nitrogen removal have their background in comprehensive research activities carried out by the Department of Sanitary Engineering, Technical University of Denmark, and Akvadan A/S. These activities were started in the early 1970's. A process – the Bio-Denitro process – was developed (1) and research still takes place for further development.

Phosphorus removal has mainly been carried out by the simultaneous precipitation process with ferrous salts used as precipitant, for economic reasons. Recently a new method for biological phosphorus removal has been developed. The process is now being tested in pilot plant studies and a full scale plant is in construction.

Table 8. Concentration of phosphates and ammonia in surface and bottom layers of SGP*) in period 1975-1978 in particular seasons of the year acc.to Falkowska (13)

			Surface	Bottom
PO4 - P (μ gat/dm^3)	spring	av.	0.32	0.32
		max.	1.13	0.91
		min.	0.06	0.12
	summer	av.	0.51	0.53
		max.	2.13	2.81
		min.	0.05	0.05
	autumn	av.	0.96	1.08
		max.	7.04	7.04
		min.	0.22	0.12
	winter	av.	1.12	1.25
		max.	1.16	3.08
		min.	0.42	0.47
NH_4^+ - N (μ gat/dm^3)	spring	av.	1.00	1.06
		max.	5.98	2.59
		min.	0.06	0.14
	summer	av.	1.00	1.10
		max.	21.60	6.43
		min.	0.07	0.10
	autumn	av.	2.80	3.20
		max.	11.68	10.54
		min.	0.30	0.13
	winter	av.	4.31	2.10
		max.	22.80	7.19
		min.	0.79	0.71

*) SGP - the Small Gulf of Puck

The work (18) points out 10 times greater quantity of zooplankton in the Small Gulf of Puck than in the Southern Baltic Sea and 6 times greater than in the Gulf of Gdańsk, and simultanously the reduction of phytoplankton of the number $21-91\cdot10^3$ units/m^3 in the Small Gulf of Puck in comparison with $21-238\cdot10^3$ units/m^3 in the Gulf of Gdańsk and approx. 1.10^6 in the Southern Baltic Sea (19). The data mentioned above indicate a highly advanced degradation and transition of the water body into the state of saprotrophy (18). Based on

2.1 THE BIO-DENITRO PROCESS

The Bio-Denitro process is a one sludge process using raw wastewater as carbon source for the denitrification. It is operated with distinct separation of the anoxic and aerobic processes and there is no mixed liquor recirculation.

The process is performed in a system with two complete mixed reactors and one sedimentation tank. The two reactors are connected by a pipeline and each is equipped with a mechanically adjustable weir and mixing and aeration devices.

In order to obtain nitrification and denitrification, the plant is operated in an alternating mode which can be described as a repetition of a sequence consisting of four phases (A-D), as shown in Fig. 1. In phase A raw wastewater is led into tank 1, where only mixing is performed. Consequently, the conditions are anoxic and denitrification of the nitrate nitrogen generated and accumulated during the previous phases takes place.

During this phase mixed liquor flows from tank 1 into tank 2 in a quantity corresponding to the flow of raw wastewater and return sludge. Tank 2 is operated with aerobic conditions (aeration) for nitrification and removal of remaining BOD.

During phase A the nitrate concentration in tank 1 and 2 decreases and increases respectively. The duration of phase A corresponds to the time required for removal of the nitrate in tank 1.

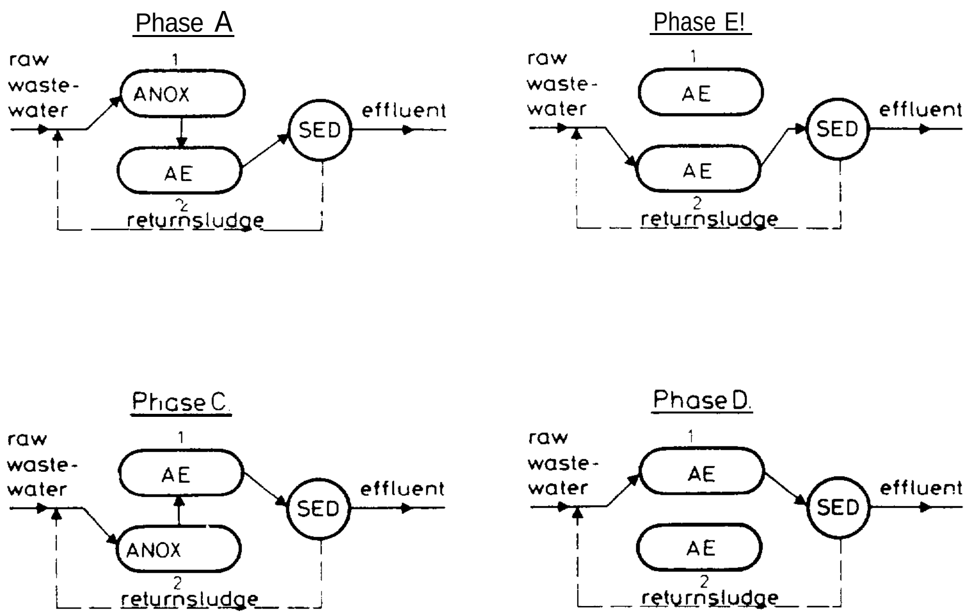
As the raw wastewater enters tank 1, the ammonia concentration in the tank will increase. Phase B is a short intermediate phase with aeration in tank

1 as well as in tank 2, with the raw wastewater flowing through tank 2 only, where BOD removal and nitrification take place. The duration of phase B corresponds to the time required for nitrification of the ammonia in tank 1.

Phase C is the other main phase. The direction of flow between the two tanks is now reversed compared to phase A, and tank 1 and tank 2 are now serving the same function as tank 2 and tank 1 respectively during phase A.

Phase D is the second intermediate phase which corresponds to phase B.

The duration of the phases A through D is normally 4-8 hours.



ANOX Anoxic conditions, denitrification
AE Aerobic conditions, nitrification

Fig. 1. Operation sequence for nitrogen removal by the Bio-Denitro method.

2.2 COMPARISON OF METHODS FOR NITROGEN REMOVAL

The major difference between the well-known recirculation method (the Bardenpho process) and the Bio-Denitro method is that the latter does not require any recirculation and that it is more flexible. By the Bio-Denitro process the conditions required for nitrification and denitrification are created when and where the ammonia and the nitrate are present, contrary to the recirculation method where the two components, ammonia and nitrate, are pumped to the reactors having the required aerobic and anoxic conditions.

In a Bio-Denitro plant the duration of the aerobic and anoxic phases – and consequently the capacity for nitrification and denitrification – can be varied within rather wide limits. Because of this, the operation of the plant can be adjusted for maximum nitrogen removal even at wastewater compositions very different from the design figures.

This does not apply to plants designed for the recirculation method, where the ratio between nitrification and BOD removal capacity and denitrification capacity is fixed by the dimensioning of the plant.

By comparison of the one-tank system (the carrousel type plants) with the Bio-Denitro method, the most important difference is that by the latter process the aerobic and anoxic zones are sharply separated in different reactors, thus controlleable, independently of each other. The possibility of increasing the nitrification rate during cold winter periods by increasing the DO-concentrations in the aerobic zones cannot be utilized in a one-tank system without a deterioration of the efficiency of nitrogen removal. Further a one-tank system requires a very close DO-control which can be difficult to obtain in small plants with only a few aeration devices.

2.3 EXPERIENCE WITH THE BIO-DENITRO METHOD

The reduction of nitrogen in wastewater treatment plants has been employed in full scale plants in Denmark since the beginning of the 1970's. Today 10 plants ranging from 7 000 - 105 000 PE are in operation.

Operational experience from these plants shows that the discharge of total-nitrogen may very often be reduced to approx. 5 mg/l or even lower.

The implementation of the removal of nitrogen in plants already operating with nitrification will in practice result in a saving of power of 15-20 8. The removal of nitrogen will moreover result in an increase in alkalinity of the purified wastewater compared with plants operating with nitrification only. This increase in alkalinity contributes - particularly in areas with soft water - to a reduction in the demand for pH-adjustment in the wastewater treatment plant and to a reduction of the acidifying contribution of the wastewater to the recipients.

Operating experience from three Danish plants is given below.

2.3.1 FREDERIKSSUND WASTEWATER TREATMENT PLANT - REDUCTION OF NITROGEN

Frederikssund wastewater treatment plant treats wastewater from the municipality of Frederikssund, situated northwest of Copenhagen. Besides domestic wastewater, the plant is also supplied with wastewater from a slaughterhouse and a fruit juice factory.

The purified wastewater is taken to Roskilde Fjord. The main dimensions of the plant are seen in Table 1. The plant consists of 4 oxidation ditches and a final clarifier. A construction of this kind without a primary clarifier is rather common in Denmark.

Table 1. Frederikssund wastewater treatment plant. Basis of dimensioning and design.

Basis of dimensioning	Design data
Water quantity in dry weather 950 m^3/h	Volume oxidation ditches 3400 m^3
Maximum water quantity 1075 m^3/h	Oxidation/mixing 6 m rotors, 8 pcs.
BOD load 2000 kg/day	Sedimentation tank area 1000 m^2

The plant has been operated with reduction of nitrogen with the specialized Bio-Denitro process since 1978. Operational data from the years 1978-1982 appear from Table 2. The plant has been subject to max. load during this period (2000 BOD/d on the average or more).

Table 2. Frederikssund wastewater treatment plant – operational results

Year		1978		1979		1980		1981		1982	
Number of 24 h samples		29		21		17		11		7	
		Mean mg/l	st.d mg/l	Mean mg/l	st.d. mg/l	Mean mg/l	st.d mg/l	Mean mg/l	st.d mg/l	Mean mg/l	st.d. mg/l
Total N	inlet	38.7	8.0	41.6	7.8	30.8	6.3	39.3	9.8	37.3	6.0
	outlet	3.5	1.3	8.6	3.4	2.8	1.8	4.0	2.2	2.6	0.8
NH_3-N	inlet	18.8	3.7	19.5	4.6	14.1	2.9	18.5	5.8	18.0	2.7
	outlet	1.0	0.6	3.5	2.6	0.51	0.47	0.32	0.30	0.2	0.2
NO_3-N	inlet	0.2	0.3	0.5	0.9	0.24	0.3	0.62	0.50	0.75	0.7
	outlet	0.5	0.8	0.8	1.1	0.85	1.5	1.77	2.10	0.71	0.3
BOD	inlet	285	84	325	85	305	101	348	104	382	57
	outlet	7	3	15	13	9	4	6	2	10	5
Total P	inlet	11.6	2.8	10.6	3.0	11.4	3.2	11.3	3.4	11.1	1.5
	outlet	3.0	1.9	3.4	2.0	3.7	1.8	2.5	1.5	2.6	1.8
SS	outlet	4.2	1.5	10	21	–	–	4	2	4	4
Flow m^3/day		6372	1353	6903	1686	7505	1384	7799	2792	6069	870

2.3.2 ODENSE NW WASTEWATER TREATMENT PLANT – REDUCTION OF NITROGEN AND ENERGY SAVING

Odense NW wastewater treatment plant treats part of the water from Odense city, the largest city on the island of Fyn (Funen). The purified wastewater is taken to the small river in Odense, from where it is discharged into the extended Odense Fjord.

The main design parametres of the plant can be seen from Table 3. The plant design is rather complicated, as the plant has been enlarged from a traditional trickling filter to a plant also comprising removal of nitrogen. The operation of the reduction of nitrogen is the same as for Frederikssund waste-water treatment plant, i.e. employing the specialized Bio-Denitro process.

In connection with the commissioning of the plant for nitrogen removal, the plant was operated only with nitrification for a period, after which the operation was switched to reduction of nitrogen. Fig. 2 shows operational results from the periods before and after the switch-over.

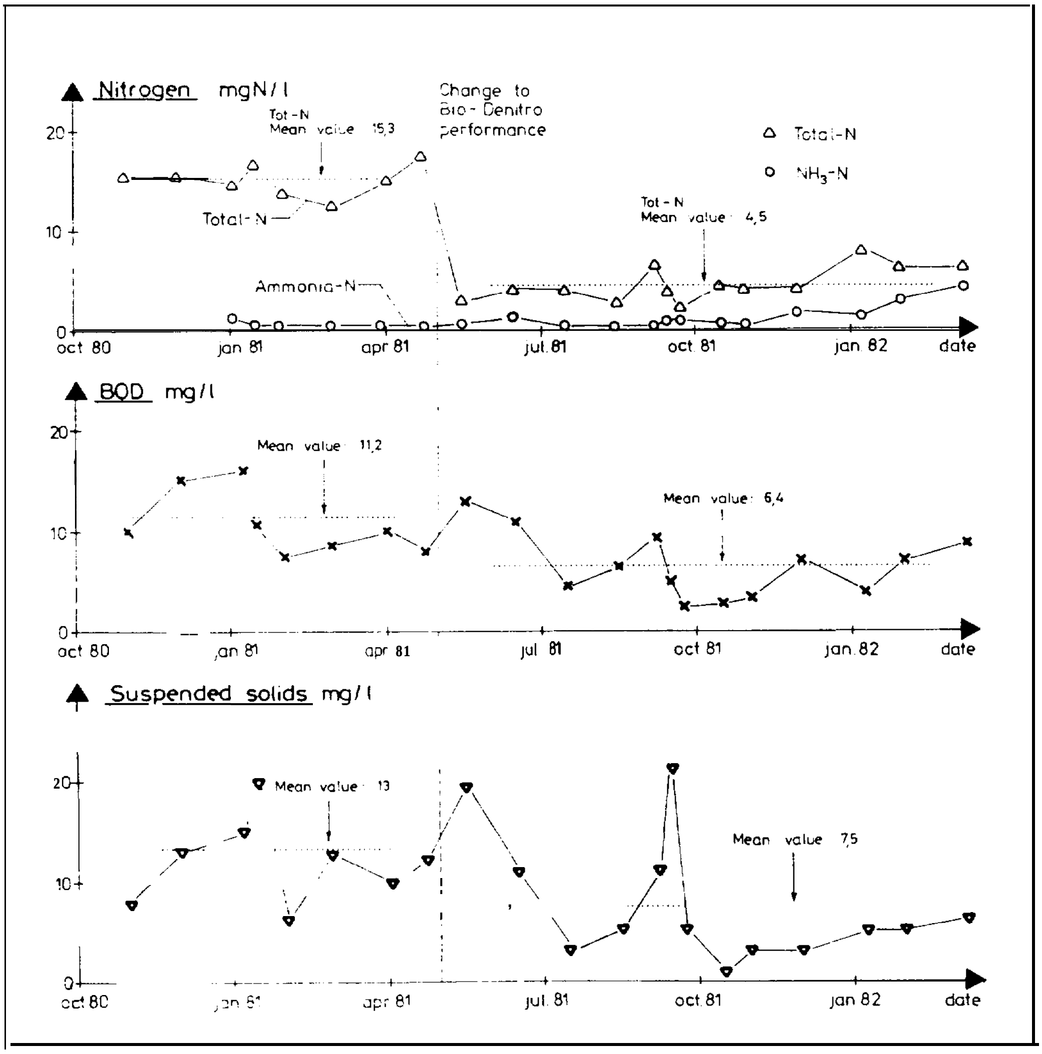


Fig. 2. Operational results from Odense NW treatment plant before and after switch-over to Bio-Denitro.

Table 3. Odense NW wastewater treatment plant.
Basis of dimensioning and design.

Basis of dimensioning (total plant)	Design data (plant for removal of nitrogen)	
Water quality in dry weather 1825 m^3/h	Volume of oxidation ditches	14 000 m^3
BOD load 5180 kg/day	Oxidation/mixing	
	9 m rotors	6 pcs
	7,5 m rotors	3 pcs
	Sedimentation volume x)	5 000 m^3
	x) Sedimentation takes place alternatingly in the oxidation ditches according to the special mode of operation	

It can be seen immediately than the switch-over from operation with nitrification to operation with denitrification will bring about a decrease in the total nitrogen concentration of the discharged water from approx. 15 mg/l to 5 mg/l. Complete nitrification and the effective purification of BOD and suspended matter is maintained.

During the two periods the total energy consumption of the plant was determined. The load of all the plants was 10 % higher during the denitrification period than during the nitrification period. Fig. 3 shows that the total energy consumption of the plant dropped approx. 20 % by the switch-over to denitrification.

The reason for this is that by the denitrification process, a part of the organic matter is oxidized by nitriate. The demand for supply of oxygen is thus declining.

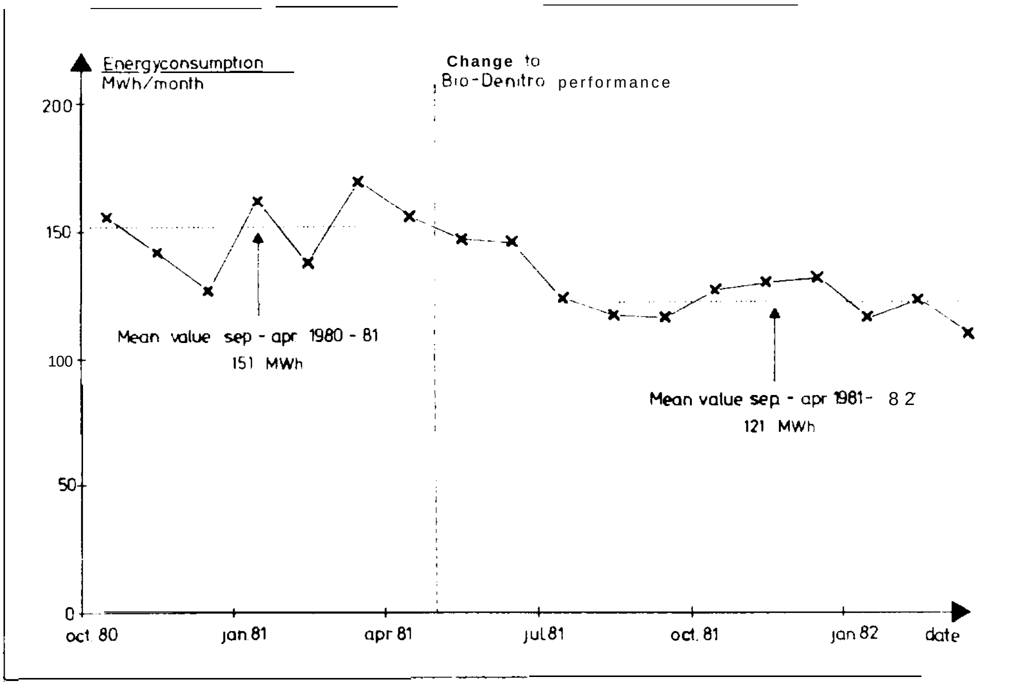


Fig. 3. Energy consumption on Odense NW plant before and after switch-over to reduction of nitrogen.

2.3.3. KRONJYDEN, RANDERS WASTEWATER TREATMENT PLANT - REDUCTION OF NITROGEN AND PROBLEMS WITH ALKALINITY IN WASTEWATER TREATMENT PLANTS AND RECIPIENTS

The wastewater treatment plant Kronjyden, Randers, is an industrial plant treating wastewater from the processing cf fat, meat and bone meal from a slaughterhouse. The plant is situated in Jylland (Jutland) at Randers Fjord, north of Århus. The wastewater is characterized by a high content of organic matter and ammonia and by very varied loading.

The main data of the plant appear from Table 4.

Table 4. Kronjyden, Randers wastewater treatment plant. Basis of dimensioning and design.

Basis of dimensioning	Design data
Water quantity in dry weather 850 m^3/d	Volume of oxidation ditches 4 200 m^3
BOD load 2150 kg/d	Oxidation/mixing 9 m rotors 4 pcs
Ammonia load 595 kg/d	Sedimentation tank area 85 m^2

The plant was started up in March 1979 and was commissioned with the object of reaching full nitrification. Then the process was optimized in order to reach full nitrification and denitrification. The operational results from the two periods are shown in Table 5.

Table 5. Kronjyden, Randers wastewater treatment plant - operational results.

