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Cost Effective Measures to Minimise Nutrient Pollution
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Methodology for selecting cost-effective measures to tackle nutrient pollution from the agricultural, municipal and industrial sectors in the Black Sea

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1 Introduction

1.1 Aims and relevance for the Black Sea region

The key aim of the present project is to introduce national policy markers in the Black Sea countries to basic cost-effectiveness assessment approaches as well as to identify the data required to undertake such assessment of measures for controlling individual sources of nutrient pollution.

On the one hand, the project results will contribute to the formulation of strategies for nutrient pollution reduction from land-based activities, which is key to achieving better protection of ecosystems of the Black Sea and its coastal zones. On the other hand, the importance of the project lies in moving Black Sea countries towards water management approaches, which live up to the requirements of the EU Water Framework Directive (WFD). The EU WFD clearly requires cost-effectiveness analysis of measures for pollution control and water use.

Cost-effectiveness analysis in the Black Sea region will help to identify the economically most efficient way to fulfil pre-determined objectives of nutrient pollution reduction. In economics, cost-effectiveness refers to the comparison of the relative expenditure (costs) and outcomes (effects) associated with two or more courses of action. Cost-effectiveness analysis can be used as a tool for identifying and selecting the most cost-effective combination from a range of alternative measures.

In this context, the purpose of this report is to present a sound and practical methodology for assessing cost-effectiveness of measures that can be applied on a regional level, such as that of the Black Sea countries. The approach presented is practical and pragmatic rather than academic, to take account of the realities of limited resources, lack of full data availability and the need to consider several uncertainties.

1.2 Structure of report

Section 2 of this report presents a general practical methodology for selecting cost-effective measures under the Water Framework Directive (WFD). The approach is based on previous work of different European experts and researchers for implementing the WFD and is made suitable for application on the regional level.

As defined in the inception phase of this project, the theoretical and methodological background work will be followed by practical work in case studies dealing with the reduction of nutrient pollution in each of the following sectors: agriculture, municipal and industry.

The intention is to use the general methodological considerations of section 2 as far as possible as a conceptual guide in the more practical case study work.

In this context, section 3 outlines specific methodological issues and assumptions relevant to each of the case study sectors concerned. This also involves the identification of minimum data requirements that have to be fulfilled to apply the methodology for assessing effectiveness and costs. The identification of data needs for the Black Sea region will be refined through the planned case-study work of the project.

2 General methodological issues for cost-effectiveness analysis under the WFD

Under the WFD, cost-effectiveness analysis is to be used for assessing the relative performance of potential measures for achieving the environmental objectives of the WFD. According to the WATECO guidance [Common Implementation Strategy Working Group 2 (WATECO) 2002] of the WFD Common Implementation Strategy (CIS), the information should be collected for individual measures or units of measures, thus at a spatial or disaggregated scale depending on the scale at which the measure is applied or implemented.


The measures to be considered within this project are both technical measures that can be locally applied as well as instruments, such as N-taxes, applied on a national/basin wide level. Both types of measures are considered in the present methodology.

The following sections discuss in more detail the estimation of effectiveness and of costs of potential measures as well as the important issues of political enforceability of measures and methodological uncertainties, based largely on Dworak (to be published). It represents current discussions on the EU level under the implementation process of the Water Framework Directive. The methodology starts with a rather broad approach considering the different aspects set out in the Directive. As not all Black Sea countries are part of the EU and the situations are different in all countries this general approach is turned into a more pragmatic approach.

2.1 What does cost effective mean?

Public decision making requires estimating the effects of policy interventions on ecosystems or on society. Policy evaluation can be considered as the systematic assessment of the effectiveness, efficiency, implementation, or impacts of public policies for further improvement. As the development of our society is strongly measured against economic development, economic evaluation has become a central tool to value the effects of policy making and is thus broadly used for policy evaluation. Cost-effectiveness analysis (CEA) is one of the main economic tools, which can be used to help policy makers to determine the best policy options.

Cost-effectiveness analysis (CEA) identifies the economically most efficient way to fulfil a pre-determined objective (quantified in physical terms). It is a tool for identifying and selecting from a range of alternative option with the same objectives [O'Connor, M.; et al; 1999] but only when all the resource implications associated with each alternative – both direct and indirect - are included in the analysis.

	<p>Cost effectiveness is usually displayed as the ratio of the cost of an intervention to a relevant measure of its effect. However this single ratio approach is not always sufficient in a decision making process as a lot of additional information needed is lost. Therefore a set of common attributes to assess cost effectiveness can be helpful as it allows displaying more information (e.g. information on the political acceptance). Furthermore, numerous uncertainties are related to the cost calculation and to the estimation of the effectiveness and can be addressed by such attributes.</p> <p>Further when comparing different measures it is important that the objectives of the measure are the same. For example, each sector (agriculture, industry or urban waste water) is polluting the environment in different ways. There is no measure which can address all problems at the same time. Different measures (e.g. i) buffer strips; ii) waste water treatment), with different objectives (e.g. i) reduce pollution from agriculture; ii) reduce pollution from urban sources) are needed. A ranking of measures among their cost-effectiveness (expressed as a single value) without considering the different objectives would not be very useful in a decision making process. The selection of measures has first to follow the problem and then the costs!</p>
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2.2 Estimation of effectiveness of potential measures

In order to consider information on the larger context and to clearly outline all relevant uncertainties, a qualitative description should be included when assessing effectiveness. The following sections deal with various important aspects relevant to the estimation of effectiveness.

2.2.1 Types of effects

A water management measure can have various types of effects (water and non-water related ones). These effects should be structured in order to attach the related costs to each type of effect, to estimate how each measure will contribute to achieving a given target or to justify why a measure will not be applied. Three types of effects can be distinguished [Longdong, G , et al 2006] and for each the magnitude of the effect should be described:

- Primary effects: The selection of a measure is based on the way or the extent to which this measure could contribute to the achievement of the set environmental objective. As environmental objectives are defined by parameters, the primary parameters addressed should be indicated here. The key question behind the assessment of primary effects is: To which extent can the chosen measure contribute to closing the gap between the current/predicted status and good water status?
- Water-related side effects: Several measures have additional water-related effects beside the primary effects. For example, the primary effect of a buffer strip is to reduce nitrogen pollution. However the buffer strip will also have a positive effect on trapping sediment from runoff and at reducing channel erosion which has to be considered as a water-related side effect (Wenger, S. 1999). It is important to outline these side effects in order to estimate the synergistic or antagonistic interactions with other measures. Further, a measure that positively addresses more than one pressure at the same time may prove more cost-effective than a combination of several measures tackling only one pressure each.
- Non-water-related side effects are all other effects which are not directly related to water such as social effects, effects on other environmental aspects or income.

Taking again the example of the buffer strip, non-water-related effects could be loss in income of the farmer due to a smaller field size. In order to allow a clear cost calculation, the non-water-related side effects should be split into (i) effects on other economic sectors and (ii) non-water environmental effects (see section 2.3.2.1). This information is also needed when discussing political enforceability. Measures with a broad set of negative non-water-related side effects might be difficult to enforce, while measures with high benefits, creating win-win solutions, might be more easily enforced (see section 2.4).

2.2.2 Characteristics of effects

It is also important to consider following characteristics of effects when estimating measure effectiveness:

- Geographical scale of the effect: Different types of measures may have effects on different geographical scales. For example, a waste water treatment plant affects one water body, while a ban of a certain priority substance might affect a whole river basin including hundreds or thousands of water bodies.

In the context of this specific project, there must be a distinction made between the effects of measures on a local water body and the effects on the Black Sea. In fact, the impact of measures on nutrient loads in the Black Sea is a function of nutrient transport, leaching/runoff and retention. There is considerable uncertainty in quantifying the transport of nutrients from source to the coast. For all emission sources not discharging directly into the Sea, this implies the need to understand the functioning of different types of ecosystems with respect to the transformation and transport of nutrients.

Some measures will be more effective in some locations than others, e.g. buffer strips trap more particulate matter (from soil erosion), including particulate nutrients, notably P, when located on gently sloping land than they do in steeply sloping mountainous regions.

- Time scale required for measures to become effective: Such a description should include the time that is needed to implement the measure and, once a measure is implemented, the time needed for an effect to be measured in the water. At least a distinction between short, medium and long term effects of measures should be made:
 - Short-term: The measures will take effect quickly and well within the next 3 years.
 - Medium-term: The effect will occur slowly or with a time delay, but still within the next 5 years.
 - Long-term: The effect will essentially come into play after 5 years.

Such a distinction is especially necessary for those countries which are part of the EU and have to comply with the WFD by 2015.

- Durability of an effect: The effectiveness of a measure also depends on its durability. In most cases the effect will last for the whole lifetime of a measure if it is properly maintained¹. If such maintenance is difficult to guarantee, the risk of the measure

¹ The term “maintenance” does not only refer to technical maintenance here. It also includes all activities that are needed to guarantee the full performance of a measure, such as training, information campaigns, technical performance checks, replacement of damaged equipment, etc.

being ineffective will be higher. While the cost for such maintenance will be considered in the cost assessment, it is important to consider the key factors which could reduce the durability of a measure. Measures that are put into place once and need a relatively low level of maintenance might be preferred against measures which need frequent interventions.

- **Adaptability** of a measure is important as it allows the optimisation of a measure or increasing its effect as soon as new knowledge regarding the effectiveness becomes available. For example, if new techniques in waste water treatment become available it may be possible to integrate these in existing treatment plants, without having to replace the whole measure.

2.2.3 Certainty of effects

The certainty of an effect cannot always be guaranteed and uncertainties have to be considered. In order to deal with uncertainties, the upper and lower boundaries for each of the effect characteristics discussed above should be considered. Upper and lower boundaries can be expressed in absolute values (e.g. from 4mg/l to 10 mg/l reduction) or qualitatively (e.g. most likely the effect will occur in the short term). In order to be as transparent as possible, references (e.g. pilot studies, modelling, empirical calculations) for the setting of boundaries should be made. If the boundaries are set due to expert judgement this should be mentioned.