Period		1979-1980		1980-1981	
Number of 24 h samples		17		5	
		mean mg/l	st.d. mg/l	mean mg/l	st.d mg/l
Total N	outlet	166.6	35.7	17.2	13.1
NH_3-N	inlet	454.3	135.7	457.7	100.0
	outlet	5.7	7.2	1.1	1.7
BOD	inlet	1 816	697	2 100	436
	outlet	16.9	17.3	9.4	4.6
SS	outlet	39	25		
Flow		418	125	342	35

The high concentrations of organic matter and nitrogen (ammonia) at the inlet and the excellent reduction of these components are seen in both periods. For the first period, where the aim was full nitrification, it is seen that a 65 % reduction of total-N is obtained, whereas this reduction is increased to approx. 95 % after the final optimizing of the plant operation.

Wastewater with a content of ammonia as high as mentioned above represents two particular problems, firstly the ammonia concentration is toxic for bacteria, and secondly the nitrification will bring about a considerable consumption of alkalinity. Anyway, nitrification takes place in the wastewater treatment plant or - if the plant was operated without nitrification - in the recipient. By implementing the nitrification in a completely mixed plant the bacteria are protected against unacceptably high concentrations of ammonia.

The drop in alkalinity is counteracted in the wastewater treatment plant, partly by addition of lime and partly by the denitrification process. Thus, not only nitrogen is removed, but there is also a saving in the consumption of lime for pH-adjustment.

By the denitrification process 2 equivalents of alkalinity are destroyed per mole (14 gram) of transformed ammonianitrogen. By the denitrification process 1 equivalent of alkalinity per mole of transformed nitrate-nitrogen is regenerated. Denitrification thus brings about a saving in the consumption of lime of 50 % compared to nitrification alone. In practice it has been demonstrated at Kronjyden that the lime dosing necessary for maintaining a pH of approx. 7-7.5 is considerably lower than what could theoretically be expected.

3. CHEMICAL PHOSPHORUS REMOVAL

Phosphorus removal from wastewater is only carried out at a limited number of treatment plants. By 1990 approximately 50 treatment plants are expected to perform phosphorus removal.

Several methods for phosphorus removal: pre-precipitation, simultaneous precipitation and post-precipitation have been considered and all processes are used in Denmark. The most widely used process is the simultaneous precipitation process. The reason is that this process is very suitable for upgrading extended aeration plants with phosphorus removal. The cheap ferrous salts, ferrous sulphate, heptahydrate as ferrous sulphate or monohydrate, are added directly into the aeration tanks, where the ferrous iron is oxidized to ferric iron and which then forms a good settleable chemical-biological floc. No extra tank volumes are required for the process and no pH control is necessary as the process operates at pH 7-8.

In 1978 a large research project was carried out by the Danish Water Quality Institute regarding operation, phosphorus removal and economy of the simultaneous precipitation process used at three different extended aeration plants (4).

The three plants investigated were designed for 105 000 PE, 21 000 PE, and 3 100 PE respectively. The largest plant, the Søholt plant, is an oxidation ditch type plant where nitrogen removal is also performed by the Bio-Denitro method.

The second largest plant, the Haslev plant, is a conventional oxidation ditch plant and the smallest plant, Slagslunde, is a countercurrent plant.

The project was carried out over a period of 2 years, and the main conclusions are given below.

3.1 EFFLUENT QUALITY

Table 6 shows the effluent quality from the three plants.

Table 6. Influent and effluent quality from treatment plants with simultaneous precipitation.

Plant		Slagslunde		Haslev		Søholt[x]	
Parameter		Mean	SD	Mean	SD	Mean	SD
BOD ppm	in	104	37	130	46	162	43
	ef	4	1	6	2	10	4
ss ppm	in	115	33	228	53		
	ef	a	6	7	3	a	5
NH_3-N ppm	ef	0.4	0.3	1.7	2.0	2.2	1.6
NO_5 ppm	ef	21	1.4	a.3	1.1	2.8	0.8
Tot P ppm	in	9.6	3.1	8.2	2.6	a.4	1.8
	ef	0.9	0.4	0.8	0.3	0.6	0.1
Flow m^3/day		1 000	260	5 100	1 420	17 320	3 400

in = influent, ef = effluent, SD = standard deviation

[x]Søholt: Effluent data are before filtration

The use of the simultaneous precipitation process has resulted in a phosphorus removal of 90-93 % corresponding to an effluent quality of 0.6-0.9 mg/l P. The fraction of dissolved phosphorus in the effluent has varied between 30 % and 90 % of total P. Further phosphorus removal has been obtained by contant filtration at the Søholt plant.

BOD removal, nitrification and denitrification were not affected by the chemical addition.

3.2 PHOSPHORUS REMOVAL AND MOLAR RATIO

Fig. 4 shows the relation between effluent concentrations of dissolved phosphorus and the applied molar ratio Fe:P.

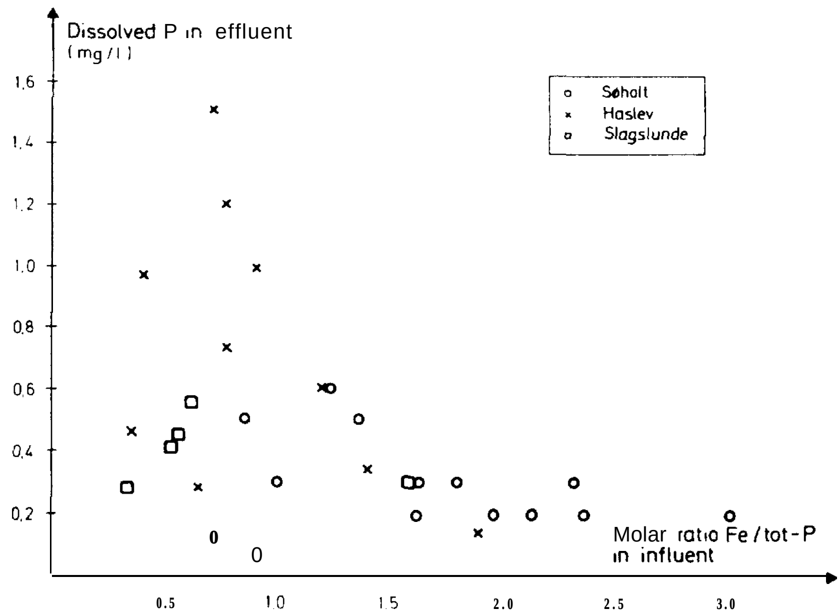


Fig. 4. Corresponding values for molar ratio and dissolved-P in effluent from simultaneous precipitation plants.

The figure shows that there is a rather high scattering between the results. The reason for this is partly variations in molar ratio from day to day. However, pH as well as the calcium activity of the mixed liquor is of importance for the phosphorus removal. In hard water areas (Haslev) the iron requirements for a specific phosphorus removal are not as high as in soft water areas. These mechanisms have been studied at the Technical University of Denmark, Department of Sanitary Engineering (5).

The importance of the method used for chemical dosing has often been discussed. At the Søholt plant and the Haslev plant flow proportional dosing is used while time proportional dosing is used at Slagslunde. It has not been possible to conclude which of the two methods is to be preferred.

3.3 SLUDGE PROPERTIES AND SLUDGE PRODUCTION

The general experience that the addition of ferrous salts to mixed liquor gives an improvement of SVI and sludge thickening properties was confirmed in this project. At Søholt the SVI was about 65 mg/l, i.e. a sludge with good settling properties.

Sludge production due to the chemical addition was estimated to 3.5-4.5 kg/kg Fe. However, sludge mass-balances are very difficult to carry out and the figures are only indicative.

4. BIOLOGICAL PHOSPHORUS REMOVAL

During the last 10 years it has been observed in various parts of the world that phosphorus removal can sometimes be obtained without addition of chemicals, if the sludge undergoes cyclic anaerobic/aerobic treatment steps.

Barnard (1974) was one of the first to give a description of the observations (6): For phosphorus removal to take place in a biological system, the activated sludge must at some stage, except the final stage before the clarification, pass through an anaerobic stage where phosphorus is released, and if this requirement is met, phosphorus removal may take place in the following aerobic stage.

In three Danish treatment plants operated with biological nitrogen removal, observations have been made concerning enhanced phosphorus removal. These plants are the Frederikssund plant, the Odense NW plant, and the Faaborg plant. All three plants are operated according to the Bio-Denitro process (Fig. 1).

From Table 2 it can be seen that 70 % phosphorus removal has been obtained at the Frederikssund plant in this way.

An experiment showing the cyclic parameter variation at the Frederikssund treatment plant was carried out by Jansen and Behrens (8). The experiment covered a 24 hour period with measurements in inlet, oxidation ditches, and outlet. The 24 h variation in ammonia, nitrate, oxygen, and phosphorus in one oxidation ditch is shown in Fig. 5.

The figure clearly demonstrates the effect of the alternating mode of operation. The ammonia content increases in periods with low oxygen concentration and inlet of raw wastewater. Nitrate increases in nitrification periods with high oxygen content. Furthermore, it is obvious that an extended simultaneous denitrification takes place.

The behaviour of the nitrogen components is predictable from the general, well established knowledge concerning nitrogen removal processes.

As for the dissolved ortho-phosphate this parameter also shows a periodically varying picture. In periods with low oxygen and low nitrate the phosphorus concentration increases. Maximum concentration of 14-16 mg P/l is reached within 1-1 1/2 hours. This is succeeded by a rapid decrease within 1-1 1/2 hours to a zero level when the oxygen concentration is increased.

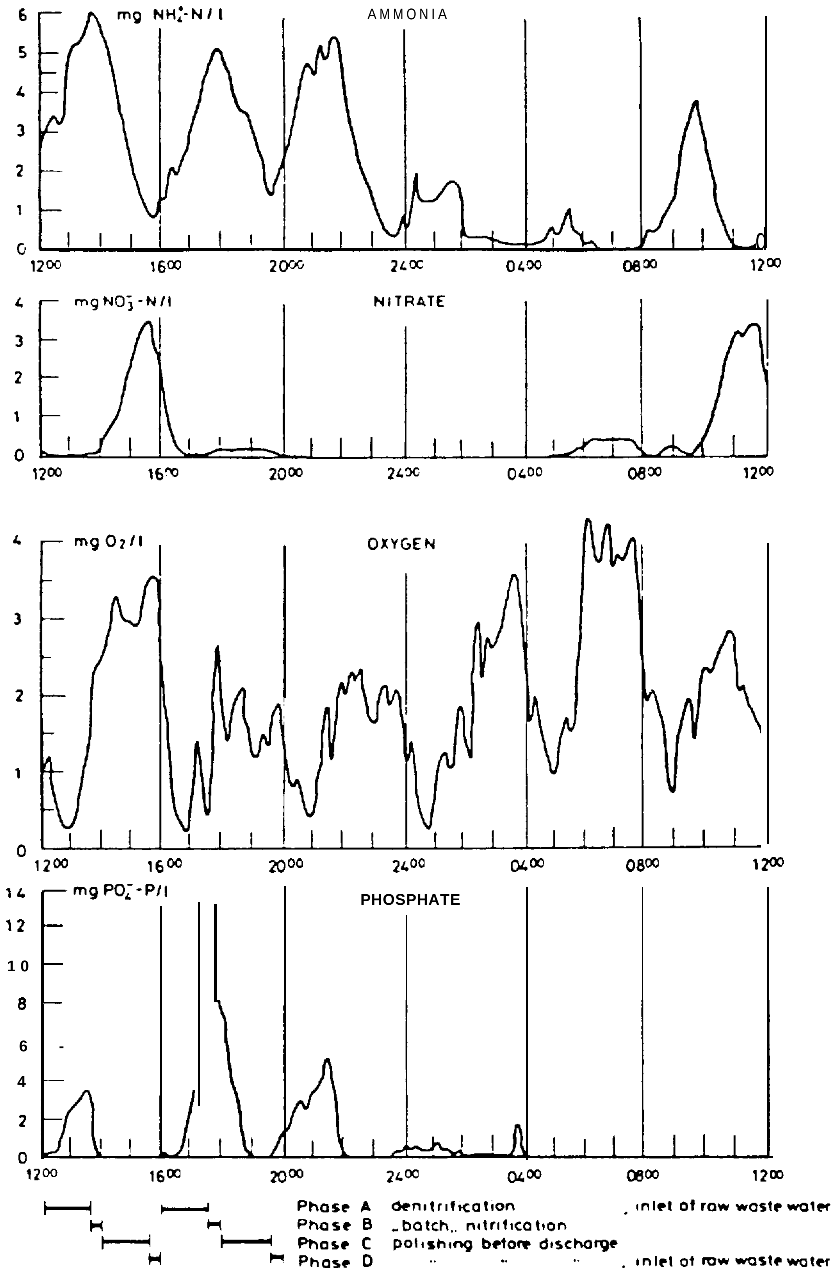


Fig. 5. 24 hour variation in ammonia, nitrate, oxygen, and phosphorus at the Frederikssund plant. Figure taken from Jansen and Behrens (1980).

The experimental results thus agree with the general findings that phosphorus is released from the activated sludge during anaerobic periods and taken up as soon as aeration is started.

At the 'Faaborg plant, designed for 105 000 PE, a phosphorus removal from 10.2 mg/l down to 2.5 mg/l has been obtained as an average for 21 samples.

Later studies of the mechanism of phosphorus removal indicate that the process is attributed to a biological uptake by special strains of bacteria combined with a chemical precipitation via the natural content of the calcium and iron in the raw wastewater (9).

For further disclosing of this mechanism and for optimizing the biological removal of phosphorus a research project has been established by the Department of Sanitary Engineering, the Technical University of Denmark in co-operation with Akvadan.

The Bio-Denitro process has been modified by the addition of an anaerobic process step before the anoxic/aerobic reactors. This new process is called the Bio-Denipho process.

Fig. 6 shows the layout and the mode of operation of the Bio-Denipho process. The phosphorus concentration is increasing at the end of the anoxic phases just before changing over to aerobic conditions. Therefore the discharge from the treatment tanks into the sedimentation tanks is phase-shifted compared with the anoxic/aerobic phases.

Fig. 7 schematically shows the variations in PO_4-P, NO_3-N and NH_3-N in the two tanks during the four phases. The inlet and outlet phases are also indicated in the figure.

By appropriate adjustment of the different phases for treatment and discharge and effluent low in phosphorus as well as in nitrate and ammonia can be obtained.

In pilot plant experiments with the Bio-Denipho process a reduction of phosphorus from 7 mg/l P to 0.5 mg/l PO4-P and a reduction of nitrogen from 25 mg/l N to 0.8 mg/l NH_3-N and 3.2 mg/l NO_3-N was obtained as an average of 34 samples taken out during a period of three months.

A full scale plant using the method is now in construction.

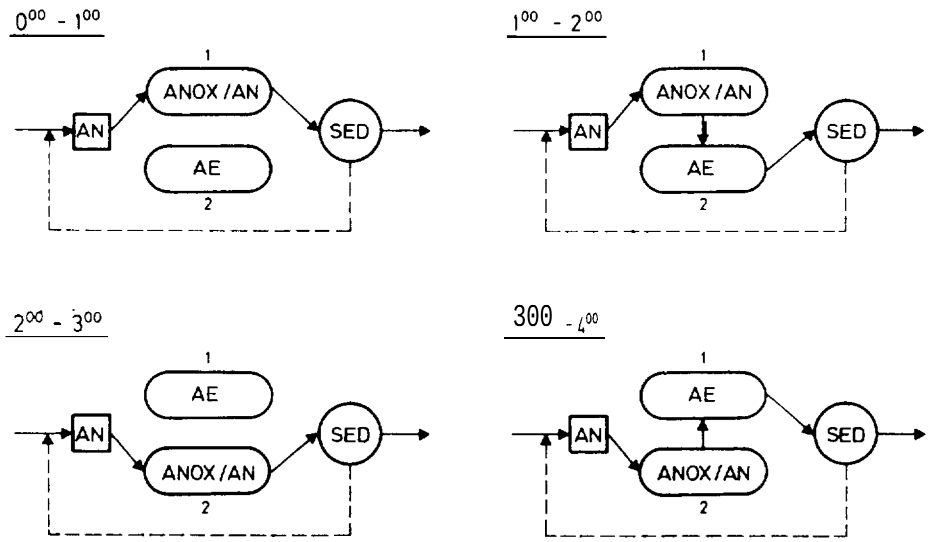


Fig. 6. Operation of the Bio-Denipho proces.

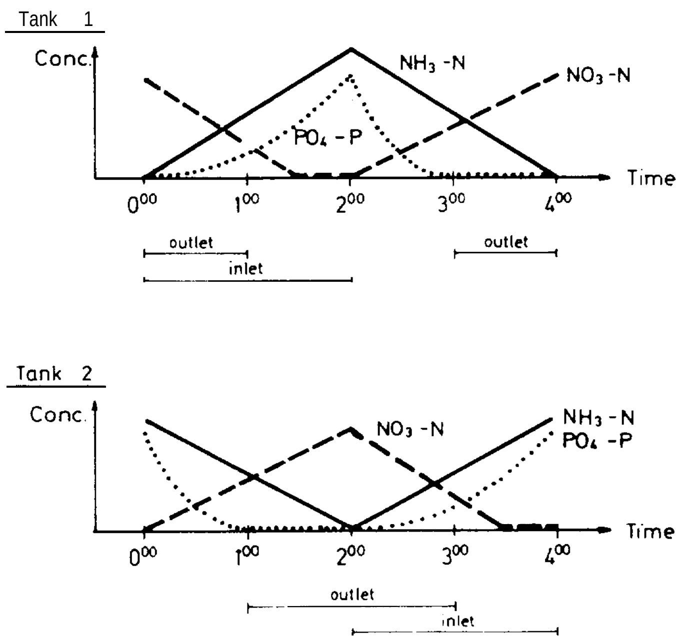


Fig. 7. Variations in NO_3-N, NH3 and P during the four phases of the Bio-Denipho proces.

5. SUMMARY

The Bio-Denitro method for biological nitrogen removal developed in Denmark has proved its efficiency and flexibility in many full scale installations. Results of operation have shown that stable effluent qualities of 3-6 mg/l nitrogen can be obtained by the method.

Phosphorus removal can be performed reliably and economically by the use of cheap ferrous salts for application in the simultaneous precipitation process. In addition to the molar ratio Fe:P the calcium content in the wastewater is of importance for the efficiency of the process, as calcium forms part of the phosphorus precipitate. The process can be performed without any adverse effect upon nitrification and denitrification.

The future concept of plants for the removal of nutrients will comprise biological removal of nitrogen as well as phosphorus. The basic mechanisms of the process are now being disclosed and successful pilot plant studies have been carried out with an effluent quality around 0.5 mg/l PO_4-P.

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PULP AND PAPER INDUSTRY EFFLUENT TREATMENT

Juhani Orivuori
Ekono Oy
Finland

1. INTRODUCTION

Industrial pollution control is usually divided into internal and external measures. With internal measures, the industry desires to reduce the quantity and improve the quality of untreated waste water, in order to minimize or avoid the costs of external waste water treatment. Each pulp and paper mill is unfortunately different, so that the mixture of internal and external measures varies case by case.

Especially environmental constraints cause problems to the mill management, because pollution abatement requirements are not stable. This forces the management to flexibility in regard to the timing of investments for closing up water systems and for external treatment facilities.

This paper examines how the waste water treatment in the Finnish pulp and paper industry has in general developed due to internal methods in recent years. Some examples of closed water circulation systems are also illustrated. External treatment possibilities and costs are discussed.

2. MEASURES OF INTERNAL WASTE WATER TREATMENT AND PRESENT PRACTICE

2.1 FINNISH PULP INDUSTRY

In 1980, the total pulp and paper production in Finland was about 8 MADT/a (million air dry ton). In the same year, Finnish pulp and paper industry gave rise to a effluent amount of approximately 1 200 Mm^3/a (excluding cooling waters). The average water use was thus about 150 m^3/ADT (365 m^3/ADT in 1967). The total discharge of pulp and paper industry in 1980 was 100 000 t/a as suspended solids, and 260 000 kg/a as BOD_7. The development of effluent characteristics in 1972-1980 is shown in Fig. 1.