Uncertainties entering the cost-effectiveness analysis due to the issue of political enforceability should also be addressed (see section 2.4).

2.2.4 “Being effective does not mean solving a problem”

One of the biggest challenges when looking only at the effectiveness of measures is that it does not tell us anything about whether a target is likely to be achieved or not. A measure might have a high effectiveness ratio but that does not mean that it solves the water problem at hand fully. Additional measures might be needed to achieve the set threshold value. In order to make different measures comparable, the “**attainment ratio**” of the environmental objective and the effectiveness ratio of a measure should be displayed. The attainment ratio is a function of the effectiveness ratio and defines the extent to which a measure contributes to reaching the environmental target. As the rate depends on distance to/from the target, points of changes should be identified.

One could question why there is a need to display both values if the attainment ratio is calculated on the basis of the effectiveness ratio. In order to answer this question the following examples should be considered:

Nr.	Pressure	Environmental objective	Measure	Effectiveness rate of the measure	Effect in the WB	Attainment ratio of the environmental objective
1	NO ₃ - N pollution	Max concentration of 5 mg/l	Treatment plant	Up to 90 %	Reduction of N in the WB from x mg/l to 10 mg/l.	50%

Table 1: Examples for the effectiveness and attainment ratios of measures

The distinction of the effectiveness and the attainment ratio is necessary as the attainment ratio might vary among different water bodies in cases of a fixed effectiveness rate of a measure. For example a treatment plant with an effectiveness rate of 90% will have different

effects on a small water body and a large water body. While in a small water body the attainment ratio may be 100%, in a large water body it might reach only 10%, so additional measures would be needed.

2.3 Estimation of costs of potential measures

2.3.1 Costs to be considered in a full cost assessment

The assessment of the full cost of a measure requires the identification of different types of costs and their aggregation. The WFD does not refer to which costs should be considered in the selection of the most cost-effective combination of measures (Art 11). However it is important to clearly define the costs considered in CEA in order to make the measures considered comparable. A CEA requires the estimation of at least the direct costs of an intervention but in some cases also the indirect costs resulting from an intervention. The direct benefit (e.g. improvement of the water status) is not monetised in a CEA as it usually would be in a cost/benefit analysis. As mentioned before a CEA only identifies the economically most efficient way to fulfil a pre-determined objective (direct benefit that is achieved by the water related effects) (see also section 2.1). Each type of costs are defined in the table below:

Table 2: Cost types of a measure to be considered in a full cost assessment

Direct costs	Indirect costs and benefits
Cost to achieve the intervention/measure	Costs/Benefits resulting from the intervention /measure
Financial costs are the costs of providing and administering a measure.	Wider economic costs/benefits are the costs/benefits that occur in any other economic sector.
Environmental costs consist of the environmental damage costs of an ecosystem degradation and depletion caused to set up the intervention.	Environmental costs consist of the environmental damage costs of a non water ecosystem degradation and depletion caused by the intervention ² . Environmental benefits include non water related benefits to the environment such a creation of bird habitats or improved soil quality
Resource costs can be defined as the opportunity costs of the ecosystem destroyed to set up the intervention as a scarce resource in a particular way in time and space. They arise as a result of an inefficient use of the ecosystem because an alternative use would generate a higher net economic value.	Resource costs are the opportunity costs of the ecosystem destroyed by the intervention as a scarce resource in a particular way in time and space. They arise as a result of an inefficient use of the ecosystem because an alternative use would generate a higher net economic value.

In order to estimate the full costs of a measure all the direct cost have to be added as well as all indirect costs and benefits. For each type of costs (direct or indirect ones), it is necessary to clearly identify the cost factors included in the calculation. This is needed, on the one hand, for the sake of transparency and on the other, to avoid double counting. For example,

² If the environmental costs and therewith the environmental damage would be to high, it can be assumed, that the measure will not applied.

if a measure requires taking off a piece of land from agricultural production in order to set up a buffer strip, there are two ways of calculating the relevant costs: a) as part of the indirect wider economic costs (income forgone due to loss of production area) or b) as part of the direct financial cost for operation (compensation payments).

Considering the frequent lack of data available and/or the fact that methods of monetising these data are insufficient or do not deliver true results, cost quantification can easily become a difficult exercise [Freemann III, A., M 1994]. Additionally, the assessment of other cost categories (other than financial costs) is not very wide spread in water management and can become a very time and resource consuming issue leading to more costs than the measure itself.

2.3.2 From full cost assessment to a practical approach

As mentioned before a full cost assessment is a difficult task, which requires a lot of effort and resources to collect the relevant information. This can easily lead to a “no action” approach on the political level using data gaps as an excuse for not taking the initiative. In order to avoid such a situation and considering the specific situation in the Black Sea region, only the direct financial costs and the wider economic costs should be calculated. Environmental and resource costs will not be further addressed by this study/ however, at a later stage they could become an issue.

In the following section a theoretical concept is presented that can provide the basis for further more detailed calculations for specific measures in the three sectors addressed by this study. From this general approach a more detailed framework has been developed for each of the three sectors (see further below). However this theoretical concept can also be used for calculating cost effectiveness of measures addressing other pressures than nutrients.

2.3.2.1 Direct financial costs

While for the waste water sector and industry sector several detailed guidelines or approaches (see section 3.2.3 and 3.3.3) exist, less information can be found for technical measures in the agricultural sector (e.g. crop or livestock-based measures) and instruments. Nevertheless the framework used for calculating direct financial costs is essentially the same.

Table 3 gives an overview of possible elements of financial costs associated with a technical measure or an instrument.

Table 3: Different elements of financial costs of measures and instruments

Measures ³	Instruments ⁴
Investment expenditure	Rule making stage
1. Project development expenditure <ul style="list-style-type: none"> • project definition, design, and planning • contractor selection costs and contractor fees 2. Installation Expenditure <ul style="list-style-type: none"> • the purchase of land • contaminated land clean-up costs • general site preparation • buildings and civil works to prepare the site (labour costs) • clean up expenditure (e.g. renaturation) 3. Pressure Reduction Expenditure <ul style="list-style-type: none"> • engineering, construction works (labour cost) • pollution control devices (e.g. waste water treatment plant, seeds or plants in case of a buffer strip) • hydro-morphological construction work (e.g. fish ladder) • performance testing • start-up 4. Administrative costs <ul style="list-style-type: none"> • field expenses • costs to for compliance check and auditing at administrative level 5. Financing costs 6. Costs for credit acquisition	1. Cost for writing the rules/legal texts/ funding programs/ information campaigns 2. Cost for discussions with stakeholders 3. Legal formalisation costs
Annual Operating and Maintenance Costs	Implementation stage
7. Energy /Fuel Costs 8. Materials for operation and service 9. Labour Costs related to operation and service 10. Fixed Operating/ Maintenance Costs <ul style="list-style-type: none"> • insurance premiums • license fees • external audits • costs for rental (e.g. if land is not owned) • compensatory payments (e.g. to farmers) 11. Administrative costs <ul style="list-style-type: none"> • annual costs to for compliance check and auditing at administrative level 12. Financing costs 13. Annual interests	4. Costs for administrative implementation <ul style="list-style-type: none"> • Staff costs • training of staff • infrastructure costs (e.g. Information technology, monitoring devices for control) 5. Costs for awareness campaigns 6. Abatement costs
End of Life costs	Enforcement stage
14. Costs for recycling or disposal 15. Decommissioning cost?	7. Costs for administration <ul style="list-style-type: none"> • Labour Costs related to administration • training of staff • maintenance of infrastructure (e.g. Information technology, monitoring devices for control)

³ Based on European Environmental Agency (1999): Guidelines for defining and documentation data on costs of possible environmental protection measures, Technical Report 27

⁴ Based on: Rousseau, S.; Proost, S. (2002): The Cost Effectiveness of Environmental Policy Instruments in the Presence of Imperfect Compliance, Working paper series n°2002-04

The calculations of direct costs of measures may relate to different time periods. For instance, the costs for investment expenditure might relate to 2010, while end of life costs might relate to 2015. The direct comparison of these costs would be misleading as the general price level and the relative prices of goods and services change over time due to inflation. Therefore, it is important to include the issue of inflation in the calculation of costs.

An additional important aspect is to outline the extent to which other cost categories are internalised in the calculation of direct financial costs. In order to explain this better, the following examples are given:

- 1) Internalisation of wider economic cost: For example, setting up a buffer strip requires removing an area of land from agricultural production. If the farmer gets a certain amount of compensation payments this would mean that the wider economic effect (loss of production) is internalised under annual operating and maintenance costs.
- 2) Internalisation of direct environmental cost: For example, in order to build a sewer system, a Natura 2000 area has to be crossed requiring the use of heavy machines. In order to compensate for the environmental damage caused, the managers of the sewer system are forced to set up a compensation area. Alternatively, lighter, smaller-scale machinery could be used requiring greater time and costs for project completion, e.g. for increased manual labour requirements.
- 3) Internalisation of indirect environmental cost: For example, a tax linked to the combustion of sewage sludge would be a way of internalising costs for additional air pollution.

In reality, such a full cost assessment, considering all direct and indirect costs, is highly unlikely to be achieved, due to lack of data or lack of sufficient methodologies to assess the different types of costs. This makes different measures hard to compare from a cost perspective⁵. In any case, it is recommended to document the grades of internalising costs other than direct financial costs in the calculations, and to use this information in the discussion process with stakeholders.

A more detailed description of how direct financial costs are calculated is given in the sector assessments (sections 3.1-3.3).