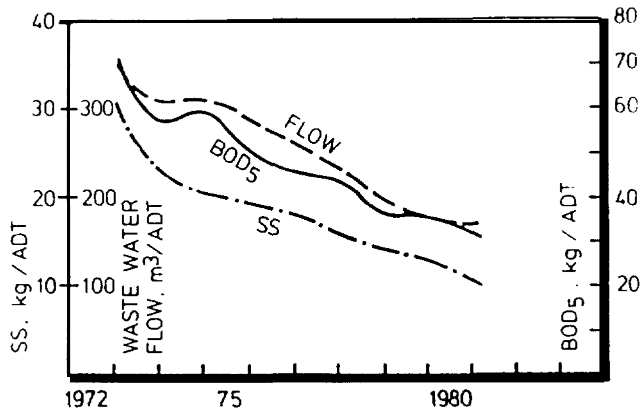

Fig. 1. Specific waste water characteristics of the bleached sulphate pulp mills in Finland in 1972-1980

The effluent quality and quality at Finnish kraft mills vary due to local differences as follows:

Table 1. Waste water characteristics of Finnish bleached kraft mills in 1980.

Effluent slow m^3/ADT	ss kg/ADT	BOD_7 kg/ADT	Effluent °C
50-300	10-50	10-80	10-40
average 170	11	32	

If a very tight water circulation system is practised, it seems possible to operate a bleached kraft pulp mill with only about 40 m^3/ADT waste water flow with conventional bleaching, and with about 30 m^3/ADT with displacement bleaching. This means that today's modern pulp mill pruduces only 1/10 of the waste water flow 20 years ago.

Fig. 2 shows a water balance of a typical modern bleached kraft mill.

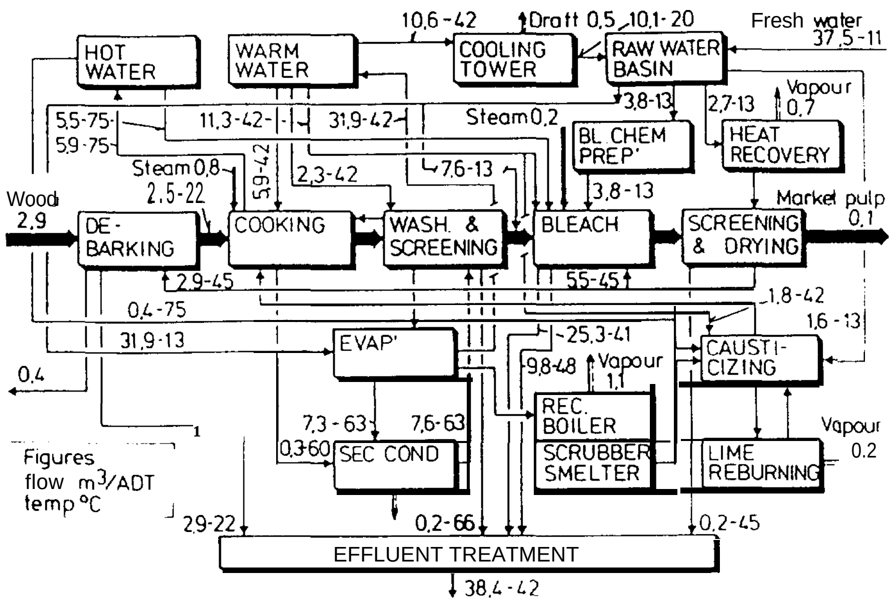

Fig. 2. Water recycling in bleached kraft pulp mill

The mill concept according to Fig. 2 is as follows:

cooking:	continuous with Hi-Heat washing, 3-stage flashing
washing:	continuous diffuser washing
screening:	closed system with pressure screen, 1st stage and 2nd stage centricleaners, and brown stock **decker** as the last washing stage
bleaching:	conventional, D/C-E-H-D-E-D, drum washing
screening of bleached pulp:	closed system with pressure screens and centricleaners
drying:	Fourdrinier machine with heat recovery

Following internal measures can be listed as the main reasons for a low specific water consumption at a modern pulp mill:

- high pulp washing efficiency
- closed pressure screening
- tight water circulation at the bleach plant
- countercurrent water use through the whole fiber line
- reuse of secondary condensates.

Since the basic pulping process has remained more or less the same, very little progress has taken place regarding the waste water quality of the pulp mills. It is naturally true that along with the replacement of old mills, and especially the change from old sulphite mills to modern bigger sulphate units, the overall pulp washing efficiency has decreased the BOD and lignin load of the Finnish pulp industry. The treatment of secondary condensates, improved water circulation systems, and the overall discipline have also improved the specific waste water quality. The pulp industry does not seem to have many rapid internal tricks left, although pulp cooking and bleaching research is done in order to reduce the lignin (color) in pulp waste waters.

2.2 FINNISH PAPER INDUSTRY

Due to high raw material and energy prices as well as the demands of the authorities, the Finnish paper industry has reduced the effluent flow from 100 m^3/ADT in 1967 to approximately 50 m^3/ADT in 1980.

Big paper machine units, tight water circulation practice, and effective internal fiber recovery systems make it possible to operate newsprint, linerboard and fluting machines with a waste water flow of only 10-20 m^3/ADT.

The increased use of groundwood and/or thermo-mechanical pulp as well as their bleaching has, however, increased the specific waste water load. A typical mechanical printing paper or newsprint mill has a specific BOD_7 load of 15-25 kg O_2/ADT which is slightly more than half of that at a modern kraft mill. With the decreased water flow and increased specific BOD load, these mills produce an effluent with a high BOD concentration (1 000-l 500 ppm compared to 500-600 ppm at a modern kraft mill).

Fig. 3 and 4 show some examples of extremely closed paper mills in Finland.

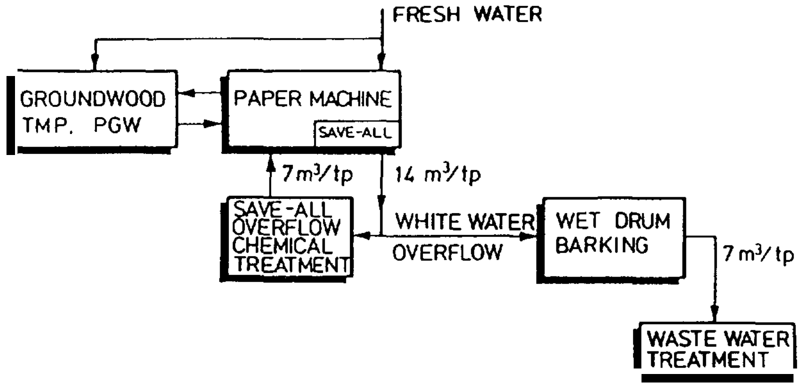

Fig. 3. Mill No. 1. Mechanical printing papers
600 t/d, two machines.

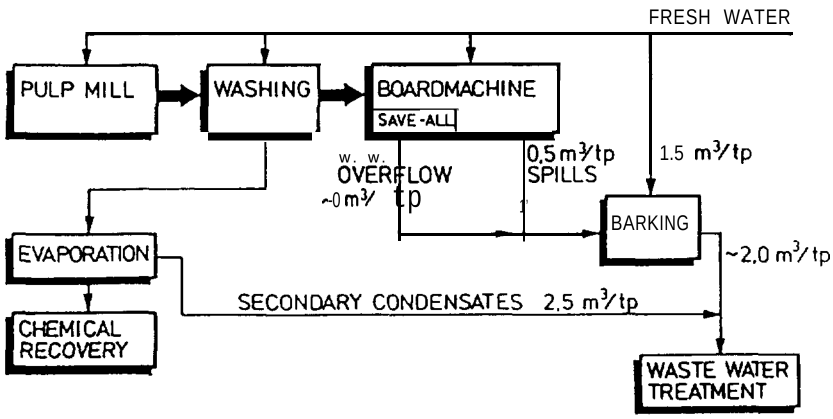

Fig. 4. Mill No. 2. NSSC + fluting Board
450 t/d, one machine.

It has not been proven in full scale to which extent the water circulation system of a paper mill can be closed by internal measures. Some newsprint mills with a waste water flow of approximately 6 m^3/ADT have been reported to be in operation.

The water consumption of Finnish paper mills is expected to decrease further, when they are modernized. Increased demands of the Water Board Authorities also force the paper mills to close their water circulation systems, and to separate rain, cooling, and sanitary waste waters from the process waste waters going to the treatment.

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3. MEASURES OF EXTERNAL WASTE WATER TREATMENT AND PRACTICE

3.1 GENERAL

The BOD_7 load in waste waters of the Finnish pulp and paper industry has decreased from approximately 500 000 t O_2/a in 1967 to 260 000 t O_2/a, mainly by internal methods and mechanical or chemical primary treatment. Only five aerated lagoons and one plastic-media trickling filter are in operation. The first activated sludge plant is presently under construction.

Anaerobic treatment is also being tested in the Finnish pulp and paper industry. Enso-Fenox process has its first application at a Finnish kraft mill, treating bleach plant waste water in order to reduce BOD and chlorinated organic compounds. One pilot-scale anaerobic test unit producing methane is running at a mechanical printing paper mill, and several laboratory-scale tests are made by Universities and District Water Laboratories. Low operating costs of anaerobic treatment are the main reason for industry's interest in this possibility.

The latest court orders and statements from the Water Board Authorities indicate that most of the Finnish pulp and paper mills have some kind of a biological treatment plant in operation at the end of this decade.

For the removal of BOD from highly concentrated industrial waste water to the level of biologically treated municipal effluents, the industry has a possibility of applying two-stage treatment, which can either be aerobic-aerobic of anaerobic-aerobic.

Both aerobic and anaerobic high rate sludge blanket or fixed film processes can release the "investment pain" in the near future, and help the industry to cope with the environmental legislation.

In general, it can be stated that techniques for the BOD reduction already exist, and it is possible to control the oxygen level in the Finnish waters by regulations.

Technically and even more economically difficult is to find a solution for the color (lignin) removal in pulp industry, if this is necessary.

Authorities all over the world are especially concerned about the possible effects of the chlorinated lignin compounds and the potential risk these might cause, when led to the recipient.

Many efforts, both internal and external methods, have been made to decrease the amount of lignins and chlorinated organic compounds in pulp mill effluents, but a widely accepted commercial system has not yet been found. As long as chlorine is needed in market pulp bleaching, the efforts for the external treatment of chlorine compounds will continue.

The easiest internal measure would be to reduce the bleaching degree, which unfortunetely seems impossible without global restrictions.

3.2 COST OF EXTERNAL WASTE WATER TREATMENT

An example, in which the bleached kraft pulp mill is assumed to produce 1 000 ADT/d and the effluent BOD_7 is kept constant at 25 kg/ADT, illustrates how capital and operating costs for external waste water treatment vary with effluent flow. It is further assumed that the discharge permit requires to reduce BOD_7 below 2.5 kg/ADT. To guarantee a minimum BOD removal of 90 %, the selected treatment scheme includes a two-stage biological treatment. It is further assumed that the waste water neutralization is done with lime. No sludge burning equipment is included.

Fig. 5 and 6 show the capital and operating costs as a function of the effluent flow.

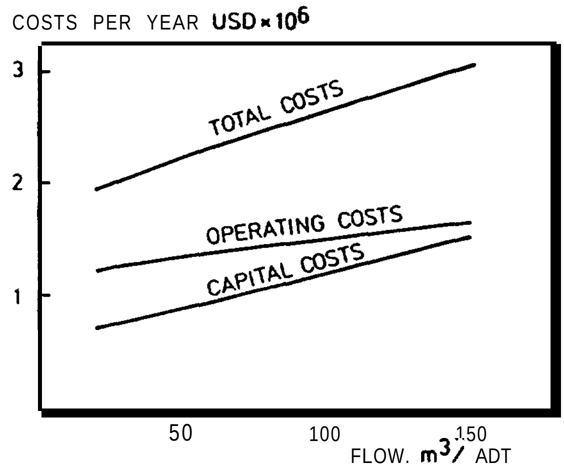

Fig. 5. Waste water treatment. Capital, operating and total costs. Bleached kraft pulp 1 000 ADT/d.

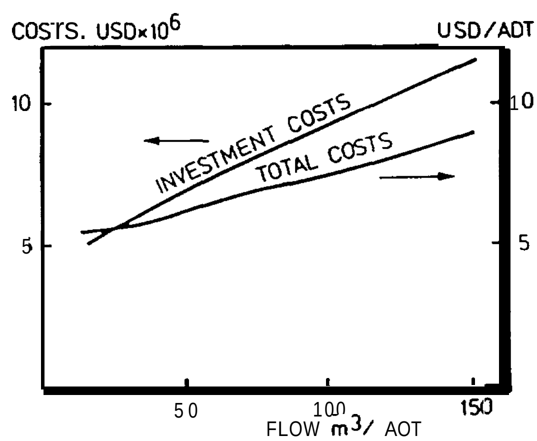

Fig. 6. Waste water treatment investments and total costs. Bleached kraft pulp 1 000 ADT/d.

Total pollution control costs in a case of a new bleached kraft mill are on the level of 10 % of the whole investment. The investment costs of the external biological treatment are in a range of 2-3 % of the total investment.

Color removal costs with today's external treatment techniques would possibly be twice or three times as much as the external treatment costs shown in Fig. 6.

In today's economical situation, the industry claims it impossible to compete with the world market prices with increasing pollution control costs.

BLEACH PLANT EFFLUENTS - SOME CURRENT PROBLEMS

G. Emil Haeger and Kristina Idner
Sweden

1. INTRODUCTION

The predominant raw material for practically all grades of white paper and board is bleached chemical pulp from hardwoods and softwoods. These types of pulp are produced extensively in Sweden and Finland. They account for an important part of the export of both countries.

In 1980, the total gobal production of bleached sulphate (kraft) pulp was about 41 mill. tons, while sulphite pulp accounted for about 10 mill. tons. The same year Finland and Sweden produced about 6 mill. tons of bleached sulphate pulp and about 1 mill. ton of bleached sulphite pulp, which correspond to about 15 respectively 10 % of the global production.

2. THE PULP MILL

A chemical pulp mill is composed of a number of process-units, coupled one after the other so that a continuous flow is maintained throughout the mill. A unit calling for batchwise operation is sometimes included. In such a case an even flow is achieved by storage space or tanks before and after the unit.

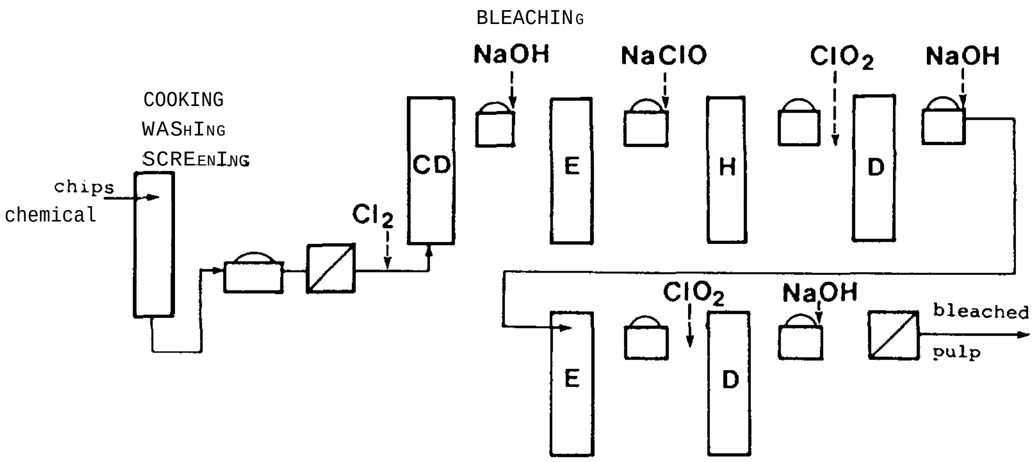

Fig. 1. Treatment of wood chips in a sulphate pulp mill.

In a sulphate pulp mill (Fig. 1) wood chips are treated for about 2 hours at 160-170 °C in an alkaline liquor referred to within the trade as white liquor. The active chemicals in the white liquor are sodium hydroxide and sodium sulphide. During cooking they dissolve most of the lignin of the wood while the fibers, that consist of cellulose and related substances, remain in their native state. Some lignin adheres to the fibers. It accounts for the brown colour of the pulp. The cellulose is pure white. In order to produce a white pulp the last traces of lignin have to be removed by bleaching. Further cooking is not an alternative as it damages the properties of the fibers and removes just a part of the residual lignin.

The lignin content of the pulp before and during bleaching is an important characteristic when different methods for bleaching the pulp are compared. It is determined by subjecting the pulp to a potassium-permanganate treatment and the result is normally given as the Kappanumber of the pulp.

Not included in the picture is the elaborate recovery system for chemicals where the dissolved lignin is used as a fuel in a chemical reactor, normally referred to as the recovery boiler, as it also has a function as supplier of the mill's need for steam. After cooking the pulp is washed in counter current equipment so that the spent cooking liquor, the so called black liquor, can be burned in the recovery boiler after evaporation to a high solids content. The next step is screening in order to remove grit, bark and insufficiently cooked fiber bundels.

3. BLEACHING

The reason for bleaching is not only to produce a white, bright pulp. It also adds to the cleanliness of the pulp by removal of various impurities by chemical action. One of them is remaining bark particles that ***otherwise*** show up as black dots in the pulp and on the subsequently produced paper.

Bleaching of softwood sulphate pulp, which is the most important of the nordic bleached pulps, is normally performed in a six-stage operation. In Sweden half of the bleached kraft pulp is produced in a sequence to as CEHDED where

C stands for chlorination
E for extraction with sodium hydroxide
H for further bleaching with sodium hypochlorite
D for bleaching with chlorine dioxide
E for extraction, again, with sodium hydroxide and
D for final bleaching using chlorine dioxide

Oxygen bleaching is applied in connection with a major part of the production of Swedish bleached kraft. In this case ***an*** oxygen rector precedes the sequence CEDED.

In both sequences the first chlorine step is fortified by a minor addition of chlorine dioxide, normally less than 20 %, in order to protect the cellulose from chemical attack and to maintain good pulp characteristics.

4. ENVIRONMENTAL PROTECTION

Swedish pulp and paper industry has sponsored research and development programmes for improved environmental protection since World War II. In the early days removal of suspended solids and fibres from the effluent was the prime object. Later on methods were found to avoid pollution by dissolved organic matter that caused oxygen depletion of the receiving waters. For a long time the bleach plant effluent was disregarded as fairly harmless. It caused discolouration where a clean river was the recipient, and there was not much that could be done about it. However, in the late sixties concerted action started in Sweden followed by the SSVL environmental care project 1970-1973, where various bleach sequences were studied from an environmental point of view in order to find the best ones. As a result the total discharge of organic matter from the bleach plants has decreased (Fig. 2).

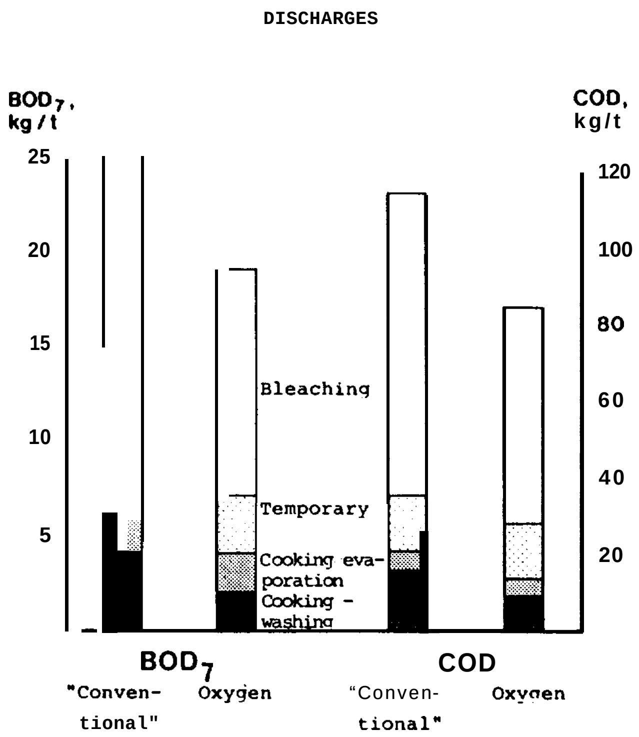

Fig. 2. Disharges of organic matter.

This comparison of the old, conventional sequence to a new one with oxygen bleaching shows what has been achieved since the early 1970's. The total dissolved organic matter as COD has for instance shrunk from just under 120 kg/t pulp to just over 80 kg/t pulp. In spite of all improvements the bleach sequence, however, still accounts for a major part of the effluent (the top unfilled part of the columns). The bleach plant accounts for between 65 and 70 % of the BOD_7 and COD in the total effluent from the pulp mills.