2.3.3 Wider economic costs and benefits

Wider economic costs and benefits relate to the non-water-related side-effects of measures, considering effects on other economic sectors. For example, wider economic costs would be relevant if a measure changed the price of particular goods significantly (e.g. the price of animal feed could increase because of new fertiliser rules, leading to a doubling of the price of meat) or has an impact on the market in which goods are handled (e.g. the production of farmers is reduced significantly because of a ban of certain pesticides). Such wider economic costs might be permanent or temporary, and are often difficult to estimate. **It is recommended that the relative importance of wider economic costs in relation to an intervention's direct costs is assessed first, in order to decide whether the indirect costs are likely to be important for the analysis.**

In order to achieve sufficient results a pragmatic approach is proposed. Using the information of the geographical scale of the effect of a measure as a starting point the following screening should be carried out

⁵ Things become even more difficult as the effectiveness of the measures might also be different.

1. Would a production activity have to cease as a result of applying the measure? How is this related to the loss of jobs and how is such a loss distributed along the production chain (e.g. primary produces, processing, retailers)?
2. Would the application of the measure stimulate a change in production activity?
3. Would the prices of a product increase as a result of applying the measure? If yes, what is the relation between the costs occurred due to the measure and the other production costs? If the production costs related to the measure would lead to an significant increase of the total production cost, a more detailed assessment of the wider economic costs might be needed.
4. Will the result be the same if the measure is applied several times in the river basin? This is important to consider as the aggregated wider economic effects and costs of single local measures applied several times in a country could become significant even if the wider economic impacts of the single measure applied only once is not considered as significant under questions 1-3.

When answering the above mentioned questions, the answers should be documented in order to achieve transparency and acceptance among the public. The documentation should at least display the non-water-related effect and if possible the related cost (qualitative or quantitative) and the stakeholder(s) that would have to bear the cost. Table 4 shows examples of a possible way of documentation.

Table 4: Documentation of wider economic effects and costs

Type of measure	Wider economic effect	Wider economic costs	Stakeholder affected	Duration of effect
Ban	Higher cost for developing a substitute	Higher prices of a product	General public	Temporary
Limitation of fertiliser input in agriculture	Less production in agriculture	Higher prices of a agricultural products	Farmers General public	Continuous

If the answers to the above mentioned questions are mostly positive, indicating that the non-water-related effects result in significant wider economic costs, a more in-depth assessment should be carried out in order to better quantify these costs⁶.

2.3.4 Role of transfer payments

An important, but sometimes difficult, problem in cost estimation is to distinguish between real costs and transfer payments. Transfer payments are payments of money by the government to an individual or a private company that does not form part of an exchange but rather represents a gift without anything being received or required in return. Examples of transfer payments include grants, welfare checks, and social security benefits (e.g. direct agricultural payments). Such transfer payments might influence the real costs of products as they have a disturbing effect on the market. While transfers should not be included in the estimates of the benefits and costs of a measure, they may be important for describing the distributional effects of a regulation. Transfer payments may change the distribution of income or wealth (wider economic cost and benefits), but do not give rise to direct economic

⁶ For example see: Firm Crichton Roberts Ltd, Graduate School of Environmental Studies at the University of Strathclyde (2000); or Centre for International Economics (2004)

costs [Frisman, L.; Rosenheck, R. 1996]. Therefore these payments should be recorded and tracked.

2.3.5 Need for discounting

In order to compare the costs of different measures, it is also important that the time horizons in which costs are considered are the same. On the one hand, the lifetime of measures can be different and, on the other hand, the costs of a measure may occur differently over time. In order to carry out a CEA, it is required that all future costs are converted into comparable units of value. In other words, it is necessary to calculate the discounted costs in order to achieve comparability between measures. Discounting is a mechanism whereby costs (and benefits) that accrue at different points in time are weighted to facilitate such a comparison. The two main reasons for discounting are:

- The productivity of capital rationale, which states that the future should be discounted on a discount rate based on the opportunity cost of capital.
- The time performance rationale, which states that humans value the present more than the future. This is based on the fact that people prefer the benefits now as opposed to later.

In order to carry out the discounting, it is important to agree on common discount rates and on common time horizons for the lifetime of a measure.

In the case of direct costs, common discount rates⁷ and detailed rules for calculating costs exist for technical measures such as waste water treatment, technical flow regulation measures and flood protection. Such rules are missing for technical measures in the area of agricultural production and instruments. However, even if the different elements of cost within each type of measure vary (see for example

⁷ In most cases are set by the government for each specific sector.

Table 3) the principles for calculation are the same.

2.3.6 Uncertainties in cost calculation

Uncertainties related to cost calculation are different for each type of measure and for each type of cost and can result from obvious factors (such as time or inflation), insufficient data or from the methodology applied to estimate costs. It is important to clarify (also for public information purposes), that cost calculations will always be estimations.

In order to reflect uncertainties, a sensitivity analysis should be conducted. Sensitivity analysis is a method for analyzing uncertainty by changing input variables and observing the sensitivity of the result [European Commission – Joint Research Centre 1999]. For example, if the direct financial costs are calculated for a range of discount rates, the analyst looks to which extent a varying discount rate would change the final result.

Sensitivity analysis in decision making is mainly used to gain information about the "robustness" of the decision making process. In this way, it can be used to analyze the dependence of results on initial assumptions. This analysis can be conducted either through group analysis and discussion, or by means of mathematical procedures. The method can be employed either on a variable basis or by changing groups of variables at once using scenario analysis. If working on a variable basis, the analysis should focus on key variables (e.g. largest cost elements, lifetime) as a full sensitivity analysis including all parameters will not be feasible due to resource or data constraints.

As a result "points of turn" can be identified. Such "points of turn" represent the values when a decision changes from using one option to another option. In the case of the WFD, these options can be seen as different measures to tackle a certain pressure. When applying a sensitivity assessment in the cost assessment, the use of cost ranges, applying low/medium/high estimations and the display of probabilities of occurrence is recommended in order to identify the "points of turn".

2.4 Political enforceability of measures

The political enforceability of a proposed measure is an important issue, as it might be the "knock out" criterion for measures with the best cost-effectiveness ratio. Political enforceability depends on how the measure or the instrument conforms to other political and/or social targets of the European and National Policy, the State's financial scopes (compensation payments, etc.), possible conflicting interests and the resistance of the public. For example, even if a permanent set aside of land would be the most cost effective measure to tackle nutrient pollution, it might not be politically enforceable if the government can not guarantee adequate compensation payments to farmers⁸.

Another important issue when discussing political enforceability costs is the question of who pays. Different measures might be paid by different stakeholder groups (e.g. household, industry, government). The relation of the costs to specific stakeholders is important information, needed for discussing the selection of measures and possible ways of financing measures.

In order to estimate the political enforceability, it is important to collect information on other effects than the primary effects as well on the wider economic costs of a measure. Such information can deliver advantages and disadvantages for the implementation of a measure

⁸ Political enforceability can also be seen from a cost or effectiveness point of view. If a measure can not be implemented due to a lack of acceptance in the public, its effectiveness ratio is close to zero. As the acceptance of a measure might be changed due to e.g. public education or awareness campaigns the cost for such activities have to be added to the direct cost of a measure.

and might be important especially in public participation processes to justify why a program of measures was designed in a specific manner.

It should be noted, that the political enforceability is not a given fact and it might change through time. Measures which are not enforceable as part of the first River Basin Management Plan might become enforceable under the second round of River Basin Management Planning if circumstances have changed, or if the measures undertaken as part of the first round have not been as effective as originally thought. Further stakeholder consultation and public information campaigns might change initial resistance of the public.

Political enforceability may be just as important in determining “points of turn” as uncertainties in cost calculation (Section 2.3.7).

2.5 Methodological uncertainties at the Black Sea application level

In the previous sections, uncertainty issues were emphasised wherever relevant both with regard to effectiveness and cost calculations.

Here, some additional issues of uncertainty are summarised which are related to the evaluation of cost-effectiveness in the Black Sea region:

- There can be a considerable amount of uncertainty in the estimates of nutrient reductions that can be achieved by tackling different sectors and sub-sectors (particularly from agricultural sources) in the Black Sea region.
- Further complications are added by economies of scale when multiplying-up costs from case studies to national or regional scales. Moreover, cost data available for different sectors are likely to be derived from a range of countries, while the direct transfer of costs from one country to another takes no account of local labour costs, differences in raw material costs, etc. To account for this uncertainty a range of potential cost-effectiveness values will be provided for each sector/sectoral approach used.
- Even if all sectors were tackled simultaneously, the period over which reductions in nutrient loads to surface waters would be realised is likely to vary enormously. For example, once upgrades to municipal sewage treatment are constructed and operational, emission reductions would be instantaneous. However, emission reductions from tackling agricultural sources may not be realised for years or even decades. From a policy perspective, this is critically important, but its importance will depend on the policy targets, e.g. a 15% reduction in N and/or P emissions within 5, 10 or 20 years. Where possible, the expected period over which identifiable emission reductions are likely to occur will be considered in the sectoral comparison methodology.

3 Specific methodological issues for cost-effectiveness analysis in the agricultural, municipal and industrial sector case studies

In the following the above motioned methodology will be further developed for each of the three sectors.

3.1 Agricultural sector (task 1a)

This aims at identifying the cost effectiveness of measures taken in agriculture to reduce nutrient leaching into groundwater and/or surface waters. Based on previous work in EU Member States (development of programs of measures for the Nitrate Directive and the WFD), an indicative list of measures for reducing nutrient emissions into groundwater and surface waters has been developed based on former UNDP/GEF projects in the Black Sea and Danube Basin. However this list of potential measures is not closed / exhaustive and other measures may also be considered. The measures in the case study report are grouped into the following categories:

- Land use
- Soil management
- Fertilizer and manure management
- Animal feeding
- Farm infrastructure
- Education and Training

Each measure is presented by nine attributes, which are (for details see section 2)

- I. **Primary Effect:** Mainly the way or the extent to which this measure could contribute to the achievement of the set environmental objective
- II. **Water-related side effects:** additional water-related effects beside the primary effects.
- III. **Non-water-related side effects:** all other effects which are not directly related to water such as social effects, effects on other environmental aspects or income.
- IV. **Geographical scale of the effect:** local, regional, basin wide scale of the effect
- V. **Time scale:** required for measures to become effective (short term refers to three years, medium to five and long term more than five years)
- VI. **Durability of an effect:** Time the effects holds on
- VII. **Adaptability:** Provides information on how a measure can be improved or adapted to circumstances
- VIII. **Certainty of the effect:** How certain an effect will take place
- IX. **Costs:** Costs refer to direct costs and if available to indirect wider economic costs.