The present attention to the environmental problems of the bleach plants is, however, not caused by organic matter as BOD or COD. It is the fairly recent knowledge that chlorinated organic matter might contain dangerous substances. That has caused intense investigations in order to find a rationale for the evaluation of the environmental impact of various bleaching sequences and effluent treatment methods. In many countries, however, there is a feeling that the urgency is not too great. Bleached pulp production has been going on on a large scale for more than 50 years and – in spite of intensive biological studies of some of the recipients – there has been very little cause for suspicions of other effects of the bleach plant effluents than those related to colour.

The chlorinated organic compounds are formed by chemical reactions between the bleaching agent and the pulp including the residual lignin. There are also similar reactions with dissolved organic matter in the part of the cooking liquor (black liquor) that is not washed away from the pulp and consequently follows the pulp into the bleach plant.

Of the total quantity of chlorine, that is added in the bleach plant, somewhat less than 10 % is found in the effluent as chlorinated organic matter, analysed as total organically bound chlorine, TOCl (1, 2). Only a minor part of the chlorinated organic matter has so far been identified with respect to chemical composition and structure.

The diagram, Fig. 3, is a useful tool when speculating over possible environmental effects.

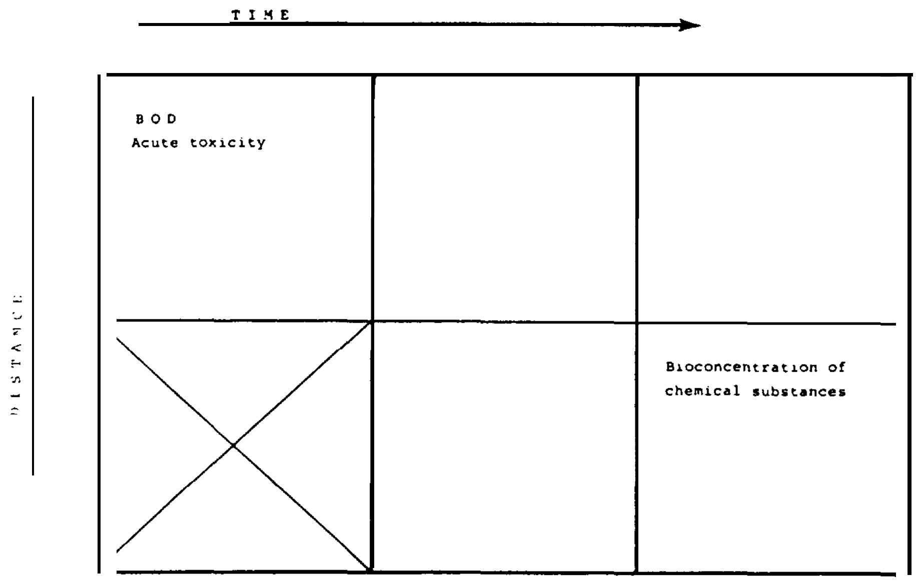

Fig. 3. Diagram for speculating over possible environmental effects.

We already know that oxygen depletion and acute toxicity from bleach plant effluents can be avoided by many methods. On the other hand carcinogenicity and mutagenicity, that suppposedly can occur regardless of concentration and thus at long distances from the point of discharge, are properties that are difficult to detect in a natural eco-system. There are of course a number of laboratory tests, but very little is known about the correlation between the results of these tests, that are carried out at comparatively high concentrations, and the effects at concentrations far below the sensitivity of the best analytical methods.

5. MODIFIED PROCESSES

There has been an ambition to modify the bleaching process in order to diminish the environmental impact as determined by various methods to characterize the effluent.

Starting with a six-stage sequence CEHDED, we can wash the unbleached pulp better so that less dissolved organic substances enter the bleach plant (Fig. 4A), and delignify the fibres more efficiently during the cook by better control, less variation in the cooking conditions and by modifying the cooking process (Fig. 4B).

The result is less organic matter and also less chlorinated organic matter in the effluent.

The Kappa number for normal pulp is 32-35. Presently we believe that it can be lowered to about 25 by a modified cooking process.

In order to delignify even more, you have to add oxygen bleaching and subsequent washing (Fig. 4C). The result is a Kappa number in the order of 18-20.

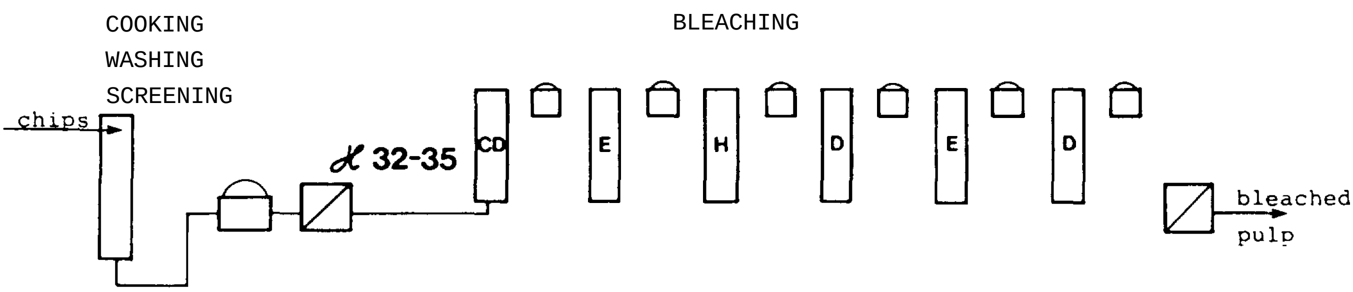

Fig. 4A Washing of unbleached pulp.

Better washing
and prelonged
cooking

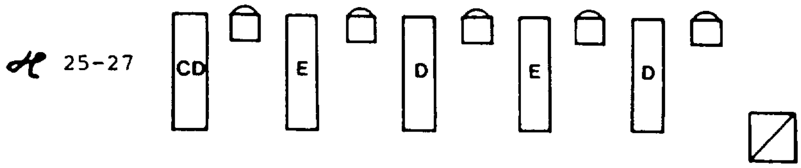

Fig. 4B Modified cooking process of unbleached pulp.

Oxygen
bleaching

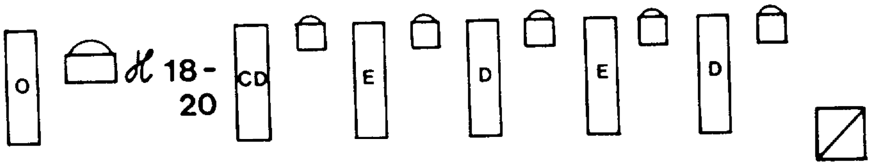

Fig. 4C Oxygen bleaching and subsequent washing of unbleached pulp.

High amount
chlorine dioxide

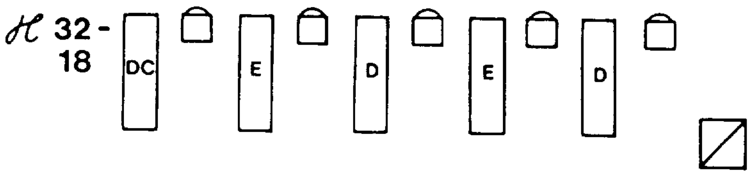

Fig. 4D Washing of unbleached pulp with chlorine dioxide.

The further improvement can be achieved by subtituting some of the chlorine by chlorine dioxide (Fig. 4D). The result is less chlorinated organic compounds. High amounts of chlorine dioxide in the first chlorine stage is not used commercially, but mill trials have been done.

6. EXTERNAL TREATMENT OF THE BLEACH PLANT EFFLUENT

There are a number of external treatment methods that will clean the effluent by removing various components or rendering them biologically less active.

Biological
- aerated lagoon
- activated sludge
- Enso-Fenox

Ultrafiltration
- Ultrasep (EKA) E-stage

Ion exchange
- Billerud-Uddeholm, total bleach plant effluent

By biological treatment the acute toxicity to fish is lowered and sometimes disappears. Aerated lagoons are common for this purpose all over the world.

Activated sludge treatment is an alternative, where for instance the necessary space for a lagoon is unobtainable, for high efficiency BOD removal.

Enso-Fenox developed by the Enso-Gutzeit Company in Finland is a new combined anaerobic- aerobic method. It is claimed that a certain dechlorination of organic compounds is achieved.

Ultrafiltration of the E-stage effluent according to the EKA Company in Sweden, and followed by evaporation and burning, is undoubtedly applicable. There is, however, uncertainty with regard to the cost and availability of membranes and just one plant for bleach plant effluent is in use. The same is true of the ion exchange method according to Uddeholm and the Enso-Fenox method.

7. EFFLUENT CHARACTERIZATION

How can the environmental effect of the bleach plant effluent be determined? Obviously the ultimate relevant method is to study the aquatic eco-system of the receiving waters in order to find deviations from the natural eco-system (Fig. 5). This is, however, extremely complicated, takes a long time and the results are difficult to correlate to the design and shape of the mill.

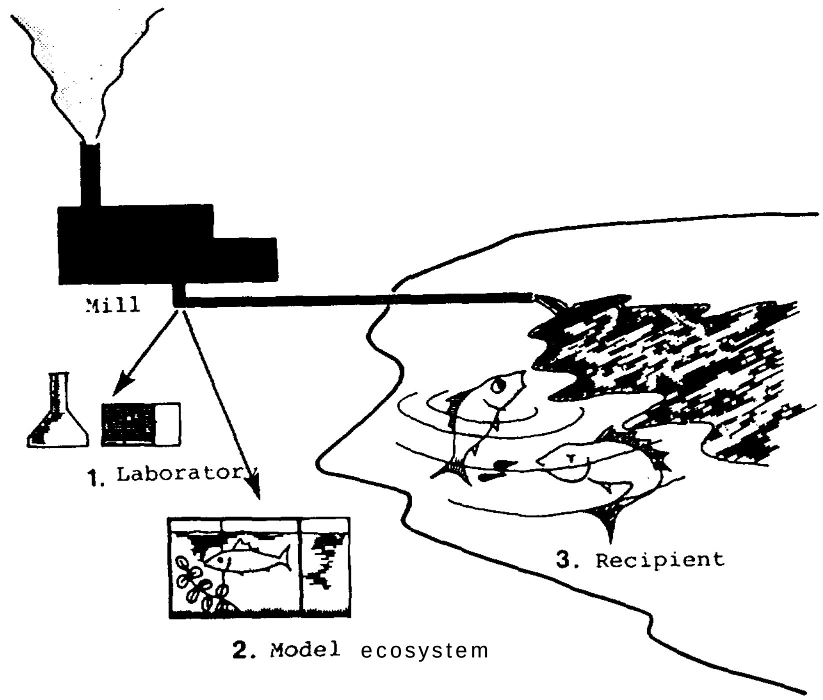

Fig. 5. Measurement of environmental impact.

So far laboratory measurement, both chemical and biological, on the effluent as such have been our basic tool. For a while we believed that it would suffice for the necessary evaluations. In order to confirm this presumption model eco-systems were studied.

A fairly complete eco-system with plants and fish and algae is kept going on clean water. In order to study an effluent, it is added to the water passing through the system at a constant rate so that a set concentration of the effluent is maintained within the eco-system. The biologists make close observations and measurements on growth, fertility, disease etc.

So far the results are partly contradictory.

A preliminary ranking of various bleach plant sequences and external treatments has been published (2) and is often referred to as a guideline for environmental improvements (Table 1).

Table 1. A preliminary ranking of various bleach plant sequences and external treatments.

Relative environmental effect	Alternative sequence		Amount D %
Most	(CD) EHDED		10
"	"	+ extra wash	10
"	"	+ UF of E	10
"	"		15
"	0 (CD) EDED		15
"	"	+ extra wash	15
"	(CD) EHDED	+ aerated lagoon	10
"	"	+ ion exchange	10
"	(DC) EDED		85
"	0 (CD) EDED	+ aerated lagoon	15
Least	0 (DC) EDED		85

The ranking was based on the following parameters:

* Chemical characterization
  - BOD, COD, colour
  - TOCl, OCl 1000
  - ClO_3^-, $CHCl_3$
  - chlorinated phenols, -guaiacholes

* Biological characterization
  - algae
  - acute toxicity on fish
  - reproduction tests on fish
  - behaviour changes
  - sublethal effects
  - genotoxicity

All of them are determined in the laboratory.

Preliminary observations of the model ecosystem have, however, caused serious doubts as to the validity of the present methods and it will take time before we can find a correlation between for instance various bleach plant sequences and the ecological effects.

A further warning came when the new pulp mill at Mönsterås had been in operation for a couple of years. It was built in accordance with all knowledge derived from studies of the classical parameters. An old mill with a conventional sequence had been in operation since the 1950's without any obvious effects. After the start of the new mill, however, it was found that the rock algae in an area of several square-kilometers had disappeared.

Recently the environmental department of the local government published a scientific report from the university in Kalmar (Högskolan i Kalmar, Institutionen for Naturvetenskap med teknik, contribution 1983:5) describing the situation and summing up the results in four questions:

1. Does oxygen bleaching create modified lignin compounds? If so, do they interfere with the rock algae (Fucus vesiculosus)?
2. Can a temporary lowering of the pH-value cause increased absorption of chlorinated organic matter by the rock algae?
3. Brown algae naturally contain various phenols. Can an exchange take place between these and the chlorinated phenols that now are present in the recipient?
4. Is the concentration of chlorate in the receiving water occasionally high enough to interfere with the photosynthesis of the algae?

8. CONCLUSIONS

The present knowledge of the correlation between the environmental impact and bleaching technology is obviously inadequate.

The previous theory, that one could evaluate biological effects from results of the present test methods, was too optimistic.

In order to further environmental improvements regarding pulp bleaching, more research is needed on the correlation between technology and ecological effects. Competing projects in several countries might be the best way to mobilize more research capacity and speed up progress in this important field.

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ANAEROBIC + AEROBIC TREATMENT OF WASTEWATER AND SLUDGES FROM THE PULP AND PAPER INDUSTRY – AN EFFICIENT WAY TO PROTECT THE RECIPIENTS AND TO RECOVER ENERGY

Jonas Norrman
Swedish Environmental Research Institute
Sweden

1. INTRODUCTION

The pulp and paper industry is very important for the Swedish economy and in spite of strict environmental protection laws this industry is still a major source of pollution. However the situation has improved considerably since 1950 (Fig. 1).

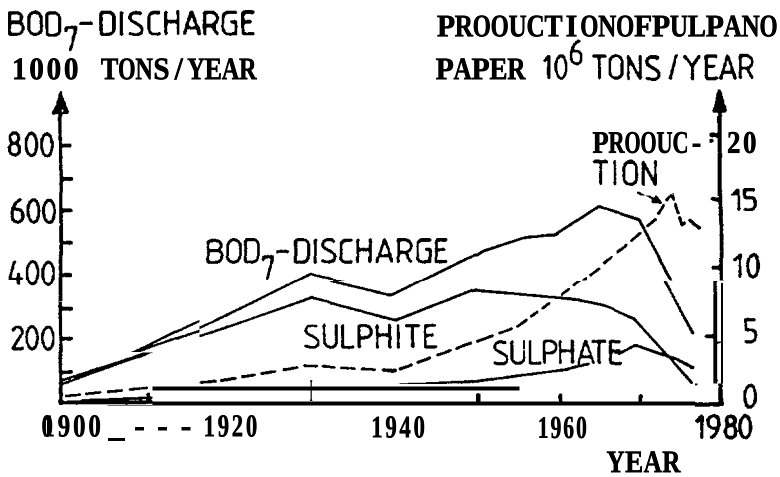

Fig. 1. BOD_7-discharge to recipients from pulp and paper industry in Sweden during the period 1900-1978. Sulphite = BOD_7 from sulphite pulp mills: sulphate = BOD_7 from sulphate pulp mills.

Although the production of pulp and paper has increased approx. three-fold, the discharge of BOD_7 has decreased to about 1/3 of the peak value in 1965. This dramatic change has been achieved by a combination of internal measures, e.g. closing of processes (recycling of water) and external measures, e.g. wastewater treatment. Some measures like decrease of fiber losses have proved profitable to the companies, but wastewater treatment on the other hand puts an extra burden on industries already struggling to survive in a competitive world market. In other countries the environmental protection laws are often more lenient or not fully enforced.

Today many Swedish pulp and paper industries use settling basins and aerated lagoons or activated sludge units for wastewater purification. These aerobic treatment systems are reasonably efficient for degradation of both BOD_7 and toxic compounds in the wastewater. However, they are rarely able to operate at the design capacity and they require a large amount of energy for aeration of the wastewater. Increasing energy prices and the general concern about reclamation of wastes and wastewaters have made the industry interested in alternative techniques. A new wastewater treatment system must, however, offer improved treatment efficiency at a lower cost than present day technology. By a change from resource- destroying aerobic to resource - conserving anaerobic wastewater treatment this can be achieved. A combination of energy-efficient wastewater purification and energy recovery (methane production) is possible. Anaerobic treatment should always be complemented by an aerobic polishing step.

At a pulp and paper industry with external wastewater treatment many kinds of sludges are produced, e.g. fiber sludge, biological sludge and chemical sludge. By anaerobic treatment of these sludges many advantages can be achieved, e.g. volume reduction, stabilization, energy recovery and improved dewaterability.

2. PROCESS CHARACTERISTICS

Anaerobic + aerobic treatment is a two-stage biological purification process, that can be explained in the following schematic way (Fig. 2). In the anaerobic treatment stage organic material is converted to biogas by a large number of co-operating microorganisms. Besides biogas new microorganisms are formed. The remaining BOD_7 is treated in an aerobic stage and converted to carbon dioxide and new microorganisms (sludge). The small amount of BOD_7 remaining after two-stage biological treatment is discharged to the recipient.

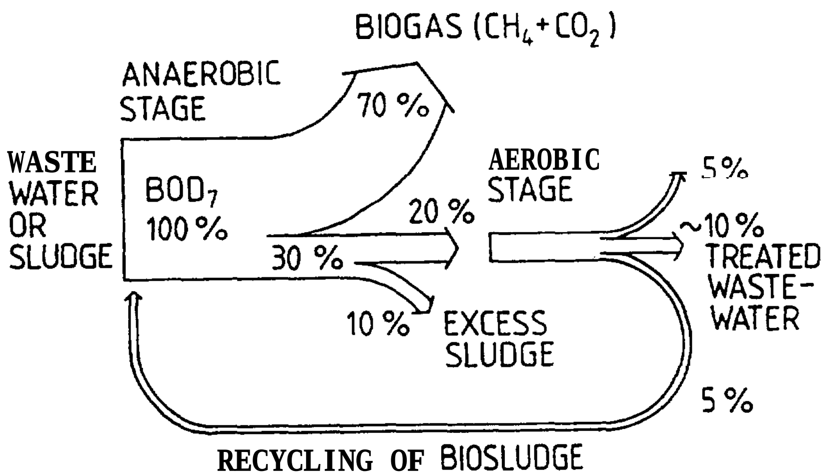

Fig. 2. Anaerobic + aerobic degradation of biodegradable organic matter in wastewaters from pulp and paper industries.

In Table 1 a comparison between aerobic and anaerobic treatment methods is made to illustrate the advantages of a conversion from aerobic to anaerobic wastewater treatment.

Table 1. Comparison between aerobic and anaerobic wastewater treatment systems. Advantage (+) and disadvantage (-). (modified from Frostell & Norrman 1976 (4).

Factor	Treatment method			
	Aerobic		Anaerobic	
	Biorotor	Activated sludge	Contact process	Filter process
Efficient treatment of concentrated wastewaters (>10 kg COD/m^3)			+	+
Efficient treatment of diluted wastewaters (>0.2 kg COD/m^3)	+	•	-	+
Energy-efficient process	•		+	+
Low sludge production			+	+
The end product methane is an energy source			+	+
Aeration with compressed air not necessary	+		+	+
Low nutrient demand			+	+
Short treatment time	+	+	-	•
Small reactor volume	+	+	-	
Heating of the reactor not necessary	+	+	-	
Can tolerate temperature changes	+	+	-	+
Can tolerate fast changes in volumetric load	+	+	-	•
Can tolerate changes in substrate composition	+	+	-	
"Low" capital costs		+	+	
Low operating costs	+	-	+	+
Can tolerate high salt concentrations	•	+	-	
Can tolerate toxic compounds	+	-	-	+
Fast start-up	+	+	-	
The sludge can be stored from year to year			+	+

The major advantages are saved aeration costs, energy production (methane), low sludge production and a low demand for added nutrients.

Disadvantages are the long start-up period and the high and even process temperature (approx. 30°C) necessary. Moreover, we have still limited experience of full-scale anaerobic treatment of wastewaters from pulp and paper industry.

4. APPLICATION OF ANAEROBIC + AEROBIC TREATMENT IN THE PULP AND PAPER INDUSTRY

According to Webb 1983 (10) to following wastewaters can be considered for anaerobic treatment:

- Mechanical pulp/fiberboard wastewaters
- Sulphite pulping wastewaters
- Kraft pulping wastewaters
- Pulping condensates
- Non-wood pulp and paper mill wastewaters
- Paper/board mill wastewaters
- Mill sludges

Many of these wastewaters have been successfully treated in laboratory or pilot experiments (10). So far there are only a few examples of full-scale anaerobic treatment. In the U.S. a mill producing corrugating medium from recycled fibers was converted from two-stage aerobic to combined anaerobic + aerobic wastewater treatment (6, 7). In the anaerobic pond a BOD_5 removal of approx. 80 % was achieved and the total BOD_5-reduction after anaerobic + aerobic treatment amounts to approx. 98 %. The sludge production was reduced 80-90 % compared to the previous two-stage aerobic treatment. The total cost of the anaerobic + aerobic treatment was approx. 10 % of the previous cost for purely aerobic treatment. Savings were possible concerning energy for aeration, addition of nutrients and sludge-handling. Moreover, the capacity of the treatment plant was increased.

Another application that might be of particular interest at this meeting is anaerobic + aerobic treatment of Kraft bleaching effluent (8). Bleaching effluent contains many toxic components, some originating from the wood, e.g. resin acids and others originating from the bleaching process, e.g. chlorinated lignin degradation products. This wastewater is especially difficult to treat biologically.

In the anaerobic stage chlorinated compounds are dechlorinated and in the aerobic stage conversion to carbon dioxide and new cells takes place. The BOD_5-reduction amounted to 52 % on average and the toxicity was considerably reduced. Comparative tests showed that anaerobic treatment at short retention times degraded chlorophenolic compounds in Kraft mill wastewater more efficiently than activated sludge treatment or treatment in an aerated lagoon (8).

Large scale anaerobic treatment plants for pulp and paper effluents are presently being built in the Netherlands, Spain and Sweden.

5. TREATMENT OF SLUDGES

The classical application of anaerobic treatment is digestion of sludges at municipal wastewater treatment plants. In a similar way sludges from pulp and paper industries have been anaerobically treated. Biosludge and fiber sludge are suitable for anaerobic digestion, but chemical sludge might upset the digestion process unless it is mixed with the other types of sludges in suitable proportions.

Many Swedish recipients contain large amounts of fiber sediments contaminated with mercury. From an environmental point of view it is very appealing to dredge up mercury-containing fiber from the recipient, treat it in an anaerobic digester and deposit the treated fiber on land after dewatering. Most of the mercury in bound to the treated fiber.

The methane produced can be used at a nearby industry or for production of electricity. In this way the recipient can be purified from mercury, the fiber removed and a considerable amount of energy recovered. A project of this kind is going on at the Swedish Environmental Research Institute.

6. PROCESS PERFORMANCE

A brief summary is presented in Table 2. More extensive data have been compiled by Webb 1983 (10).

Depending on the character of the wastewater loadings of 1-16 kg COD/m^3 d have been successfully applied to the anaerobic stage. The COD-reductions vary between 40 to 80 % and BOD_5-reductions of 60 to 80 % have been obtained. Methane yields between 0.11 and 0.33 m^3/kg COD_{fed} were observed.

No data have been included for combined anaerobic + aerobic treatment. The combined treatment will consistently achieve an efficient BOD_7-reduction of approx. 90 %. The combined system is very stable. If the anaerobic stage is temporarily overloaded and the treatment efficiency decreases, the aerobic stage will compensate for the loss of activity in the anaerobic stage and produce an effluent of high quality.

7. ECONOMY

Cost analyses made by Webb 1983 (10) indicate that the capital costs for aerobic and anaerobic + aerobic treatment are similar. The operating costs for aerobic treatment are approx. 1/10 of the capital costs (10). On the other hand anaerobic +

aerobic treatment will give a surplus. The value of the methane produced exceeds the operating costs. Calculations made by Takeshita et al., 1981 (9) and others indicate that the energy value of the methane produced amounts to 5-10 % of the total energy demand at a pulp and paper mill.

8. CONCLUSIONS

Wastewaters from the pulp and paper industry are becoming warmer and more concentrated because of increased recycling of process water. This favours combined anaerobic + aerobic wastewater treatment, which can consistently give efficient purification (approx. 90 % BOD_7-reduction). Simultaneously, energy is recovered and costs for added nutrients and sludge-handling are reduced in comparison to aerobic treatment.

Capital costs are high for anaerobic + aerobic treatment (as for aerobic treatment), but the operating costs are lower than the positive value of the methane produced.

Anaerobic + aerobic treatment can detoxify waste-waters from pulp and paper industries efficiently. The combined treatment is probably more efficient for degradation of toxic compounds than either method separately.

Table 2. Performance of anaerobic reactors treating wastes and wastewaters from the pulp and paper industry.

Waste or wastewater	Concentration kg/m^3	Reactor Type	Size	Temp °C	Volumetric loading kg/m^3 d	Efficiency % removal	Methane production	Refer-
Recycled fiber wastewater	2.4-3 BOD_5	Lagoon	Full	48	0.56 BOD_5	84 BOD_5		(6, 7)
Fiberboard wastewater	24 COD	Contact	Pilot	35-37	2 COD	59 BOD_7 38 COD	0.11 $m^3/kg\ COD_{fed}$	(4)
Kraft evaporator condensate	0.42 COD	Fluid bed	Lab.	22	13 COD	80 COD	0.19 $m^3/kg\ COD_{fed}$	(5)
Sulphite evaporator condensate	1.05 COD 0.48 BOD_5	Filter	Lab.	35	16 COD	80 COD	0.33 $m^3/kg\ COD_{fed}$	(1)
Fiber sludge	12.7 COD	Contact	Pilot	36	1.7 COD	70 COD	0.28 $m^3/kg\ COD_{degr.}$	(2)

Anaerobic treatment of sludges and fiber sediments has mainly three advantages: (a) considerable amounts of methane are produced (b) the sludge is stabilized and the volume reduced and (c) mercury-contining fiber sediments are removed from the recipient.

A more general application of combined anaerobic + aerobic treatment of wastes and wastewaters from the pulp and paper industry would no doubt improve the environmental conditions in the recipients. Moreover, the technique is appealing from an ecological point of view. The energy in organic waste material is efficiently recovered and the major end products methane and carbon dioxide are stable.

9. SUMMARY

Most pulp and paper industries in Sweden are equipped with efficient external wastewater treatment plants, e.g. aerated lagoons. However, reclamation of wastes and wastewaters and conservation of energy are becoming increasingly important in Sweden. One step in that direction is a change from resource-destroying aerobic to resource-concerving anaerobic wastewater treatment. By anaerobic treatment, a combination of energy-efficient water purification and energy recovery (methane production) can be achieved.

Anaerobic pretreatment followed by an aerobic polishing step will give a versatile and stable treatment system. Laboratory and pilot scale studies have shown that if the anaerobic stage is temporarily overloaded, the aerobic stage will normally be able to cope with the temporary excess load and thereby ensure that the combined treatment result is consistently good.

Some data suggest that toxic material in the wastewater is more efficiently degraded by combined anaerobic + aerobic treatment than by either method separately.

Estimates indicate that 5-10 % of the total energy demand at a pulp and paper mill could be supplied by utilizing methane formed by anaerobic wastewater treatment.

Excess sludge from aerobic wastewater treatment plants, and fiber dredged from recipients can be anaerobically digested to methane. Three advantages are achieved: (a) the sludge is stabilized, (b) considerable amounts of methane are produced and (c) mercury-containing fiber sediments are removed from the recipient.

The first full-scale plant in Sweden for anaerobic + aerobic treatment of wastewater from a pulp and paper industry will be on line in 1984.

ACKNOWLEDGEMENTS

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MODERN WATER POLLUTION CONTROL TECHNOLOGY OF SOME INDUSTRIAL BRANCHES IN FINLAND

Esa Tommila
Confederation of Finnish Industries
Finland

1. INTRODUCTION

It is typical for the water pollution control in the process industries that both internal and external control technologies are used. This paper consists of brief presentations of the recently applied water pollution control technologies in the Finnish inorganic chemical industries and non-ferrous metals industries.

The internal control measures can mainly be grouped as follows:

- minimization of the use of water
- keeping different water flows separated until treated
- maximization of water reuse
- utilization of the harmful substances where feasible.

When these concepts are actively applied, only few external control measures are needed.

2. FERTILIZER INDUSTRIES

Inorganic chemicals and fertilizers are produced in Finland by Kemira Oy in five locations. Great emphasis has been given to the elimination of nutrient-containing effluents. The new plants have advanced further, quite naturally, than the old ones.

Many waste gases contain nutriens in dust which must be separated to avoid air pollution. Several wet scrubbers have been replaced by dry gas cleaning with bag filters. Separated dust is returned to the processes.

The reactor gases of modern compound fertilizer production, for instance, are scrubbed by floating bed scrubbers in two stages. Thw washing solution is led through the scrubbing stages in counter-current and then pumped to the gas scrubbing of the product spherodizers.

Several processes are connected to a water recirculation system, having only a small overflow to avoid exessive salt enrichment. The overflow is used in the granulation process, where all water is evaporated. The intake water originates from the sealing of pumps, steam condensates and washing of the equipment, as well as from the rain water collected from the plant area.

By these means nearly all traditional effluents have been eliminated. Only pure cooling water and some very dilute effluents from the process area are left. As a result, the total phosphorus load in the effluents of Finnish fertilizer plants was 44 kg/d in 1982, whereas in 1971 it had been 1147 kg/d.

One obvious phosphorus problem exists. The waste gypsum storage pile of one of the factories is located on the sea shore. Rain water leaches some phosphorus from the pile. To manage the problem, a deep dike has been dug around the pile and equipped with pumps that keep the water level below the sea. A part of the pumped water is used in the process, and the residual is treated with lime and a centrifuge to separate the phosphates.

3. PIGMENTS PRODUCTION

In Finland titanium dioxide is produced only from ilmenite with the sulphuric acid method. Ferrous sulphate is chrystallized from hot acidic waste liquor, centrifuged and stored on land. A significant iron and acid load is still left in the effluent.

To diminish the effluent load, an evaporation unit is being built for the strong waste acid. The metals will be chrystallized and the concentrated acid mainly reused in the process. By these means the iron content of the effluent will decrease by 30 % in 1985. Unfortunately, the main part of the iron is contained in weak acidic solution, the treatment of which is not feasible.

4. NON-FERROUS METALS PRODUCTION

Zinc and cobalt are the main products of Outokumpu Oy's Kokkola Works. The zinc process comprises the following steps:

- roasting of zinc concentrates
- leaching of roasted calcines
- solution purification
- zinc electrowinning
- melting, casting and alloying.

The raw materials contain several elements which could cause environmental problems if discharged from the process. The roaster waste gas contains relatively much SO_2 and also mercury, which is extracted as a by-product from the process, designed by Outokumpu Oy, before the gas is led to a sulfuric acid plant. The residue obtained from mercury production contains about 10 % selenium, which is extracted and converted to metallic selenium in a unique process.

In the zinc process, aqueous solutions are used in extraction, solution purification and electrowinning stages. All solutions are treated within the process stages so that the recycling system is completely closed. No process effluents are discharged. There is a separate recirculation for cooling waters, and a small overflow from it is led to the sea.

In one stage of the solution purification, cadmium is precipitated and transferred to the cadmium process, also developed by Outokumpu Oy. Even this hydrometallurgical process does produce any effluents, thanks to advanced design.

In the zinc plant and its by-product plants, the only sources of small amounts of pollutants to the waters are

- leakages in the processes
- operating disturbances, overflows, equipment failures
- unavoidable flushing of small amounts of raw materials and precipitates into the drainage system.

In 1982, the total effluent load of cadmium was 130 kg/a and of mercury 0.7 kg/a, corresponding to concentrations of 3 $\mu g/l$ and 0.02 $\mu g/l$, respectively.

The cobalt process consists of pyrometallurgical and hydrometallurgical phases. The introduction of PROSCON-process control system, developed by Outokumpu Oy, has impressively decreased the effluent load by eliminating operating failures and by optimizing the process.

Many water fractions are recirculated and others treated separately before discharging them. The pump sealing water flows are controlled very accurately.

By these means the effluent flow from the cobalt plant has been limited remarkably, and within the next two years the flow will be only 25 % of that in 1980. This will be the result in spite of collecting the rain water from the plant area and leading it to the process.

SOME ASPECTS OF THE ANTHROPOGENIC POLLUTION IMPACT ON BIOPRODUCTIVITY OF THE BALTIC SEA

Vladislav Ipatov and Aivars Yurkovsky
Baltic Fishery Research Institute
Union of Soviet Socialist Republics

At present a complex ecological situation is arising in the Baltic Sea region. On one hand, this is a result of a highly developed industry, developed agriculture, and intensive transportation in the Baltic countries. On the other hand, in the second half of the 1970's the stocks of commercial fishes have apparently reached the limit of the removals (about 1 mill. tons). Besides, it should be taken into account that the state of the valuable fish stocks (sprat, salmon, sea trout, eel, river lamprey) is unfavourable now. An intensification of the exploitation of water reservoirs, industrial use of rivers mainly, and an increasing pollution of the Baltic Sea basin are some of the possible causes of the situation arisen. In particular, the stocks of agar-producing algae have been significantly reduced, the production conditions for herring have become worse, and the area for natural reproduction of valuable migrating fishes has grew narrow throughout the sea. A costant excess of maximum permissible concentration (MPC) of oil-products and phenols in the sea water, the presence of the surface-active agents, a number of other ksenobiotics and heavy metals, availability of these substances and their metabolites in the tissues of hydrobionts also testify to a stable pollution of the Baltic Sea waters.

An objective analysis of the tendencies in the changes of chemical and biological characteristics of the sea with a corresponding differentiation of the changes into natural and anthropogenic ones is of a high difficulty. But, there is no other way for the investigation of the problem. All these being taken into account, scientific and fisheries organizations of the Soviet Union have laid down a programme, and on the basis of complex investigations are carrying on concrete measures in the fisheries rationalization (introduction of limits for fish catches by fishery zones, transition to seasonal fishery regulations and so on), in strengthening the protection of the coastal zone of the sea from pollution and negative impacts of other factors affecting the reproduction of living resources as well as in the restoration and increase of bioproductivity of the sea.

The components entering the Baltic Sea environment, as a result of man's activity, conventionally may be devided into two groups: nutrients and ksenobiotics. A moderate input of nutrients governs the increase in bioproductivity of the eco-system. But, having reached a definite level, their further intruduction may lead to the succession of communities with all consequences ensuing. Thus, an increase in phosphorus and nitrogen contents in the surface reproductive layer of the Baltic Sea was recorded within the last 20 years. The long-term phosphorus increase in the productive layer is controlled by a sufficiently complicated complex of regime influences and as a whole may be characterized by the superposition of the short-term effects on the non-linear, presumably parabolic trend. The biogeochemical cycle of nitrogen in the sea is more complex, since it involves the exchange with gaseous phase through nitrogen fixation and denitrification. The content of salt nitrogen in halocline, for which the tendency towards a stedy increase in subphotic sea zones was defined up to the late 1970's, seems to be the most significant in the assessment of the long-term tendency in the supply of trophogenic layer with salt nitrogen.

The increased food availability of photosynthesizing organisms affected the state of successive parts of the trophogenic chain. A significant influence of the increase in nutrient concentrations on the increment in zooplankton abundance and biomass within the periods of its maximum development is confirmed by the presence of direct and reliable ties between them. As a whole, the abundance of crustacean zooplankton in different seasons of the 1970's increased by 1.5 as compared to that of the 1960's. At such a rate the increase in biomass occured too. Zooplankton productivity grew due to the increase in the abundance of the species inhabiting the upper 100 m layer. Deeper the amount of salt-loving zooplankton decreased. Besides, different levels in the abundance increase of separate species caused not only the changes in zooplankton trophical structures (the significance of phytophages increased), but also brought about the decrease of the differences in food density of separate water layers.

The increment in zooplankton amount brought about a change in the growth rates of planktivorous species: in the last decade the body mass of the spring-spawning herring in the younger age groups increased, as compared to that of the 1960's; the tendencies towards a decrease in the growth rates within the long-term /stagnation periods, and an increase during the water renewal in the active intermediate layer being observed.

But further eutrophication of the sea may lead to negative effects, to which the presence of zones with oxygen deficit within stagnation periods, natural for this highly stratified water reservoir, testifies. This phenomenon results in periodical changes in the size of spawning grounds of cod, adoptation of which to the Baltic Sea conditions is connected with the acclimatization in the high salinity zones. At present, a negative impact of anthropogenic constituent of eutrophication is the most obvious in the coastal zone. The studies on the bottom flora of the Gulf of Finland have shown that pollution may bring about the succession of species composition and even of entire communities. For example, epiphyte Elachita fucicola, that inhabits Fucus vesiculosus growing in clear water, disappeares even in a slight water pollution. But its place is taken by enother epiphyte Pilayella litoralis, biomass of which is increasing following the pollution. Under definite conditions Fucus becomes overgrown with the epiphyte to such an extent that a disturbance in metabolism of the hostplant, and even its death in some cases, is observed. Similar changes are noted in zooplankton: the abundance of rotifers highly tolerant to pollution has increased, and the abundance of Copepoda has decreased.

Trace elements have been used for a long time as trace fertilizers, food additives, etc. But, analogous works in fisheries, and especially in marine reservoirs, are still in an initial state. The information on the trace element contents in commercial ichthyofauna of the Baltic Sea is hihgly odd and discrepant that results in the absence of traditional ideas on mean concentrations of a number of trace elements *in* separate species. The absence of the information, in its turn, makes difficult to understand the biological significance of trace element concentrations in fish organisms and environment, noted by some authors. Recent investigations testify to an increase in the content of a number of metals in the water and bottom of the Baltic Sea, and in its coastal zone, in particular.

But, the investigations in the Gulf of Riga have shown that mean concentrations of a number of heavy metals were below MPC determined for fisheries reservoirs. Only at separate stations copper and zink concentrations have reached the values able to inhibit the phytoplankton production.

Chlorinated hydrocarbons able to accumulate in the higher parts of the trophic chain are the most dangerous for commercial fishes of the Baltic Sea. The analysis testify that the content of chlororganic compounds in fish tissues (DDT and its metabolites, lindane, PCB and others) reach significant values in some cases. For all this, any dependence between their content in fish tissues and fishing place was not defined by us. Taking into account the conception of equilibrium distribution of lipophilous chlororganic compounds between the lipids of an organism and the environment, one may come to a conclusion that the differences in DDT and PCB contents in the tissues of the fish from different Baltic areas, noted by various authors, are controlled by physiological state of fishes to a great extent and the intensity of lipid exchange, in particular. Really, DDT concentration in cod liver, that is the fat deposit, exceeds significantly that recorded in herring and sprat muscles. Besides it grows, as a rule, following the increase in the intensity of generative exchange and accumulation of lipids for energetic supply of reproduction processes. Since antitoxic resistance of the organism is exposed to significant changes in both the course of natural physiological processes and fluctuations of environment conditions, the energy expenditure for the detoxication processes in a definite coincidence of circumstances may serve as a modifying factor and affect the intensity of reproduction (the fall in fish fecundity, the shift in spawning terms). Since every toxic element influencing the dynamics system takes part in the survial of a progeny, and in the end, in the well-being of the population, an increase in DDT and PCB concentrations in fish gonads as far as they become mature is of great interest. In this case concentrations of the substances reach the values when the tendency towards various infringements in embryogenesis is observed: the changes in the terms of separate stages, abnormalities in development. All these testify to the fact that separate components of pollution influencing the historically established links in production cycles of the Baltic Sea, are the factors sufficient to change the abundance of commercial fishes. To our regret we ought to note that material insufficient compiled on this problem if we take into account that there is no information on the fate of the majority of substances potentially toxic for hydrobionts, that have entered the Baltic waters. In view of this, an increase in the frequency of occurance of abnormal embryoes in ichthyoplankton and fishes with different deseases (pseudobranchial tumours, trophical ulcers, epidermalpapillomas, etc) near the most polluted sea areas in recent years cause an alarm.