This approach was chosen as the limited resources of this study do not allow representing the costs and effects in a single number for all agricultural measures and for the whole the Black Sea area.

Such a “single value” approach would require better understanding of the detailed nutrient loss pathways and the factors that affect the likelihood of these losses. For example nitrate is highly soluble and if present in soils during periods of drainage (the late autumn, winter and spring period, when drains flow) will be dissolved in water passing through the soil and may be transported to rivers and groundwaters. Variations in nitrate loss across the Black Sea result from the interplay of soils, environmental (including climatic) conditions, land use, and

agricultural practices. However these factors also influence the effectiveness of a measure and require a more detailed assessment on the regional level. Also the agricultural costs in vary in the region vary and therewith influence the cost efficiency. For example, Bulgaria and Romania as EU Member States are forced to pay compensation payment to farmers for environmental friendly production measures out of their Rural Development programs. Other Black Sea countries are not obliged to do so. In any case such payments increase the costs of a measure.

The authors believe that the way how measures are presented in the case study report is sufficient to take action in the agricultural sector. In a first step it is recommended to carry out regional assessment, analysing roughly the nutrients load coming from the different agricultural sub-sectors (e.g. different animal production, different crop cultivation) and to develop standards of “good agricultural practice”.

3.2 Municipal sector (task 2a)

3.2.1 Introduction

This task aims to evaluate the cost effectiveness of different upgrading options in municipal sewage treatment works. The evaluation will also consider the impact of policies e.g. the compulsory introduction of P-free or reduced-P detergents on the cost effectiveness.

Within the Danube countries the status of waste water management differs considerably. Differences exist in (1) the degree of the population connected to sewer systems, (2) the part of waste water collected that is treated in a waste water treatment plant (WWTP) as well as (3) the level of waste water treatment. Many countries within the Danube Basin are already members of the European Union. These countries have to implement the legislation of the EU within fixed deadlines. With respect to municipal waste water treatment, the Urban Waste Water Treatment Directive [91/271/EEC] has to be considered. All agglomerations above 2000 p.e. have to be sewered. The waste water entering collecting systems shall be subject to secondary treatment or an equivalent treatment before discharge. Furthermore, requirements for discharges from urban waste water treatment plants to sensitive areas that are subject to eutrophication are stipulated. N and P-concentrations in discharged effluents as well as a percentage of reduction are clearly stated. One or both of these parameters may be applied depending on the local situation. The values for concentration or for the percentage of reduction shall apply. To comply with the full implementation of the EU Urban Waste Water Treatment Directive (UWWTD) requires high efforts from the member states. Numerous new plants have to be constructed and/or existing plants have to be upgraded to meet these specifications.

3.2.2 Overview on requirements according to the UWWTD

agglomerations > 2,000 pe: secondary treatment (C-removal)

agglomerations 10,000 – 100,000 pe, sensitive areas:

N_{tot}: 15 mg/l or 70 - 80 % min. percentage of red.

P_{tot}: 2 mg/l or 80 % min. percentage of red.

agglomerations > 100,000 pe, sensitive areas:

N_{tot}: 10 mg/l or 70 - 80 % min. percentage of red.

P_{tot}: 1 mg/l or 80 % min. percentage of red.

The use of UWWT Directive standards is used for demonstration purposes only. In some Black Sea countries (e.g. the Russian Federation), discharge standards are not based on concentrations, but on loads. These load limits depend on the level of dilution offered by the

receiving waterbody, since the aim is to achieve compliance with environmental quality standards. As the level of rainfall/dilution varies from year-to-year, so can the discharge standards be changed. The methodology presented in Section 3.2 will, therefore, require modifying to be used in these countries.

Cost effectiveness in waste water treatment is assessed as ratio of costs of the additional treatment process (nitrification/denitrification; P-precipitation) versus the obtained additional emission reduction. Selected “side effects” like the potential improvement of groundwater as a result of measures in waste water management (especially the construction of sewer systems) will be discussed only in a qualitative manner.

The cost effectiveness analysis will be carried out in two main steps:

- estimations of emissions reduced for different treatment levels: C-removal (C-plants), C-removal + nitrification (CN-plants, C-removal + nitrification + denitrification (CND-plants), C-removal + P removal (CP-plants) and C-removal + nitrification + denitrification + P removal (CNDP-plants)
- costs of different upgrading options in municipal sewage treatment works; the costs will consider effects of the “economy of scale” (dependency of costs on the design capacity of the plant).

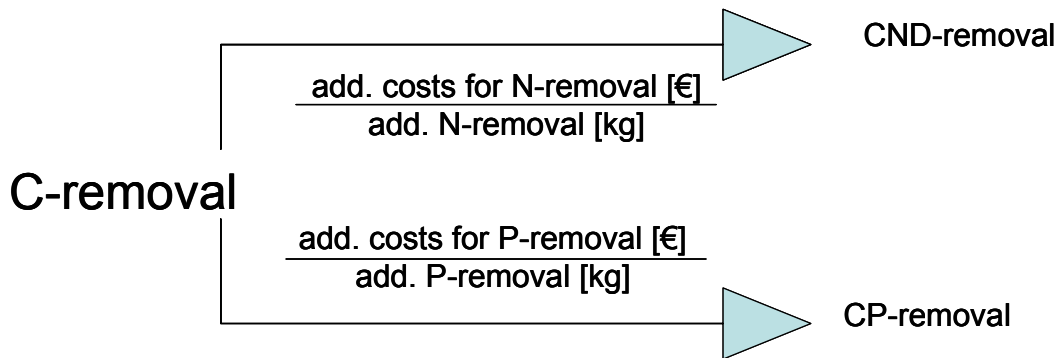


Figure 1: Main Principle of the cost effectiveness analyses in the UWWT sector

The general approach will be as follows: Existing cost functions for capital costs as well as operation costs for (“western”) treatment plants will be adapted for several countries in the Black Sea catchment using “local”/national data. Case studies in the countries will support the derivation of the cost functions.

For the case study-plants, information originally provided to support the upgrading of municipal waste water treatment plants will be used. The selected case studies shall meet one of the following criteria: (i) “new” waste water treatment plant, (ii) recently upgraded plant or (iii) plant which will be upgraded soon. Data will be gathered via questionnaires. The detailed questionnaires developed are enclosed in the Annex. A translation of the questionnaire into Russian language is carried out.

In the questionnaire two different types of information are requested:

- 1) general “national” information which is not plant specific, e.g. labour costs per month, price of electricity, costs of precipitants, effluent standards in the country, etc.
- 2) specific data including economic data (operation costs, investment costs) of the case study plant. An important part of information is also the costs of sludge management (disposal charges, etc.) (this information is partly plant specific but probably regulations on a national level exist).

It has to be expected that not all (detailed) information requested will be delivered. However the more local and national data will be obtained, the more the results will reflect the specific

national situation.

Up to now contacts to treatment plants in Ukraine, Romania and Bulgaria have been established. For four Hungarian treatment plants data was provided from the Technical University of Budapest. A further case study is foreseen for the Czech Republic.

3.2.3 Assessment of direct financial costs

Several studies on direct financial costs of waste water treatment already have been established and cost functions have been derived for investment costs as well as for operation costs. However, these cost-functions are strongly influenced by national characteristics (salaries, price for electricity, charges for sludge disposal, etc.) and therefore have to be adapted to the local situation in the Black Sea region. In order to obtain this information the collection of non-monetary data is needed. This information also helps to compare cost data over national borders (man-hours, energy consumption, chemical consumption, etc.).

The approach respectively the main assumptions of the assessment will be as follows:

- the plant configurations and operations schemes of treatment plants in other countries to fulfil certain emission requirements (C-removal only, C+N-removal, C+P-removal, C+P+N-removal) are similar to those included in the studies on cost functions which will be adapted. This implies also, that the productivity of labour, the efficiency of aeration, etc. is comparable.
- Cost functions for investment costs and operation costs will be split up to several cost categories. Cost functions show the effect of economy of scale. This effect also will be considered in the adaptation of the cost functions.
- From the cost categories the non-cost-information will be derived (e.g.: from the amount of personnel cost the number of person month will be calculated).
- Combination of the non-cost-information with local prices/salaries to obtain local cost functions
- Finally the case study results will be compared with the local cost functions derived

In the following sections investment costs as well as operation costs will be discussed.

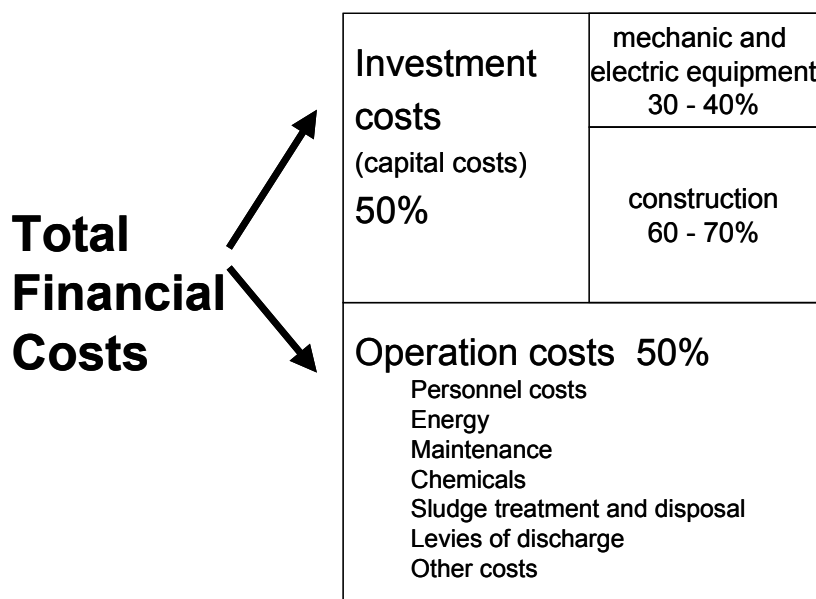


Figure 2: Distribution of investment costs and operation costs in Austria [ÖWAV 2007]

Some financial costs, e.g. electricity for aeration and chemicals for phosphorus precipitation and sludge conditioning ought to be related to the actual load of pollutants to the plant while other operating costs such as maintenance probably are related to the physical size of the plant and the number of tanks and pieces of machinery it is composed of.

3.2.3.1 Investment costs ((capital costs)

Investment costs can be split up into costs of construction and to costs of the mechanic and electric equipment. In Austria typically the construction costs amount to 60 -70% of the total investment costs of the treatment plant.

In order to compare investment costs with annual operation costs, the investment costs have to be transferred into annual costs (capital costs).

Annual investment costs can be found from the total investment costs and a pay back time or return of investment time of X years = annuitization

Annuitization:

Annuity = investment * annuity factor

$$a = C_0 \frac{q^n (q - 1)}{q^n - 1}$$

Where:

$$q = i + 1$$

a... annuity

C₀.. investment costs

i... adequate target rate

n... number of years

Investment costs show a clear impact of the economy of scale. As an example the investment costs of waste water treatment plants in Austria in 2004 are depicted below (means of 8 different capacity sizes from < 50pe to >100.000pe; in total 288 plants, all classes comprise at least 8 plants, 61 treatment plants larger than 5000 pe). Further the sizes of treatment plants are indicated where the emission standards according to the UWWTD change.

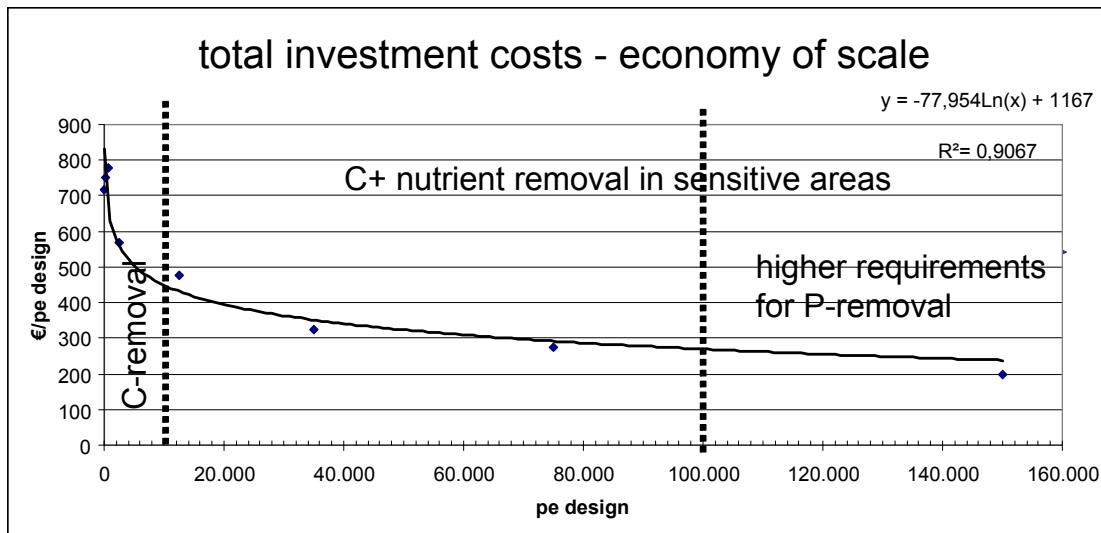


Figure 3: Investment costs of Austrian wwtps (P removal at plants > 1000 pe, N > 5000 pe)

The level of treatment influences the investment costs. For N-removal in addition to C-removal a nitrification/denitrification step is required. The denitrification step can take place in the same tank as the nitrification (simultaneous denitrification plant, alternating process), or in a separate tank (pre-denitrification). Nitrification (transformation of Ammonia to Nitrate) requires a higher sludge age, as the growth rate of nitrifying bacteria is low. A higher sludge age means that the volume of the secondary treatment tank has to be enlarged. Further nitrification has a considerable oxygen demand. The N-removal step is the denitrification (transfer of Nitrate into N₂) which takes only place under anaerobic conditions. Providing areas of anaerobic conditions require additional volume. Compared to C-removal only nitrification and denitrification require larger tanks.

- CND-Plants (C-removal, nitrification and denitrification) have 1/3 higher construction costs than plants with C-removal only.
- Denitrification requires an additional volume of about 1/3 of the aeration tank volume for nitrification (of the aeration tank or alternatively of an additional tank).
- Additional expenditures for process measuring and control technology and mechanical installations occur: + 1/4 of electrical and mechanical installation costs.

Table 5: Investment costs of CN and CND plants in relation to C-plants (C-plants= 1)

	construction costs	Electr. and mechanic. installation costs
C-removal	1	1
C-removal + nitrification	1,3	1,2
C-removal + nitrification + denitrification	1,33	1,25

3.2.3.2 Operation costs

Operation costs can be subdivided into the following categories:

- Personnel costs
- Energy
- Maintenance
- Chemicals

- Sludge treatment and disposal
- Levies of discharge
- Other costs

It is not possible to directly transfer operation costs (or related shares of costs) obtained for treatment plants e.g. in Austria to many of the countries in the Black Sea catchment as prices and wages differ in a broad range. The methodology to overcome these problems (differences) will be illustrated below. In addition several examples illustrating the differences will be given.

In all cases the results of the Austrian case studies are the base for calculations.

3.2.3.2.1 Personnel costs

The costs for labour depend on the local/national salaries/wages.

Method:

1. Derivation of the number of employees of the plants from Austrian case studies: Annual personnel costs divided by average wages equals to person/years
2. Calculation of number of employees per population equivalent (resp. per actual pe)
3. Investigation of labour costs in the country under investigation

E.g. the average wages in Bulgaria in the economic activity group “construction” in the private sector in 2005 amounted to 267,5 LEWA/month [NSI 2006] (1 Lewa = 0,5 €), in Austria for workers about 1500 €/month which is more than a factor of 10.

3.2.3.2.2 Energy costs

In numerous waste water treatment plants sludge digestion is applied. The biogas produced is processed in co-generation units and the energy content is transferred to heat as well as to electricity (typically 30%-35% electricity, 50% - 55% heat, 10%-15% losses). Some of the plants are almost energy-autarkic which leads to the situation that the energy costs for the plants can be close to zero. The range of the share of energy costs is between 0 and 35% of the operation costs. Counteracting additional investment costs for the co-generation unit accrue. Therefore to avoid these problems the consumption of electricity per actual p.e. is a useful unit, that can be transferred from one country to an other (assuming similar treatment procedures).

The larger part of electricity consumed at a treatment plant is used for aeration (about 60% in the case of anaerobic stabilisation to 70% in the case of aerobic stabilisation). Aeration is needed for C-removal as well as for nitrification. Plants with additional denitrification show a lower oxygen demand compared to plants with C-removal and nitrification as nitrate is used to reduce organic matter.

In the case of anaerobic stabilisation and therefore the production of biogas, the costs of purchasing electricity decrease considerably.

The costs for energy depend on the local/national price for electricity, the tariff-reading, the type of sludge stabilisation, etc.

Method:

1. Evaluation of electricity consumption of the plants from Austrian case studies for plants with (i) carbon removal only, (ii) carbon removal plus nitrification, (iii) carbon

removal plus nitrification and denitrification

2. Transfer of the electricity consumption to the actual loading of the plant
3. Investigation of electricity costs in the country under investigation

Only C-removal: 10% less energy consumption compared to nitrification/denitrification

C-removal and nitrification only: +10% compared to C-removal +nitrification/denitrification

Prices of electricity in different countries vary considerably: Furthermore in some countries (like Bulgaria) different tariffs are offered - from 1-tariff reading (day and night electricity) to 3-tariff reading (peak electricity, day electricity, night electricity) with significant differences. The price of 100 kWh in 2007 in Bulgaria for industrial use 1-tariff reading amounts to 5.5€ (including VAT). Using a 2-tariff-reading the prices are 5.7€ for day electricity and 2.75€ for night electricity [SEWRC 2007].

In the following table mean values of electricity prices in 29 European countries (25 at that time member of the EU) for industrial consumers for the consumer type 1e (2000 MWh.a) are depicted (countries within the Danube Basin in bold letters).

Table 6: Costs of electricity in €/100 kWh excluding value added tax (stand 1.7.2006), price for industrial consumers, type 1e (2000 MWh.a) [Eurostat 2006]

country	AT	BE	BG	CY	CZ	DE	DK	EE	EL	ES	EU-25	FI	FR	HR	HU
price/100 kWh	8,48	10,50	4,50	11,50	7,42	10,22	9,29	5,26	6,68	8,03	9,00	5,89	5,78	6,07	6,57
country	IE	IT	LT	LU	LV	MT	NL	NO	PL	PT	RO	SE	SI	SK	UK
price/100 kWh	10,11	13,96	4,98	8,95	4,43	8,97	9,93	7,51	5,72	8,04	7,91	7,07	6,34	7,53	8,95

3.2.3.2.3 Maintenance

Maintenance is related to the physical size of the plant and the number of tanks and pieces of machinery it is composed of.