Thus, a stable sea pollution turns to be a specific factor for the life of the water reservoir, effective control of which and rational exploitation of its biological reseources are impossible without investigations on the problem. Since sea fishes, as the basis of the Baltic fish production, the areas they inhabit and migration ways are not attributed to definite areas and national fishing zones, in particular, co-operative efforts of all the Baltic countries in the protection of the environment and hydrobionts in the Baltic Sea acquire a special significance.

CONCENTRATIONS OF DDT AND PCB IN SEDIMENTS IN THE FINNISH SEA AREAS

Matti Perttilä
Institute of Marine Research
Finland

The DDT and PCB discharges were prohibited at the end of the 1960's into the Baltic Sea and a little later, in 1970, the use of DDT, with a few exceptions, was banned. As the main reason for these restrictions was the fact that the halogenated hydrocarbons accumulate strongly in biomaterial, and cause well-known diseases at the top of the food chain, it has been in the interest of many research groups to study how the restrictions have affected the DDT and PCB concentrations in the marine environment.

The study of the area1 and especially temporal changes in the concentrations of most organochlorine compounds is difficult, because during the time that DDT and PCB discharges have been banned, also rapid methodological developments have taken place. Also, when methodological advances are taken, insufficient is always paid on the thorough relation of the results given by new methods to those given by earlier methods.

One possible way of obtaining reliable results for trend evaluation would be provided by specimen banks. However, there is no such thing yet for the Baltic Sea are. The Baltic Sea monitoring programme probably yields in a few years data suitable for trend analyses, provided that appropriate care is taken when analytical and sampling methods change. However, so far the existing results do not allow trend analyses.

The comparison between old and new results is often difficult also because of the inhomogeneity of the sample material.

If certain requirements are satisfied, the marine sediments form a kind of sediment bank, which allows for taking samples representing different periods of time. If the perturbations caused by currents, changes in hydrochemical conditions, biological activity etc. to the sedimentation processes can be considered negligible, the concentrations found in a certain sediment layer can be assumed to reflect the concentrations in the sea water at the period when the layer was formed.

The following figure shows the sites from which we have taken sediment samples for organochlorine analyses.

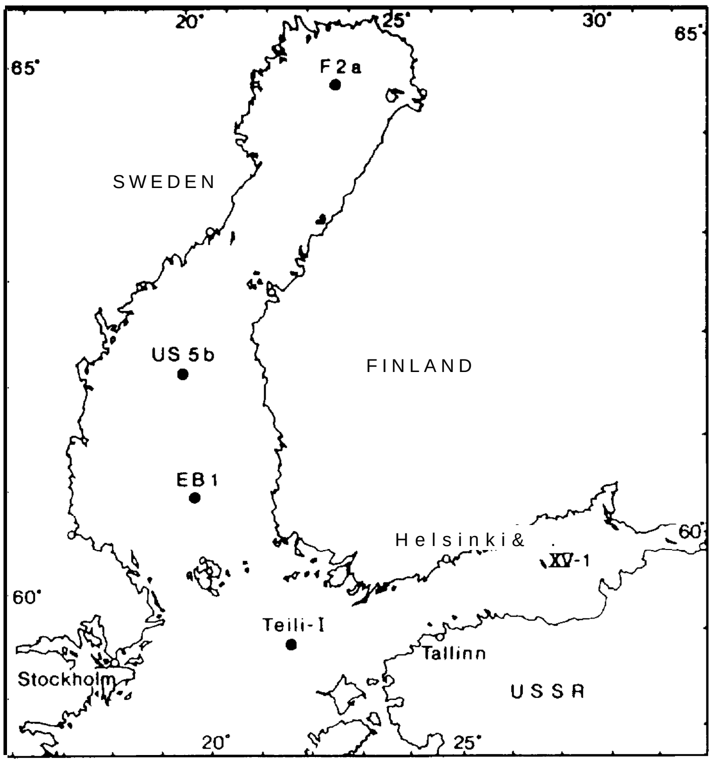

Fig. 1. Sediment sampling sites.

The samples have been taken by a gravity corex. The sediment core has been cut the slices 1 cm thick which have been analysed separatedly.

The following figures show the concentrations of DDT and PCB in sediments a functions of depth from the sediment surface.

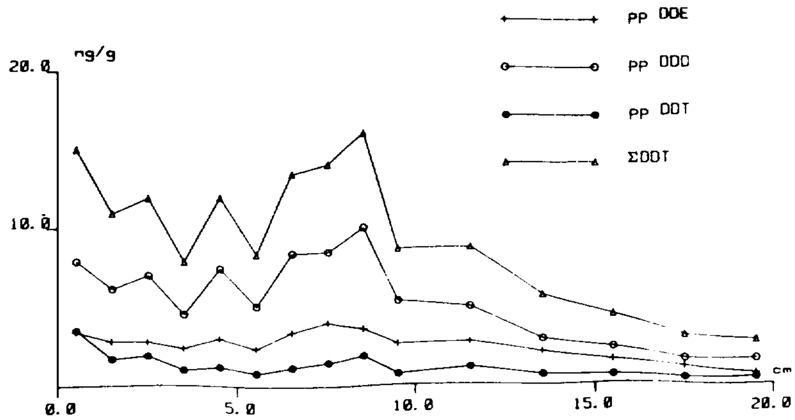

Fig. 2. DDT with metabolites (XV-1) (ng/g d.w.t.)

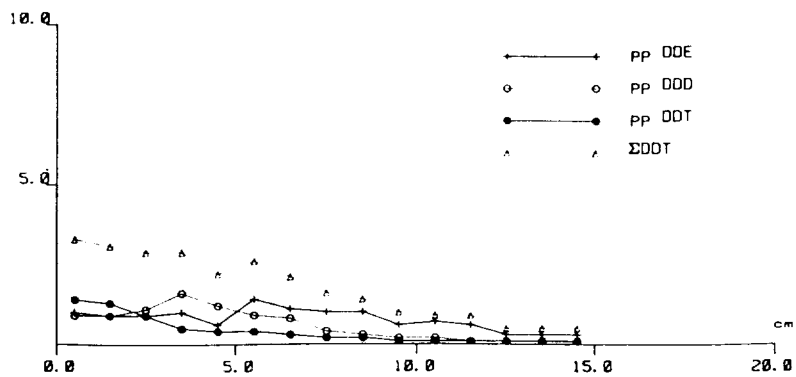

Fig. 3. DDT with metabolites (EB-1) (ng/g d.w.t.)

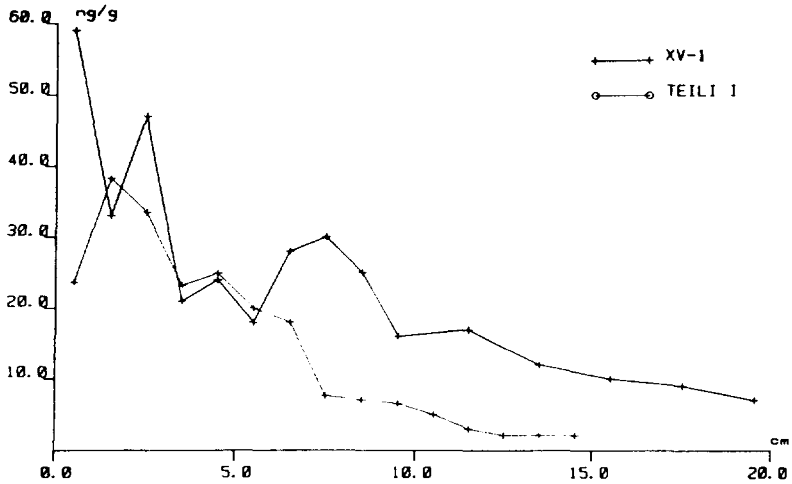

Fig. 4. PCB concentrations in sediments (ng/g d.w.t)

At all sites the concentrations rise from the bottom upwards. At EB1, where the sedimentation rate is slow, the DDT concentrations rise steadily towards the top of the sediment core. In the Gulf of Finland, however, the DDT concentrations attain a maximum at the depth of 8-9 cm, where after the concentrations slowly decrease. As the rate of sedimentation at XV-1 is about 7.4 mm/a, the DDT maximum corresponds to the period 1972-1973. At Teili in the northern Baltic Proper the maximum DDT values are at 3-5 cm. Sedimentation rate is 3.7 mm/a, and the maximum values correspond to the years 1970-1975. In the case of the PCBs, the concentrations increase steadily towards the sediment surface.

According to the concentrations in the sediments, the Gulf of Finland has been much more polluted by the organochlorine compounds than the Gulf of Bothnia. The PCB concentrations in the surface sediment of XV-1 vary between 40 and 60 ng/g.

concentrations vary between 5 and 15 ng/g. The total DDT concentrations in the Gulf of Finland are 15-20 ng/g, and in the Gulf of Bothnia 2-4 ng/g. Similar area differences have been obtained also in biomaterial studies. In Baltic cod, the average PCB concentrations of liver in 1979-1980 were 5.3 mg/kg in the eastern Gulf of Finland, 2.3 mg/kg in the Bothnian Sea, and 1.7 mg/kg in the Bothnian Bay.

Corresponding total-DDT values were 0.8, 0.3 and 0.4 mg/kg (fresh weight).

SEWAGE TREATMENT WITH LAGOONS

Gunther Leymann
Amt für Land und Wasserwirtschaft
Federal Republic of Germany

1. INTRODUCTION

In the Federal Republic of Germany sewage lagoons for biological treatment have been built and used for approximately 10 years with considerable success.

At present there are almost 100 lagoons in operation, half of which run without additional aeration.

2. LAGOONS WITHOUT AERATION

In unaerated lagoons oxygen is inserted through the water surface and through biogenic aeration. Because of the extended area1 demand the application of these lagoons in the Federal Republic of Germany is limited to an amount of sewage of 1 000 population equivalents. In Schleswig-Holstein, however, there is a lagoon with 1 300 population equivalents.

For small rural communities unaerated lagoons are appropriate especially when, in addition to domestic sewage also liquid manure and silage are occasionally added.

For the dimension of a lagoon a load of 4 g BOD_5/m^2 d is estimated. This means that per population equivalent 15 m^2 are needed. There are usually 3 ponds in a line. The area1 ratio is 3:4:3. The depth of the first pond is 2 m, the other two are 1.2 m deep.

In the effluent of unaerated lagoons values smaller than 10 mg/l, BOD_5 and 60 mg/l, COD are obtained.

The decomposition results for phosphorus and nitrogen are better than those obtained by small biological treatment plants.

There are no differences in the efficiency of sewage treatment between lagoons with domestic sewage and those with domestic sewage and storm water.

Furthermore, no differences in the treatment were observed between summer and winter.

3. AERATED LAGOONS

In the Federal Republic of Germany aerated lagoons are often built for communities with a combined storm water and sewage system and when there are food industries or factories with high organic polluted sewage in the catchment area of these lagoons. Usually such ponds are built up to a load-carrying capacity of 10 000 population equivalents. In Schleswig-Holstein we run already one lagoon with 16 000 equivalents. One advantage of such lagoons is that they can be combined with systems for phosphorus reduction in the same way as it is done in normal tertiary treatment. Also with this systems we got some very good experiences.

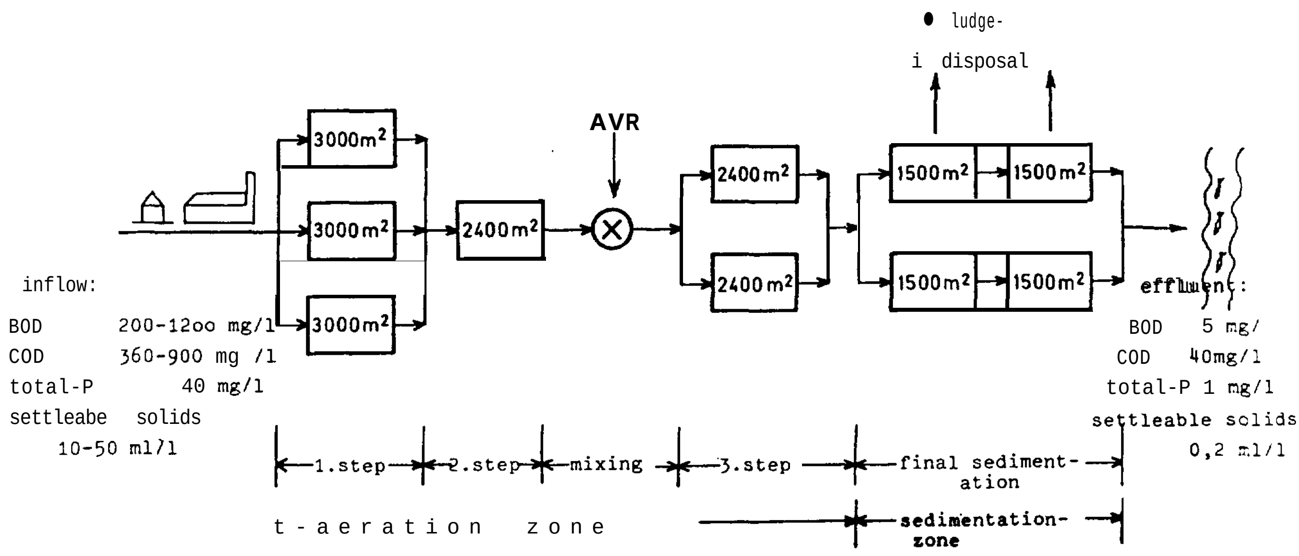

Fig. 1. General lay out of an aerated lagoon for 16 000 population equivalents in Wankendorf (Schleswig-Holstein)

In such cases the precipitation agent, for example AVR, is added into a special mixing tank. This tank is situated just before the last aeration step. In this way the effluent total P concentration is kept below 1 mg/l.

The overall results in the effluent are almost as good as those from unaerated lagoons.

The design of the lagoon is based on the following data:

- rate of flow at dry weather	3 days
- rate of flow of the final treatment	1 day
- BOD-load	30 g BOD_5/m^3
- OC-load	1.5 kg O_2/kg BOD_5
- energy density	1-2 W/m^3
- depth	1.5 m

If an additional phosphate precipitation is carried out one has to take care that there are no unaerated zones within the basin, so that there will be no resolution of phosphate from the sludge.

4. SUMMARY

Unaerated and aerated sewage lagoon provide biological treatment for domestic sewage which - with considerably little effort - allow a high treatment efficiency.

Further advantages are:

- inexpensive construction
- limited expenditure for equipment (machinery)
- no demand of energy with unaerated ponds
- little need of maintainance
- easy sludge-disposal
- large buffer capacity
- facility for treatment of storm water

The only disadvantage is the considerably high demand of area of 15 m^2/population equivalent with unaerated ponds and of 2-2.3 m^2/population equivalent with aerated ponds.

STATE OF SEWAGE TREATMENT IN SCHLESWIG-HOLSTEIN IN THE FEDERAL REPUBLIC OF GERMANY

Gunther Leymann
Amt für Land used Wasserwirtschaft
Federal Republic of Germany

The state of Schleswig-Holstein in the North of the F.R.G. borders the Baltic Sea and the North Sea. Therefore sewage from this region is discharged into the Baltic Sea and into the North Sea. This part of the F.R.G. comprises about 2.6 million inhabitants, the major part of which lives in small towns and communities. There are neither major conurbations nor big industrial areas. Only in the southern part of the state one can find some chemical industry which discharges its waste waters, after treatment in efficient purification plants, into the Elbe respectively into the North Sea.

The sewage of almost 75 % of the inhabitants of Schleswig-Holstein is led through drainage systems into efficient purification plants, where it is treated mechanically and biologically. As to the requirements of treatment efficiency within the whole F.R.G. there are one and the same limiting values. Consequently in the effluent from sewage treatment plants the following values must be adhered to in the purification:

BOD_5	20 mg/l (24-hours' sample)
COD	100 mg/l (24-hours' sample)
Settleable solids	0.3 ml/l (random sample)

Only with extremely delicate waters higher effluent quality is demanded. This applies for example to the discharge into lakes and channels, resp. into waters with limited water exchange. In these cases the following limiting values are required:

BOD_5	16 mg/l
COD	60 mg/l
Total P	1.6 mg/l

In actual usage these values are generally not reached. However, a certain tolerance must be granted as to the operation of the treatment plant, so that every variation in the effluent of the treatment plant does not lead to an unpermitted increase of sewage discharge and consequently to an illegal act.

Up to now there are no treatment plants for ammonia reduction in Schleswig-Holstein. However, such plants are being planned.

Some of the new treatment plants are already laid out on such a large scale that during the summer months a nitrification can be reached to a certain extent. The general trend of development aims at a denitrification with plants of this kind in order to reduce energy costs.

In that area of Schleswig-Holstein draining into the Baltic Sea almost the total amount of sewage is transferred to central purification plants, where it is mechanically and biologically treated. This was necessary not only to protect the Baltic Sea but it was also an indispensable requirement to permit swimming along all the beaches. Swimming is allowed along the Baltic coast of Schleswig-Holstein.

In order to reach this aim draining systems have been extended tremendously *during* the last ten years, existing treatment plants have expanded and a number of new plants have been built. A comparison of capacity shows that - in terms of BOD_5 - 5 400 t were discharged into the Baltic in 1973, whereas in 1982 only 1 500 t entered the Baltic. This means a reduction of almost 70 %. At the same time, the number of sewage treatment plants with a treatment efficiency of more than 90 % BOD_5 - decomposition and herewith the total amount of treated sewage could be increased.

There are 226 sewage treatment plants in the total catchment area of Schleswig-Holstein draining into the Baltic. The total amount of waste water comprises about 78 million m^3 per annum. 98 % of the waste water is mechanically and biologically treated. Of this amount almost 10 million m^3 (14 8) are additionally chemically treated as to phosphorus precipitation. Since today there are biological treatment plants for the Schleswig-Holstein catchment area draining into the Baltic, in the future main emphasis will be paid to further extension of these treatment plants.

SOME ACTIVITIES OF THE USSR MERCHANT MARINE MINISTRY IN THE FIELD OF POLLUTION PREVENTION OF THE BALTIC SEA AREA

Vladimir Gorbaschov
Shipbuilding, Engineering, Superintendance and Shipprepairing Corporation
Union of Soviet Socialist Republics

The prevention of pollution of the marine environment by oil and other harmful substances has become one of the important tasks of the Humanity and this task - to prevent pollution and preserve the marine environment - is a common goal of mankind.

The USSR, as a Party to the Convention for the Protection of the Environment of the Baltic Sea Area and other marine environment protection instruments, has fully recognized the importance of of the environmental issues with respect to the Baltic Sea - an area with unique oceanographical and ecological conditions surrounded by major industrial enterprises.

The USSR Ministry of Merchant Marine operate more than 1 900 transport vessels out of which some 420 vessels belong to four shipping companies registered in the USSR Baltic area. Six major ports in the Baltic area provide for the cargo turnover of these vessels as well as of other companies including foreign ones.

Retrofitting of the existing ships, bringing ports and shiprepair yards into compliance with the requirements of international conventions and stregthening of the national ability to fight accidental pollution have proved to be a large-scale problem with numerous peculiarities.

For the last 10 years since signing of the Final Act of the Baltic Convention the USSR has been taking an active part in scientific and technical studies and all activities of the Helsinki Commission.

With regard to practical achievments in the course of implementation of the national pollution prevention programme of the USSR Ministry of Merchant Marine it is worth mentioning that at present a number of technical means to combat oil pollution incidents has been developed. Among the above mentioned new technical means the first that should be noted is the project of the multipurpose environmental vessel M/S "Svetlomor". The ship is a reconstructed 10 000 deadweight ton tanker with the weir-type intake system which showed under the test conditions an effectiveness of oil recovery of 72.4 8. Ready for oil spill combating the ship has been employed mainly for its secondary mission, that of cleaning bunker tanks and handling of waste oil.

The task of a regular cleaning harbour area in the Baltic area is carried out by 16 standard oil and debris skimmers which have been designed by the Black Sea Central Design Bureau. The trials at OHMSETT test tank (USA) in 1979 have proved its high recovery efficiency on calm water (up to 94 %). Some 100 such skimmers operating in the USSR merchant marine ports annually collect about 40 000 m^3 of floating contaminants. The subsequent model test and engineering analyses revealed the possibility of improving the skimmer's characteristics such as speed, storage capacity and range of sailing.