To evaluate the costs of maintenance, the ratio of maintenance costs to capital costs of the Austrian plants will be used.

3.2.3.2.4 Chemicals

Chemicals used in the plants are mainly related to P-precipitation and to sludge dewatering. The amount of P to be removed to meet the effluent standards is decisive for the costs of precipitants. The P-load to the treatment plant is primarily caused by human faeces, the use of P-based detergents and contributions from industry. However, diffuse contributions from urban drainage, as well inputs from mechanical waste disposal systems (built into the outlets of kitchen sinks) may also make a contribution. Where separate foul and clean water sewage systems are used, mis-connections between the two systems and of wastewater from washing machine wastewater outlets to the foul sewer system, may by-pass waste water treatment works. In the project the compulsory introduction of P-free or reduced-P detergents will be considered.

In addition to the costs due to the purchase of precipitants, P-removal increases the amount of sludge and therefore increases the costs of sludge management (dewatering, disposal, etc.).

As precipitants Fe- and Al-salts will be considered.

The P-concentration in the raw municipal waste water is relevant for those treatment plants which have to apply P-removal to comply with the P-emission standard.

The following assumptions were made:

Emissions from population:

- The specific P-emission per inhabitant excluding detergents is 1.65 gP/inh.d
- Automatic dish washer detergents are P-based. In the last 15 years a considerable increase in the use of P-containing detergents in automatic dishwasher products was observed in Germany. In the beginning of the 1990ies the P-emission in Western Germany stemming from detergents use in households dropped to 2000 tP. Mainly due to the increase of the use of automatic dishwasher products the P-emissions increased again amounting to 3000t in 1996 and 5100 tP in 1999 [UBA 2007]. Including the total German population this would mean a specific P-emission of 0.2 gP/inh.d. It can be assumed that the consumption of automatic dish washer products in the eastern parts of Germany was considerably lower at that time and the specific emission from persons in the western parts is higher. The number of dish washers has increased between 1993 and 2003 in Germany by about 100% (considering only the "old" German countries by 65%) [UBA 2007a]. In 2005 about 60% of German households possessed a dish washer [Destatis 2007] still bearing a potential for an increase. In our calculations a consumption of 0.3 g P/inh.d is assumed. For eastern European countries this value will be lower. It is currently not possible to replace sodium tripolyphosphate (STPP) in automatic dish washer products. The "zero-laundry detergent scenario" depicted below includes the specific loads stemming from faeces and automatic dishwasher detergents.
- The amount of P-based laundry detergents consumed per inhabitant differ in a broad range. In Western countries like Austria, Germany or Switzerland, the maximum consumption of P-containing laundry detergents in the 1980s amounted to 3 g P/inh.d. It has to be recognized that the composition of detergents has changed in the last decades. For instance the total amount of STPP contained in washing powders has been reduced from 50% to about 25% (or even less). Therefore "modern" P-containing laundry washing powders use less STPP per washing cycle.
- Depending on the hardness of the washing water 4 to 13 kg [Fox et al. 2002] of washing powders are consumed per inhabitant. Assuming a consumption of 4 – 13 kg washing powder with an STPP concentration of 25% per inhabitant would mean a specific P-emission of 0.7 – 2.2 gP/inh.d. In 7 countries of the EU 25 only phosphate free laundry detergents are used [EU Commission 2007]. The term "phosphate free" indicates compliance with national legislation limiting phosphate content (not necessarily zero). The specific consumption of P-based detergents differs in a broad range – from 0 gP/inh.d up to 0.84 gP/inh.d in Hungary (and an outlier of 2.8 gP.inh.d) in Slovak Republic [INIA, 2006]. It has to be recognised, that in several countries (i) P-free and P-based detergents are available on the market, (ii) that the current consumption can change and (iii) that several countries in the catchment of the Black Sea currently consume (much) less detergents as before the economic breakdown. This means current consumption patterns can not be seen as representative for the future consumption. Therefore in an example below the consumption of P-based detergents covers the range 0 to 1.5 g P/inh.d.

Emissions from Industry treated in municipal wwtps

- The number of industrial population equivalents (pe_{ind}) was assumed as follows: agglomerations > 100000 pe: 1.2 $pe_{ind}/inhabitant.day$, 2000-100000 pe: 1 $pe_{ind}/inh.d$, <2000 pe: 0.2 $pe_{ind}/inh.d$; These assumptions are based on recent studies in Austria reflecting well developed economic activities. In respect to the economic transition process with lower economic intensity in the CEE countries the following reduction for

the amount of pe_{ind} per inhabitant.d have been done for the calculations: CZ, HU: minus 25%, all others: minus 50%

- P-Emissions from industry: 1.1 gP/ $pe_{ind}.d$ [Zessner & Lindtner 2003]

General assumptions

- The water consumption of 1 pe: 200 l
- The amount of sewer infiltration water influences the P-concentration in the raw waste water and as a consequence the efforts required to meet the effluent quality standards differ; calculation were carried out with 100 l sewer infiltration water per p.e.

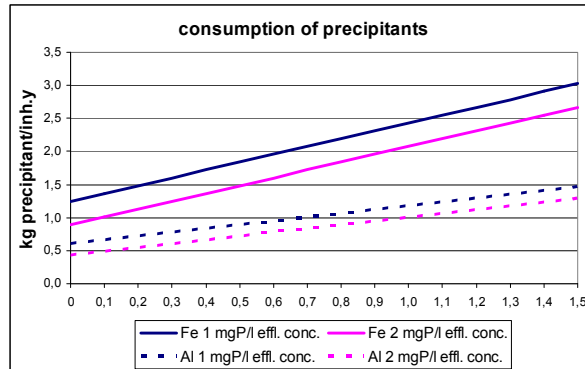


Figure 4: consumption of Fe- and Al-precipitants depending on the consumption of P-based detergents (Beta = 1.8)

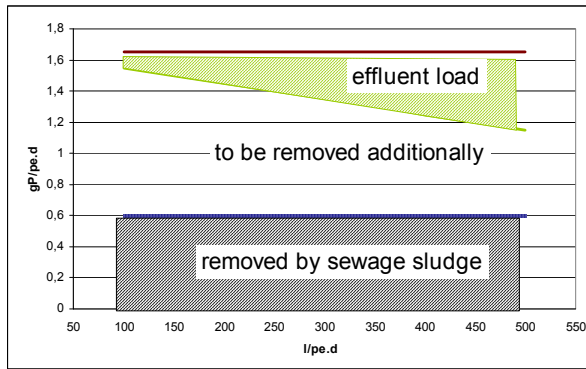
The demand for Fe-salts is about double that of Al-salts.

The water consumption per pe and the sewer infiltration rate impact the amount of P to be precipitated and the total load emitted by wwtps. Sewer infiltration rates in the same order of the water consumption per pe double the effluent load. Higher amounts of sewer infiltration loads lower the amount of P which has to be removed and consequently lowers the consumption and costs of precipitants. On the other side high sewer infiltration rates increase the costs e.g. of pumping and often lowers the temperature of the waste water. The temperature of the waste water influences the removal capacity for Nitrogen. High amounts of sewer infiltration water and low temperature of the waste water impacts the dimensioning of the plant.

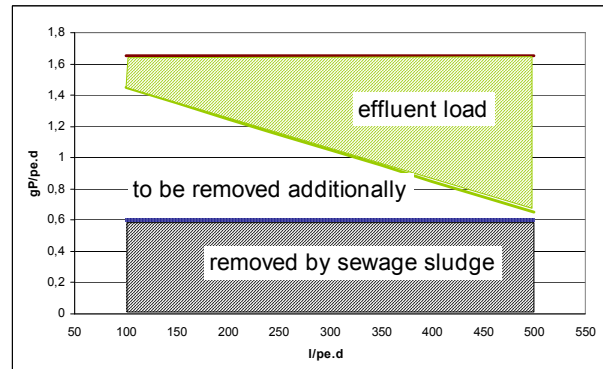
In the figures below a specific P-emission of 1.65 gP/inh.d (caused by faeces only) is assumed. If the sewer infiltration would amount to 150% of the water consumption of the population equivalents (200 l/pe.d) no P would have to be removed from the waste water meeting an emission standard of 2 mgP/l.

In practice normally the sewer infiltration rate will be lower.

The use of P-based detergents increases the amount of P to be removed.



Impact of raw waste water amount on the effluent load:
effluent conc.: 1 mgP/l



Impact of raw waste water amount on the effluent load:
effluent conc.: 2 mgP/l

Figure 5: Impact of raw waste water amount on the effluent load

If standards for P-concentrations of 1 or 2 mgP/l in the effluent exist, P-precipitation is necessary even if no P-based detergents are consumed (except the sewer infiltration rate is very high as depicted above). If the effluent standard is 1 mgP/l P-precipitation (or enhanced biological P-removal) will be required, even more if P-based detergents are consumed.

Costs are assessed as follows:

1. Calculation of the amount of P to be removed via precipitation to meet the emission standards
2. Calculation of the amount of precipitants needed (Beta 1.8)
3. Evaluation of the costs of precipitants (Fe and Al-salts)

The amount of P to be precipitated will be calculated as follows

- i. Removal of 0.6 gP/pe due to biological treatment
- ii. Total load minus P-load removed by biological treatment minus P-load in the effluent according the emission standards = P-load to be precipitated

3.2.3.2.5 Sludge treatment and disposal

Sewage sludge is a main product of the waste water treatment process. The amount of sludge produced depends of the treatment steps of the plants: CN- and CND-plants produce (slightly) less sludge as plants with C-removal only. P-removal increases the amount of sludge considerably. Increasing P-loads to be removed (e.g. due the consumption of P-based detergents) increase the amount of sludge produced). A replacement of P-based detergents e.g. by Zeolites also increases the amount of sludge produced.

The costs of sludge treatment and disposal depend on the amount of sludge produced.

Especially the costs of sludge disposal vary extremely. From almost zero (in the case that the landfill and the treatment plant are owned by the municipality and no disposal charge is required [Tsagarakis, 2002] to > 100€/t dry matter [ÖWAV, 2007].

Costs are assessed as follows:

1. Calculation of sludge production (see below)

2. Evaluation of disposal options
3. Estimation of costs for dewatering
4. Related costs for disposal

For the sludge production in treatment plants without P-removal an amount of 40g dm/pe.d (dm = dry matter) was assumed. The amount of additional sludge produced in plants where P-removal is required is based on the following assumptions:

- Calculation of the P-amount to be precipitated (see chapter on chemicals)
- Calculation of the specific amount of additional dm/kg P:
 - Precipitant per kg P: 1.8 kg Fe/kg P, 0.87 kg Al/kg P
 - Beta-value: 1.8 (Beta value: molar ratio of precipitant (Fe, Al) : P)
 - Sludge production: 2.5 kg dm/kg Fe (Beta = 1,5), 4 kg dm/kg Al (Beta = 1.5)

These assumptions lead to an additional dm production of 9.7 kg dm/kg P using Fe, and 7.5 kg dm/kg P using Al.

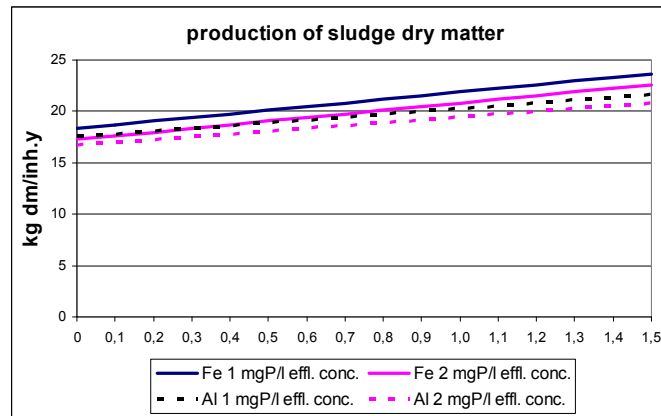


Figure 6: specific production of dry matter depending on the consumption of P-based detergents

The total amount of sludge produced using Fe-salts is 5 to 10% higher compared to the use of Al-salts.

The use of Zeolites instead of P-based detergents also increases the production of sewage sludge as almost the entire amount of Zeolites remain in the sludge. The Zeolite consumption in Germany amounted in 1999 to 4.5 g/inh.d [UBA 2007]. This amount can be considered as a maximum amount.

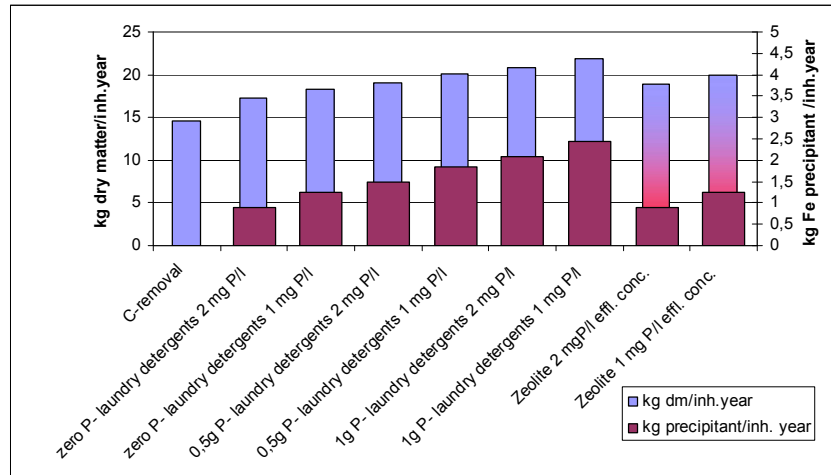


Figure 7: Sludge dry matter production and use of Fe-precipitants; Zeolite consumption 4,5g/inh.d

3.2.3.2.6 Levies of discharge

Will be obtained from the questionnaires.

3.2.3.2.7 Other costs

Other costs (including costs for the laboratory, streets within the plant etc.) will be a fixed percentage of the total operation costs.

3.2.4 Effectiveness

The effectiveness of treatment plants is defined as the ratio of the load of a substance in the outflow to the load in the inflow.

In our investigations only conventional activated sludge reactors are considered, as these systems are very common, and a lot of data is available (at least for “western” countries). However the methodological approach depicted above can also be applied to other treatment processes.

A part of the nutrients in the inflow is incorporated in to the biomass of the bacteria and is removed as primary sludge (if there is a primary settling tank) and as excess sludge (secondary sludge). As well as for N and for P the removal via the sludge is between 30 and 40% of the inflow load.

For an additional N-removal a nitrification / denitrification step is needed. Usually 70% (maximum 90%) removal can be achieved. The removal is limited by the availability of carbon sources and the temperature of the waste water (in winter time).

Additional P-removal can be increased simply by adding precipitants. Enhanced biological P-removal can lower the demand for precipitants. Total removal rates of 80 to 85% for P can easily be reached. However lower effluent concentrations as 0.5 gP/l would require higher efforts (e.g. additional filtration step).

For the calculations of the cost effectiveness the N- and P-amount additionally to the N and P removed via sludge will be used. (N/P removed via sludge + additionally removed N/P = N/P removed total).

3.3 Industrial sector (task 3a)

Industrial production, especially manufacturing industry is often connected to large water

uses and therewith with large volumes of wastewater produced. Within the European Union industrial facilities, existing as well as new constructed ones, have to meet the demands of IPPC-Directive (Directive 96/61/EC) since 30 October 1999 which aims to reduce emissions from industry to the environment as far as possible using the best available technology (BAT).

This task will deal with nutrient emissions from fertilizer production industry, which can be associated with the application of best available technology (BAT) for the reduction of emissions from the production process to surface waters of either new or existing (upgraded) plants.

3.3.1 Fertilizer production lines and associated nutrient emissions

As far as information are easier to obtain for central European countries it was decided to concentrate the investigations concerning nutrient emissions from fertilizer producing industry at first on fertilizer production companies within EU-15 countries. Fertilizer production in general covers a wide spectrum of processes and various product types, which can be either straight nitrogen (N), phosphorus (P) or potassium (K) fertilizer or multi-nutrient products (NP, NPK, PK). In respect to diverse intermediate or final products the production processes involves various steps, which may vary for different production lines using different raw materials and where recycling operations within one or between different production lines provide opportunities to save raw materials as well as to reduce the specific energy consumption and waste water production. Since single fertilizer production lines (which focus on the production of a certain fertilizer product) are highly interactive with other production lines (in terms of recycling operations), their integration in one manufacture site is desirable. Thus, different production processes (lines) cannot be regarded as single system and will be investigated as complex interacting system.

The production processes can be grouped in respect to the produced fertilizers into:

- Nitrogen based fertiliser with consideration of production of
 - Ammonia (raw material for the production of N-containing fertiliser)
 - Ammonium nitrate (AN) and calcium ammonium nitrate (CAN)
 - Urea and urea ammonium nitrate (UAN)
 - Multi-nutrient fertilizer (NP, NPK) using the nitrophosphate route
- Phosphate based fertiliser with consideration of production of
 - Superphosphates (Single Superphosphate SSP, Triple Superphosphate TSP)
 - Multi-nutrient fertilizer (PK, NPK) using the mixed acid route

Two large fertilizer production companies will be investigated which are focused on the productions of either phosphate or nitrogen based fertiliser. Each fertilizer type which is produced in one of the two manufacture facilities is characterised by a specific production line with a certain amount of raw material, energy and water used and with a specific waste water production. According to the IPPC directive (96/61/EG) on Integrated Pollution Prevention and Control, best available techniques (BAT) have to be introduced to industrial facilities to prevent pollution of air, water and soil.

For fertiliser manufacture and its specific production lines best available techniques (BAT) for production processes including off-gas treatment, waste water avoidance and recycling as well as adequate treatment for non-avoidable waste water are available in form of a catalogue delivered by the European Commission [EC 2006] and the European Fertiliser Manufacturer's Association [EFMA 2000]. Introduction of BAT can contribute to waste water recycling rates of up to 100% (recycling of all process wastewater into the production

process of either the same or another production line). Arising waste water from production which cannot be recycled to on-site production processes, have to be treated with adequate techniques (e.g. biological treatment) before discharge.

For the two fertilizer production companies the individual production lines will be investigated in terms of being state-of-the-art due to introduction of BAT measures to reduce emissions to the water / air and in terms of associated nutrient emissions to surface waters. BAT application will be assumed to be valid for most of the production lines of the two fertilizer production companies under consideration. If BAT are already applied to specific production lines, waste water emissions from those production lines (as far as discharged waste water arises) can be regarded as target emissions or desired emission levels which can be achieved with a reasonable cost – efficiency. These target emission values for specific production lines can be used for further analyses of other fertilizer production facilities, where BAT is not applied yet and which therefore have potential for reducing nutrient emissions from process waste waters via the introduction of measures for application of BAT.

3.3.2 Evaluation of emission reduction potential

Two possible ways for emission reduction from fertiliser manufacture industry are to:

- reduce emissions to the surface water via treatment of process waste water in waste water treatment facilities before discharge (for some production lines BAT are defined for the level of treatment for discharged process waste water)
- avoid process waste water discharges as far as possible via recycling operations of process waters to other on-site production processes with the introduction of BAT

For newly (to be) constructed plants consideration of BAT in the production process with regard to introduction of recycling operations for process waste waters can be expected. Upgrading of existing plants can become very expensive, particular if existing plants have been in operation already for some decades. Then upgrading of the existing technology is likely to be incompatible to techniques which conform to BAT due to obsolete production technology.