A major spill from the British tanker "Globe Asimi" gave impetus to further development of new means for containment and recovery of spilled oil as well as to organization of response operations and training of personell. The spill occured adjacent to the port of Klaipeda on November 21, 1981 when, as a result of an accident, *some* 17 000 tons of fuel oil were discharged in cold weather conditions. The oil mixed with minor garbage blown by a gale wind down the Kurchki Canal, thus forming an asphalt-type substance which could not be collected by conventional means and transferred by pumps. The standard oil and debris skimmers however showed reasonable performance having collected up to 2 000 tons of pollutants. As the result of cleaning operations more than 9 000 tons of 53.5 % spilled oil was recovered which is considered to be a satisfactory result. A conslusion was drawn that there is a need to increase the stock of means, in particular those needed in massive quantities and the need to improve training programmes for response teams and port personell.

At present all oil ports of the USSR have been equipped with shore facilities for the reception of oily ballast from tankers. In the Baltic area all dry cargo ports are also equipped with the fixed or mobile reception facilities. Eight floating reception vessels provide for collection of bilge water from ships and subsequent transportation to the shore reception facilities. A new generation of the reception vessels will be launched in 1984 which will be equipped with a fine-cleaning oily-water separator, allowing treatment of the bilge waters and their discharge without restrictions. Availability of the above-listed technical means made it possible to abolish since January 1, 1983 fees for the use of reception facilities in all the USSR major ports in the Baltic Sea area (except Tallin) in order to minimize probability of the operational pollution in the coastal waters. In 1985 a first section of the new development of port of Tallin will become operative and this project envisages a comrehensive solution of all environment protection aspects.

All transport vessels of the USSR Ministry of Merchant Marine, in order to comply with requirements of MARPOL 73/78 and the Baltic Convention, are being equipped with oily-water separating, monitoring and control units. This programme with regard to the existing vessels is to be finalized by October 1986. At the same time the USSR Maritime Administration believes in principle that "prevention is better than cure" and in this respect made appropriate arrangements to prohibit any discharge of oil contaminated water from ships which operate solely within the Baltic Sea area. Under this scheme oily water is discharged into the shore reception facilities. To support the scheme "Regulations on Registration of Operations with oil, Oil Products and Other Substances Harmful to People and Marine Living Resources to be Carried Out on Ships" were made effective in USSR in 1983.

The organizations and enterprises of the Ministry of Merchant Marine are currently engaged in developing a Comprehensive Programme of preventing sea pollution from shipping for 1985-1990 which undoubtedly will cover environmental aspects of the Baltic Sea area.

AIRBORNE LOAD ON THE BALTIC SEA: A PRELIMINARY STUDY

Tuija Ruoho-Airola, Vuokko Karlsson and Antti Kulmala
Finnish Meteorological Institute
Finland

1. INTRODUCTION

A marine research expedition was made on the Baltic Sea during April-May 1983 in a joint Finnish-Soviet project for co-operation in air pollution research. The aim of the expedition was to obtain information on airborne load into the sea as well as to measure concentrations of gas phase, particulate and deposited components far away from source areas. The joint expedition also presented the opportunity to compare the measurement methods used by different institutes.

Experts from five institutes participated in the expedition. These were the Finnish Meteorological Institute, Technical Research Centre of Finland, the Institute for Applied Geophysics Gosgomgidromet, Moscow, the Institute of Physics, Vilnius and the Institute of Arctic and Antarctic Research,, Leningrad. The measurements were carried out on board a new research vessel Akademik Shuleykin, owned by the Leningrad institute above.

In this paper only the results of the Finnish institutes are discussed.

2. PROGRAMME

The route of the expedition is shown in Fig. 1. It covers fairly representatively the northern, central and southern parts of the Baltic Proper.

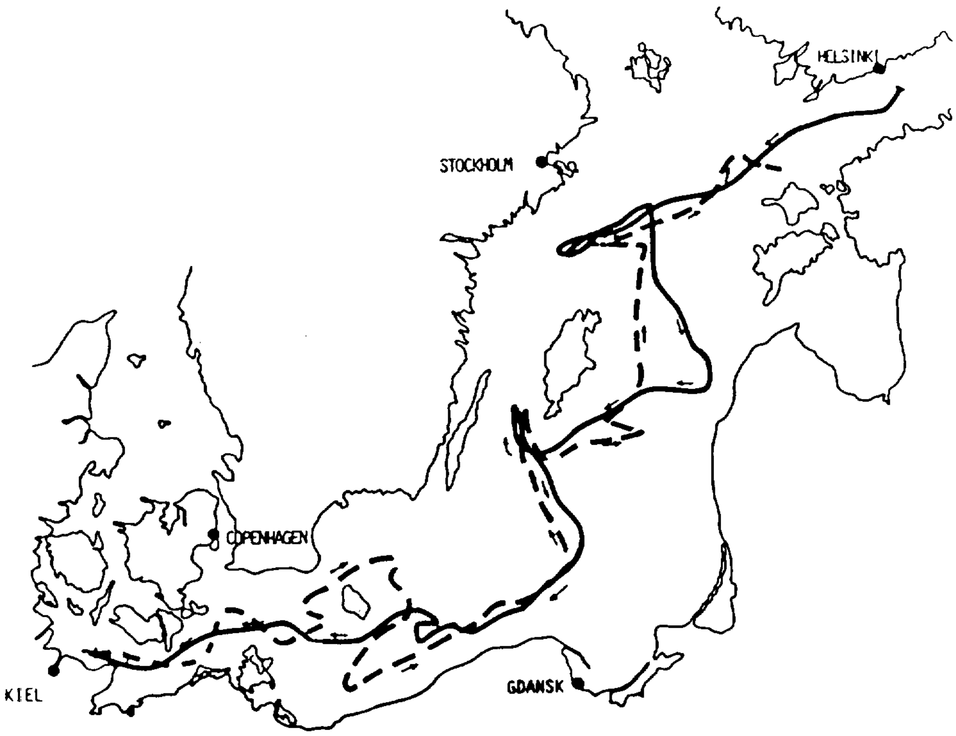

Fig. 1. Route of the expedition 10.4.-15.5.1983

The measurement programme consisted of daily samples of sulphur dioxide, ammonia, particulates in two fractions, benzene, toluene, m- and o-xylenes and wet deposition. Gas phase mercury was mainly sampled for 48 hours. Weekly samples were collected for PCB and PAH analysis in gas and particulate phase. Some microlayer samples were also taken for the same purpose. Weather was observed every 3 hours. Trajectories for air masses arriving in the route area were calculted.

3. METHODS

Sulphur dioxide was sampled in acidic hydrogen peroxide solution and analysed with the Thorin method (1). Gas phase mercury was sampled on gold plated quartz granules and analysed by cold AAS (2). Ammonia was sampled with a glass tube with an oxalic acid cover inside and analaysed in water solution by the indophenol blue method (3).

Particulates were sampled on two consecutive filters (Nucleopore polycarbonat 12 pm and Millipore AAWP 0.8 um) with the cut of a range of about 2.5 urn. The samples were analysed by PIXE at the Danish Air Pollution Laboratory, Risø for 25 elements between Al and Pb in the periodic table (4).

Aromatic hydrocarbons (benzene, toluene and xylenes) were absorbed on Tenax GC-filled cartridges (5). PCB and PAH compounds in particulate phase were sampled on glassfibre filter and gas phase on XAD-2. Aromatic hydrocarbons were analysed by gas chromatography. PCB and PAH compounds will be analysed by gas chromatography/mass spectrometry.

Wet deposition was sampled separately for metals and nutrients. An automatic regulator opened the sampling gauges during rain. The sampling devices were mounted on the highest deck of the vessel. The metal samples were preserved with strong perchloric acid, and all bottles were cooled until analysis. The deposition samples obtained were analysed for sulphate, nitrate, ammonium, lead and cadmium. The methods used were Thorin, Cd reduction, indophenol blue and AAS (1), respectively.

In order to avoid contamination of the samples by the vessel itself an automatic control device stopped the pumps and covered the deposition samples with a lid when the wind blew from the direction of the stack. The wind direction cut-off angle was 180^o.

4. MEASURED VALUES

4.1 GASEOUS COMPOUNDS

SO_2 concentration values are given in Fig. 2. The circles are drawn taking into consideration the sampling time along the route. The concentrations vary between 1 and 11 $\mu m/m^3$, the three highest values were measured near the southern coast of the Baltic Sea. Interesting enough, concentrations approaching 1 $\mu m/m^3$ were found in the **same area**.

Fig. 2. SO_2 concentration ***on*** the Baltic Sea Area April-May 1983.

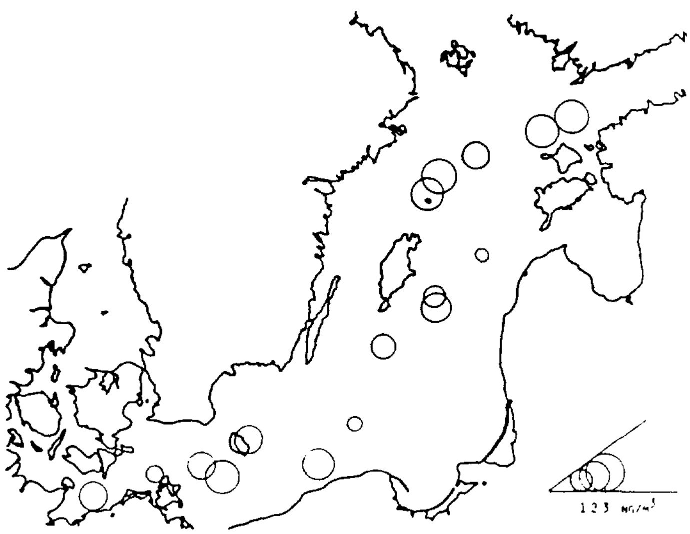

Fig. 3. Concentration on Hg on the Baltic Sea Area April-May 1983.

Concentrations of gas phase mercury did not vary greatly in different parts of the route (Fig. 3). Most of the results are two day mean values, ranging from 0.5 to 3 ng/m^3. Concentrations along the route are more homogenous than for the other elements. The reason for this is not yet known.

One answer might be that the sea itself plays an important role in the global circulation of mercury, sometimes acting as a source and sometimes as a recipient.

The sampling of gas phase ammonia posed some problems. When the relative humidity was high, the absorption surface was partly diluted and sampling efficiency decreased. The method will be improved in the near future. No results for ammonia are available from this expedition.

4.2 PARTICULATES

The concentration of sulphur in particles is shown in Fig. 4. In fine particles (<2.5 μm) it varies between 1 and 3 μg S/m^3, and in coarse particles (>2.5 μm) between 0 and 1 μg S/m^3. The highest values were obtained near Gotland and in the southern part of the Baltic.

Fig. 4. Concentration of sulphur in particles on the Baltic Sea Area April-May 1983; fine fraction.

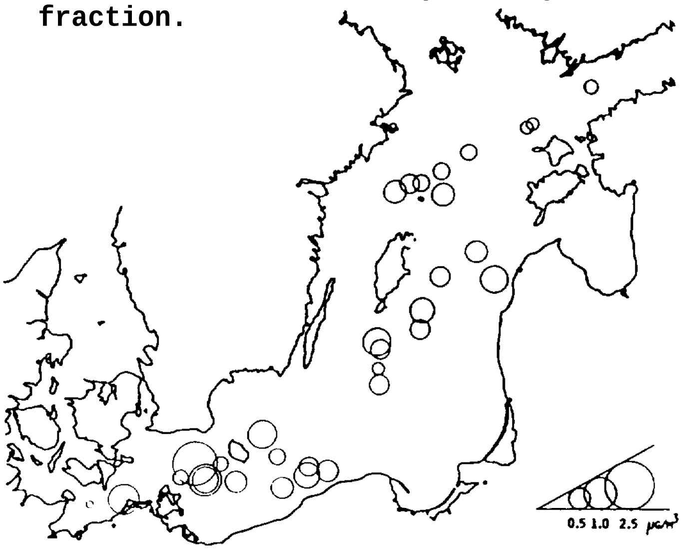

Fig. YA. Concentration of sulphur in particles on the Baltic Sea Area April-May 1983; coarse fraction.

The range of lead concentration was wide 3-60 ng/m^3 in fine particles and 1-20 ng/m^3 in coarse particles (Fig. 5). A major source is gasoline combustion, which contributes to 60 % of the total (6). Concentrations near the coast also seem to display higher values than in the open sea. The values recorded showed some inconsistency.

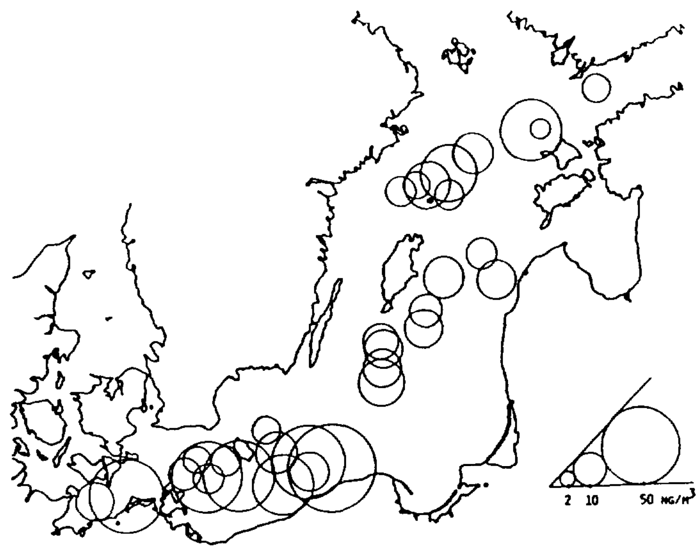

Fig. 5. Concentration of Pb in particles on the Baltic Sea Area April-May 1983; fine fraction.

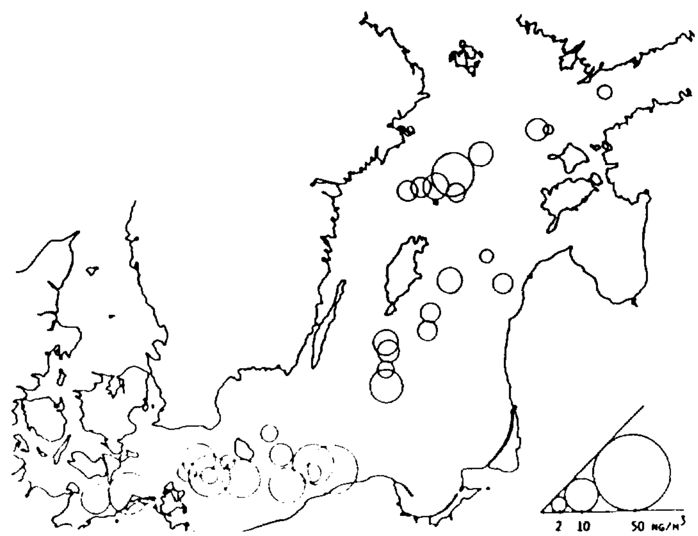

Fig. 5A. Concentration of Pb in particles on the Baltic Sea Area April-May 1983; coarse fraction.

Sr, Ti, V and Zn have been chosen as examples of metals in particulated matter from different sources. Sr and Ti are emitted mainly in coal combustion. V is linked with the use of oil and Zn with the use of both fuels and the metal industry (6). Fig. 6-9 show measured concentrations of these components. Sr is found only in coarse particles: concentrations vary between 1 and 8 ng/m^3, the highest value being in the southern Baltic. The Ti concentration is more uneven along the route, mostly found in coarse particles with a maximum value of 60 ng/m^3. The correlation 0.89 between Ti and Zr in coarse particles points out to common sources.

Fig. 6. Concentration of Sr on the Baltic Sea Area April-May 1983; coarse particles.

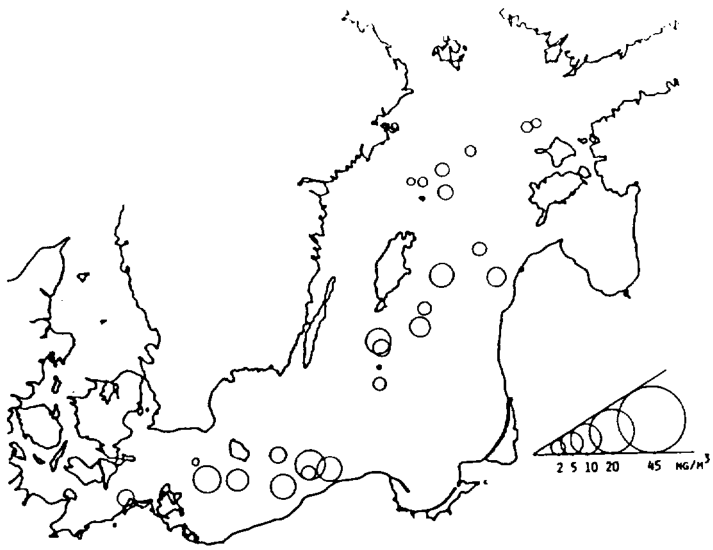

Fig. 7. Concentration of Ti in particles on the Baltic Sea Area April-May 1983; fine fraction.

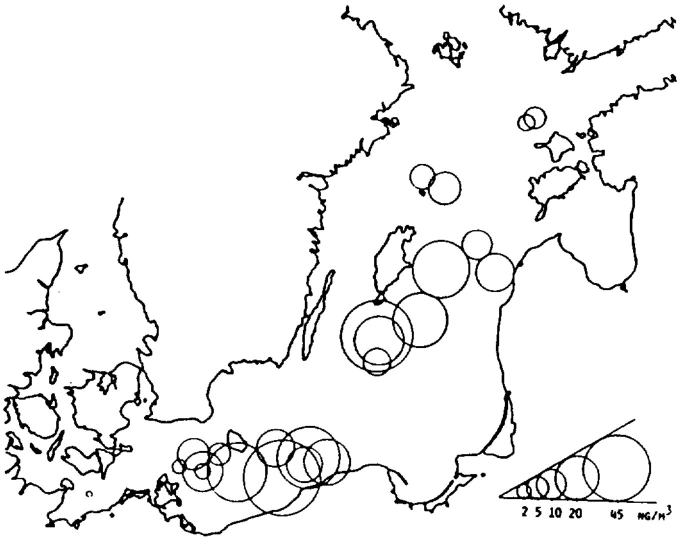

Fig. 7A. Concentration of Ti in particles on the Baltic Sea Area April-May 1983; coarse fraction.

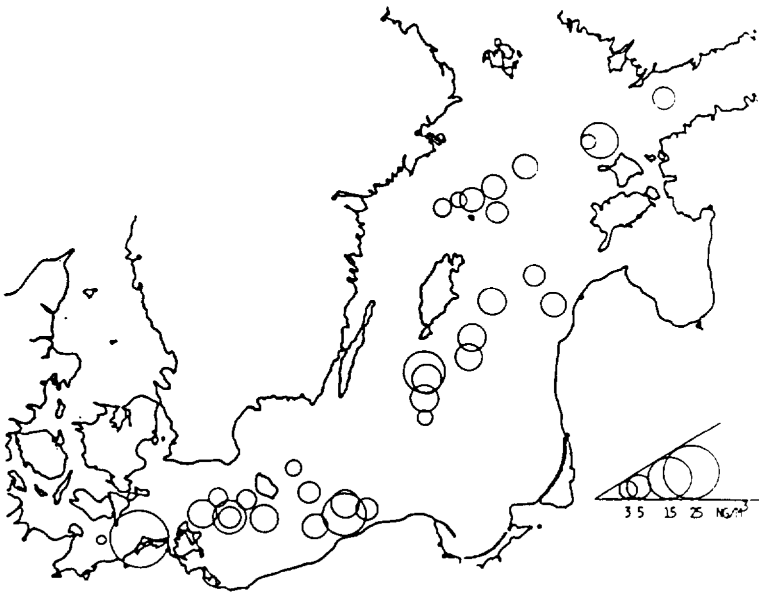

Fig. 8. Concentration of V on the Baltic Sea Area April-May 1983; fine particles.

Vanadium is mostly found in fine particles, with concentrations varying from 1 to 30 ng/m^3. High values occur in all three main areas of the route.

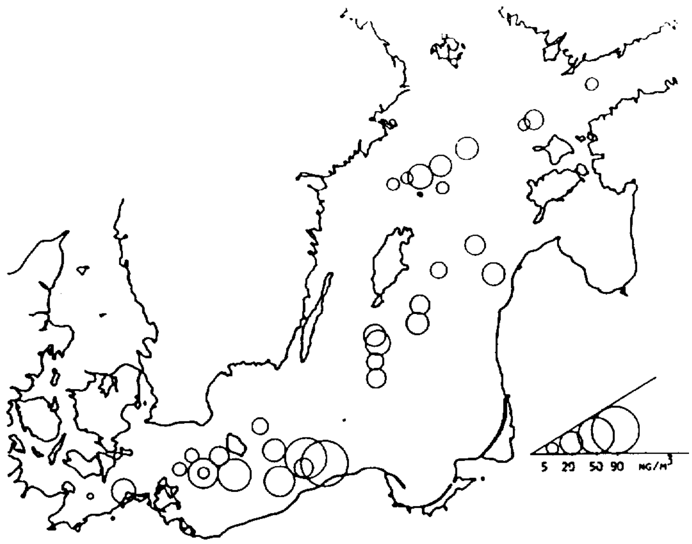

Fig. 9. Concentration of Zn in particles on the Baltic Sea Area April-May 1983; fine faction.

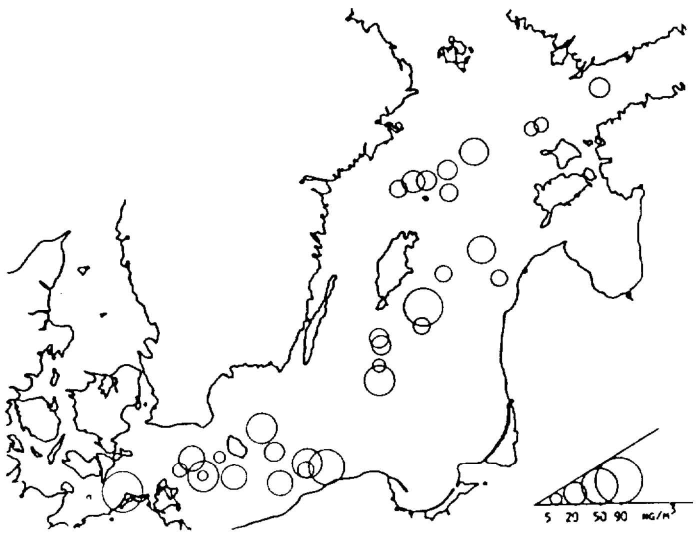

Fig. 9A. Concentration of Zn in particles on the Baltic Sea are April-May 1983; coarse fraction.

The maximum zinc concentrations are around 80 ng/m^3, both in fine and coarse particles. Zinc seems to be distributed alternately between fine and coarse paricles in different samples. One explanation to this might be its many diverse sources.

4.3 ORGANIC COMPOUNDS

On the global scale the main source of aromatic hydrocarbons is traffic, e.g. traffic emissions for benzene are 80-90 % of total emissions. According to a Finnish study exhaust gases contain from 100 to 350 mg/m^3 benzene, toluene and m- and o-xylene

The stack gas of the research vessel Akademik Shuleykin contained especially high portions of benzene and toluene. In other words, ships on the sea must also constitute a primary source of these compounds.

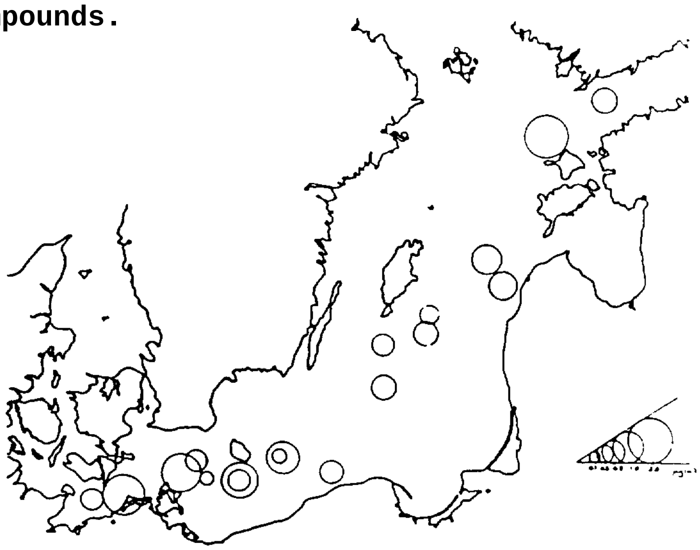

Fig. 10. Benzene concentrations on the Baltic Sea Area April-May 1983.

Fig. 11. Toluene concentrations on the Baltic Sea Area April-May 1983.

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Fig. 10, 11 and 12 seem to indicate that a minimum exists in the aromatic hydrocarbon concentrations in the central area of the Baltic Sea. This can be accounted for by the fact that in the central Baltic Sea gaseous hydrocarbon emissions caused by traffic are already well diluted, whereas in other parts of the Sea emission sources lie closer to the sampling location. In comparing Pb concentration in fine particles with those of benzene, toluene and m-xylene some coincidence between them can be expected in different parts of the Baltic (Fig. 5).

Fig. 12. M-xylene concentrations on the Baltic Sea Area April-May 1983.

4.4 WET DEPOSITION

Wet deposition measurements are difficult to perform in sea areas. When the amount of precipitation is low and a strong wind prevails together with aerodynamic flow around the sampling vessel sampling efficincy is further decreased. There is also the risk of contamination due to sea spray. A comparison of rain station measurements conducted on board a vessel with those performed on coastal or island stations does not reveal any clear differences. During the Finnish summer expeditions in 1981 and 1982 coastal stations in some shower situations had considerably higher rain levels than in the sea area. During the 1983 spring period only minor differences were observed.

During the six weeks of the expedition 7 samples for nutrient and 4 samples for metal analyses were collected: table 1 shows their concentrations. Only lead concentrations are stable, about 10 µg/l, in all samples. All other components vary greatly from sample to sample. The volume of wet deposition data is far too limited for any deposition calculations. A better method for measuring this part of the load remains to be developed.

Table 1. Wet deposition concentrations.

Sample number	Calculate precipitation, mm	SO_4 mg/l	NO_3-N mg/l	NH_4-N mg/l	Pb µg/l	Cd µg/l
2	0.2	1.4	0.0			
4	0.2	10.5	3.4	1.9		
8	0.2				16	
24	1.2	4.5	2.0	0.8	11	4
25	0.8	6.0	1.3	0.8		
30	1.1	22.5	2.2	5.2	12	40
32	4.0	5.1	0.7	0.7	8	4

5. AIR TRAJECTORIES

The Meteorological Synthetising Centre (MSC-West Oslo, EMEP/ECE) calculated 850 mb level trajectories for six fixed arrival points (EMEP stations) in the Baltic area. The trajectories regressed 96 hours in 4 hour steps and were available for 00 and 12 GMT (7, 8).

In analysing the origin and life history of each air sample those trajectories ending nearest the sampling route of the vessel were utilized.

Following up of the life history of air trajectories provided a chance to roughly classify the samples. In most cases the air flowed for considerable parts of its 4-day route over continental areas and reached sampling devices after only a few hours over the sea. Samples of this nature were classified as a continental type without regard to the source areas over which they had passed. Samples that flowed long periods over sea areas, and specifically those which were at least 12 hours over the Baltic Sea before reaching the sampling devices, were classified as sea type. An example of a sea type sample is illustrated in Fig. 13, which also elaborates on trajectory information and the link between trajectories and the ship route.

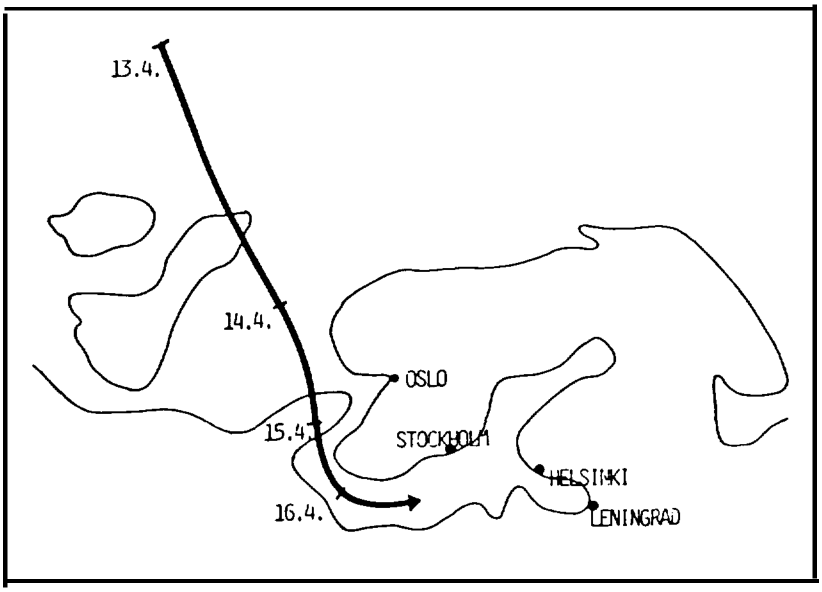

Fig. 13. 850 MB-trajectory arrival time April 17, 1983 at OOZ.

6. AREAL RESULTS

The ship was cruising on the Baltic Proper: Hence each sample represents a different location. This complicates the evaluation of mean values. However, as shown in figure 1, samples were taken in three major areas:

- western parts of the Gulf of Finland = northern Baltic Sea (P) (samples 1,2,3,4,30,31,32,33 and 34)
- area around Gotland = central Baltic Sea (K) (samples 5,6,7,8,25,26,27,28 and 29)
- area around Bornholm = southern Baltic Sea (E) (samples 9,10,11,12,13,15,16,17,18,20,21,22,23 and 24).

Assuming that changes in the emission patterns in Europe during the expedition period from April 10 to May 12 can be omitted and taking into account the variable weather in the Baltic spring season, mean values for the three major areas above have been arried at.

Fig. 14 parts l-6 give concentrations of sulphur (S), zinc (Zn), vanadine (V), lead (Pb), titanium (Ti) and strontium (Sr) in particles. Twosize categories, fine = F < 2.5 µm and coarse = C < 2,5 um, are also indicated. Parts 7 and 8 give sulphur dioxide (SO_2) and gas phase mercury (Hg) concentrations. Other indices are indicated in the small legend figure at bottom right.

Fig. 14 parts 1-4 and part 7 show a definite gradient from south to north. The difference between the central and northern parts is perhaps even clearer than expected. The gradient can not be detected in Fig. 14 parts 5-6, and for gas phase mercury it seems to be in an opposite direction. In the case of mercury the number of samples varied between 4 and 7 per area, whereas the other substances represent 9-13 samples per area.

The relationship of the content of fine and coarse particles differs from substance to substance. Sulphur and lead have a ratio 3:1 (fine:coarse), zinc has a ratio 1:1 and titanium 1:5. Zinc and titanium arouse the suspicion of contamination by the ships own engines, but vanadine (ratio > 10:1) points to quite the opposite tendency.

Self contamination can be excluded, but the possible effects of heavy ship traffic on the Baltic Sea are still evident. This is a reason that mostly the fine fraction of particle samples are taken with the aim to compare continental type and sea type air samples. In Fig. 14 parts l-5 and part 7 this comparison is seen as the difference in white and

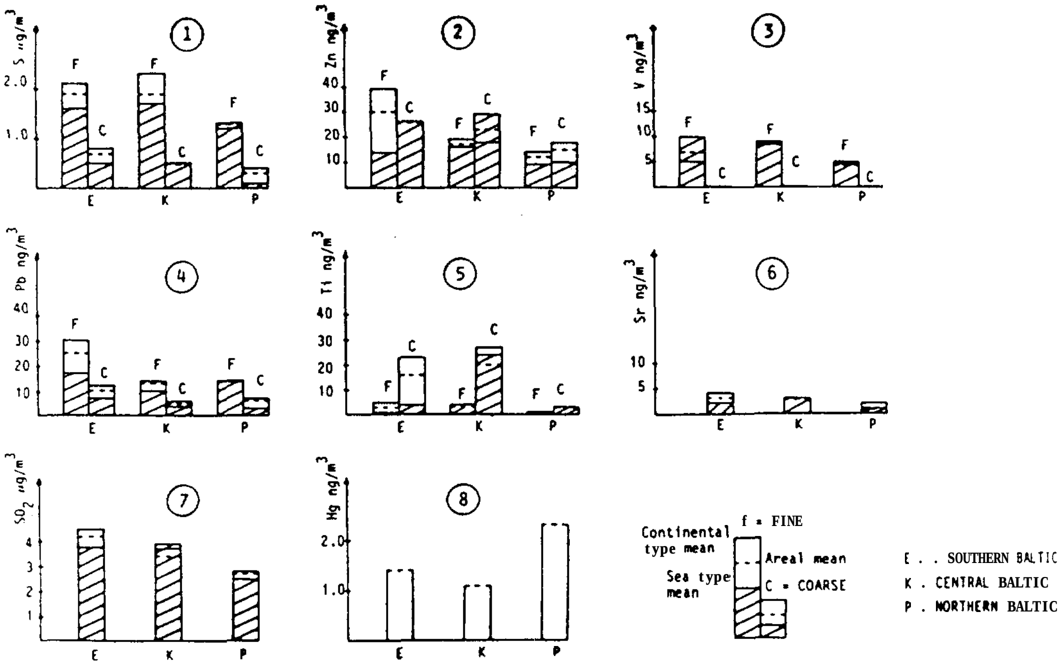

Fig. 14. Mean concentrations of substances presented in figures 2-9. Subfigures 1-6 particles, subfigures 7-8 gases.

shadowed column. For sulphur, zinc, lead, titanium and sulphur dioxide (gas), the relationship between continental and sea type samples varies from 3:1 to 5:4. Vanadine samples are an exception: in the sea type samples in each area there is at least one sample with a very high content of vanadine. A peak example is found in sample 20: the fine fraction of the sample contained 28 ng/m^3 of vanadine. If this sample is excluded, the mean value of sea type samples in the southern Baltic area is 5 ng/m^3 instead of 10 ng/m^3.

A similar area1 and origin typed compilation of mean concentrations of benzene, toluene and xylenes is reproduced in Table 2. These concentrations were not greatly dependent on the origin (continental/sea type) of air masses. However, a weak minimum in the concentrations of all measured substances can be observed in the central Baltic area.

Table 2. Mean concentrations of benzene, toluene, m- and o-xylene in the Baltic Sea **area in April-May 1983.**

BALTIC SEA	BENZENE Sea	(µg/m³) Land	TOLUENE Sea	(µg/m³) Land	m-XYLENE Sea	(µg/m³) Land	o-XYLENE Sea	(µg/m³) Land
NORTH	1.5	x)	3.5	x)	0.3	x)	0.1	x)
CENTRAL	0.6	0.7	1.0	1.2	0.07	0.07	0.04	0.01
SOUTH	1.2	0.6	2.3	2.5	0.7	0.3	0.05	0.02

x) no samples

The results of such a comparison do not permit any concrete conclusions to be drawn on the effect of a cold sea surface on the deposition rate of fine scale particles. However, a minimum 12 hr flow over a sea area seems to bring about a 20-70 % decay in concentrations when compared with samples with very short sea history.

7. LINKS TO OTHER MEASUREMENTS

In order to align the spring 1983 results with other measurements, two types of comparisons were made.

First, SO_2 samples 1 to 4 and 30 to 34 were compared with SO_2 concentrations reported by the Finnish EMEP station at Utö. Table 3 lists some local and semi-local effects in the Utö values, speaking in favour of sea stations.

Table 3. SO2 concentrations at the EMEP station at Utö and in ship samples from the same area. SO_2 µg/m^3.

Date	Utö	Vessel
10.4.	2	2
11.4.	14	1
12.4.	6	5
13.4.	6	4
10.5.	12	1
11.5.	8	1
12.5.	8	3
13.5.	2	3
14.5.	4	4

Secondly, a comparison between the results of the present expedition and those of the 1981 and 1982 expeditions was made.

Fig. 15 shows the mean values of SO_2 and S in particles obtained during these expeditions. In the first expedition measurements were made in the northern part of Baltic Sea and in the Gulf of Bothnia and the Gulf of Finland. The route of the second expedition covered the Gulf of Bothnia.

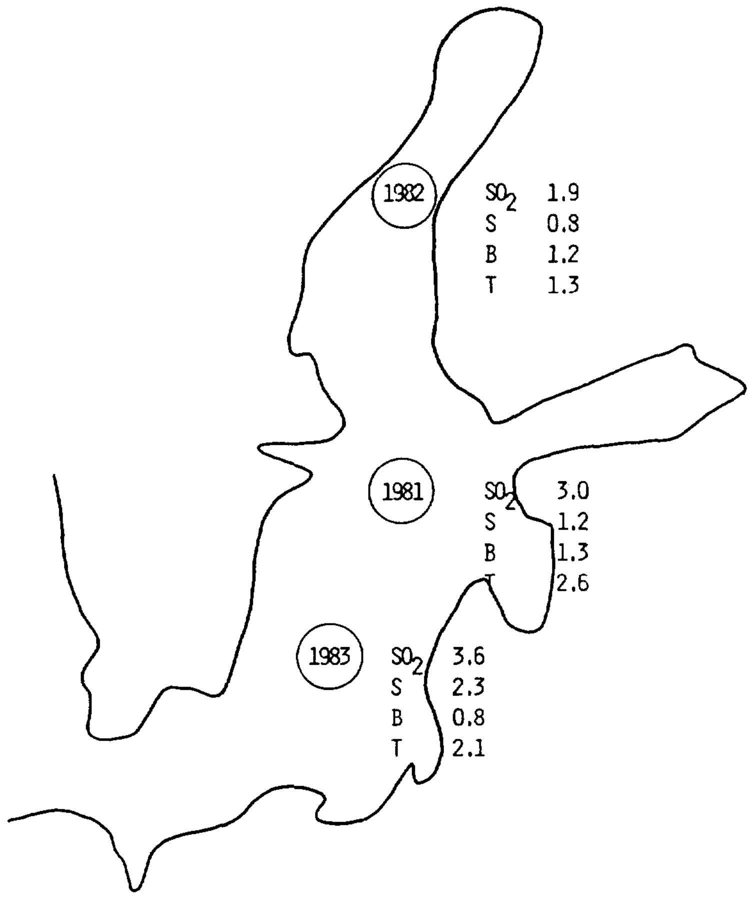

Fig. 15. Mean concentrations for SO_2, S in particles, bentzene (B) and toluene (T) from expeditions in the years 1981 and 1983. The unit is $\mu g/m^3$.

Caution is needed in making comparisons of this kind (different years, vessels, periods), but, all limitations considered, a clear gradient from south to north is apparent.

Organic substances, once again, seem to show a different distribution. No distinct gradients are apparent from one area to the next, but if this is the case, they are opposite to those for SO2 and S.

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LIST OF PARTICIPANTS

DENMARK	Ms. Gunver Bennekou
	Mr. Erik Bundgaard
	Mr. Anders Lynggaard-Jensen
FINLAND	Mr. Aaro Haverinen
	Mr. Bror Johansson
	Mr. Aarno Kavonius
	Mr. Risto Kuusisto
	Mr. Julius Lassig
	Ms. Terttu Melvasalo
	Prof. Seppo Mustonen
	Dr. Olli Ojala
	Mr. Juhani Orivuori
	Dr. Matti Perttilä
	Mr. Juhani Puolanne
	Mr. Seppo Ruonala
	Mr. Runo Savisaari
	Mr. Antti Soikkeli
	Mr. Esa Tommila
	Dr. Matti Valve
GERMAN DEMOCRATIC REPUBLIC	Mr. Klaus Winkel
FEDERAL REPUBLIC OF GERMANY	Dr. Bernd Bayer
	Mr. Gunther Leymann

POLISH PEOPLE'S REPUBLIC	Mr. Zdzisław Jarmołowicz
SWEDEN	Mr. Emil Haeger
	Mr. Johan Hartwig
	Mr. Bertil Hawerman
	Mr. Åke Liedberg
	Mr. Jonas Norrman
	Mr. Lars Thorell
UNION OF SOVIET SOCIALIST REPUBLICS	Dr. Vladimir Gorbaschov
	Dr. Ain Lääne
	Mr. Mihail Mayorov
	Dr. Leonid Soumin
	Prof. Harald Velner

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