For the investigations within this project towards the identification of cost efficient measures to reduce nutrient emissions from fertilizer production industry the way would be to perform a kind of deficiency analyses for other fertilizer production facilities to identify discrepancies in terms of produced and discharged process waste water in comparison to BAT-associated emission levels.

Nutrient emissions from discharged process waste water due to insufficient or no introduction of BAT are likely to exceed those emissions levels associated with applied BAT. They will be subject to potential measures for the reduction of nutrient emissions from fertilizer industry. It has to be investigated if introduction of (parts of) measures according to BAT is cost-effective and would result in the anticipated emission levels or if introduction of measures for an improved waste water treatment would be sufficient to reduce nutrient emissions to an acceptable level with comparable or lower costs.

In this respect also another fertilizer production facility within the Eastern European part of the Danube basin will be investigated. Impacts due to different economic development as well as due to different legislation in waste water discharge permission may result in different specific or total waste water emissions. In comparison to the fertilizer production facilities in central European countries, emissions to surface waters can be evaluated in terms of potential for emission reduction via introduction of recycling operations or via enhanced waste water treatment.

3.3.3 Evaluation of costs and effects

As this project concentrates on cost-effective measures to reduce (nutrient) emissions to surface water, evaluation of costs will be performed only for those parts of the production processes, which are dedicated to the reduction of emissions from production process to the air/water.

The total costs of emission reduction measures will consist of:

- investment costs (capital costs) for emission abatement technology of
 - newly constructed plants or
 - upgraded existing plants according to BAT or for
 - improvement of waste water treatment
- operating costs with consideration of
 - maintenance of emission abatement equipment
 - specific (energy and) water consumption for the emission abatement technology

Operating costs

Usually, personnel costs are included in the part of operating costs. Looking at one big industrial facility it is very difficult to forecast the effect of changes within the production processes on the development of personal staff as long as these investigations are still performed on a very general level. Since application of BAT to production processes or improvement of waste water treatment is expected to have only a marginal influence on personal costs of the whole production process they will be neglected within this evaluation. Additionally it is assumed that operating costs which account for personal staff are small in comparison to costs for maintaining the production process (raw materials, consumption).

As far as information on other operating costs (administrative costs, fixed operating costs, financing costs – see Table 3) will be available, they will be considered for the evaluation of cost-effectiveness.

Operating costs are usually given as costs per tonne of product produced. Cost analysis will be performed in the same way relating to materials, water and energy consumption on the produced amount of product.

Investment costs

This project should result in a more or less simple methodology for the evaluation of cost-effective measures and required input data should be limited as far as possible to those, which are absolutely necessary for the performance of these analyses. Only those investment costs will be considered within this analyses which are directly related to the measures, which account for emission reduction (for fertiliser production only investment costs will be considered, which are related to the introduction of BAT techniques / to the reduction of emissions to air/water). Investment costs for upgrading of existing plants with technology according to BAT will be evaluated only for equipment, which is involved in the recycling operations of the process waste water which result in the reduction or the avoidance of process waste water discharged (this is in line with methodology for task 2, where only costs for additional nutrient removal will be considered). For newly constructed plants, the fraction of investment costs which can be related to process waste water production and recycling has to be distinguished from investment costs of the whole fertilizer plant in order to ensure comparability to measures of upgrading existing plants.

For end-of-pipe waste water treatment investment costs of either construction or of upgrading of existing waste water treatment plants will be considered. Investment costs will

be estimated according to the methodology of Task 2, since biological waste water treatment of discharged process waste water conforms to BAT and is likely to correspond in large parts to waste water treatment in the municipal sector.

Investment costs will be transferred to annual capital costs (see chapter 3.2.3.1) and will be regarded also as specific costs (in relation to tonnes of produced product).

Comparability of costs

Operating and investment costs may vary between regions with different economic development (energy prices, salaries, insurance fees, financing costs etc). If costs will be evaluated and compared for two or more regions with different economic levels, comparability of cost assessments will be ensured by scaling the evaluated costs on the GDP (Gross Domestic Product).

Evaluation of Effects (emission reduction)

Introduction of BAT measures in terms of the reduction of emissions from the production process to the air and to the water comprises a bundle of measures, where not all of these measures will be fully implemented in production facilities, dependent on the existing equipment and of compatibility of introduced measures. So a way of the investigation within this task can be to compare measures for:

- full implementation of all BAT measures and associated BAT levels
- implementation of selected (most important) BAT measures e.g. in the regarded case study plants and analyses of associated emissions (deviations from BAT-associated emission levels)
- conventional production processes with improved end-of-pipe treatment of process waste water before discharge (the evaluation of costs for this measure is comparable to the methodology used in task 2)
- conventional production processes with comparable elevated emissions e.g. in case study plants in Eastern Europe

with achieved reductions in nutrient emissions to surface waters of these specific measures.

Based on this 4-point-assessment a simple function can be derived, which considers information on:

- total costs of specific measures for the reduction of emissions (introduction of BAT, improvement of end-of-pipe treatment) and
- emission reduction achieved by the specific measures with reference to BAT-associated emission levels

and which can be used to evaluate cost-effectiveness (ratio of total costs vs. reduced emissions of the specific measures).

Availability of information

Some information on investment costs and operating costs can be found in Reference documents for Best Available Techniques for Pollution Prevention and Control released by the European Fertilizer Manufacturer's Association (EFMA) as well as by the European Commission. A good database in this respect is provided by a report of the Austrian Federal Environment Agency (Umweltbundesamt 2002), which investigated the state-of-the-art for the production of fertilizers in 2002, but which do not provide full information on costs for fertilizer production. Thus this information has to be evaluated by an extended literature review.

3.3.4 Evaluation of cost-effectiveness

Since this task 2 and task 3 concentrate on measures to reduce nutrient emissions to surface waters, which will be subject of transport to the Black Sea ecosystem, effectiveness of measures will be evaluated as the nominal reduction of nutrient loads to surface waters due to the introduction of the regarded measure.

Cost-effectiveness will therefore be calculated from the ratio of total annual capital and operating costs / total reduction of nutrient emissions, which are discharged to surface waters.

Since chapter 2.1 described that this single ratio should not be used as stand alone criterion for evaluation of cost-effectiveness, secondary effects (wider economic effects) have to be taken into account not primarily for the evaluation for cost-effectiveness, but rather for a qualitative description of full environmental performance of measures for emission reduction. Within this context the introduction of recycling operations of process waste water according to BAT requirements is likely to change the consumption of raw materials, energy and water and may have therefore significant consequences on the production process as well as on environmental performance of the fertiliser manufacturer. Savings in material input may be overruled by enhanced operating costs or by considerable investment costs for recycling operations, which may exceed those costs for an improved end-of-pipe treatment significantly, but which may contribute to a better environmental performance and therefore to an improved public acceptance of such measures. On the other hand, prices of fertiliser products could increase due to higher labour or raw raw materials costs and, therefore, the competitiveness of these products in the global market could be affected. These effects are rather difficult to evaluate but will be considered as far as possible.

3.3.5 Evaluation of industrial emissions by sectors to surface waters

Introduction of recycling operations or end-of-pipe treatment of discharged process waste water are potential measures to reduce waste water emissions to the surface water on the local scale. To evaluate the effects on a broader scale (catchment-wide effects), the significance of point source emissions from specific industrial branches in comparison to the total point source emissions will be evaluated.

Based on the ICPDR emission inventory analyses will be performed identifying the significance of emissions from industrial sectors to surface waters in comparison to total point source emissions to surface waters. As far as data are available this comparison will be done for the Danube river basin to highlight industrial sectors, which significantly contribute nitrogen and/or phosphorus emissions to surface waters.

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Annex I

Questionnaire for new plants Part I (similar questionnaires are developed for the categories “recent upgrade” and “upgrade soon”),
Questionnaires are also translated into Russian language.

Start of operation	year	
Design capacity of the plant	population equivalent	1 population equivalent:
Current loading	population equivalent	60 g BSB5/inhabitant and day or 110 g CSB/inh.d 11 g N/inh.d 1,7 g P/inh.d
Average daily inflow	m ³ /d	
Inflow concentration		
CSB/BSB ₅	mg/l	
N _{tot}	mg/l	
NH ₄	mg/l	
P _{tot}	mg/l	
PO ₄	mg/l	
Actual effluent concentrations:		
CSB/BSB ₅	mg/l	
N _{tot}	mg/l	
NH ₄	mg/l	
P _{tot}	mg/l	
PO ₄	mg/l	
Suspended solids	mg/l	
Removal efficiency for C:	%	
Removal efficiency for P (if applied)	%	
Removal efficiency for N (if applied)	%	
Description of plant configuration – treatment steps:		
Investment costs: total	€	
costs for construction (if available)	€	
costs for machinery and electro-technical installations (if available)	€	

Questionnaire for new plants Part II

Operation costs:

Average production of sewage sludge	t dry matter (dm) per year	
P-concentration in sludge	g/kg dm	
N-concentration in sludge	g/kg dm	
Kind of sludge dewatering		
Kind of sludge disposal		
Costs of sludge management		
Costs of dewatering	€/t dm	
Disposal charges	€/t dm	
Costs for combustion	€/t dm	
Charges for agricultural application	€/t dm	
Other management option (e.g. composting) and related costs	€/t dm	
consumption of electricity (kWh/a)	kWh/year	
Price of 1 kwh	€/kWh	
Management of biogas from sludge digestions		
Amount of biogas	m ³ /year	
energy efficiency of cogeneration unit	%	
Production of electricity	kWh/a	
Costs of cogeneration unit	€	
Number of employees of wwtp		
Average salary of wwtp staff	€/month	
Average salary in the construction sector	€/month	
Use and costs of chemicals		
Polymers	kg/a	€/kg
Precipitants (please specify which product)	kg/a	€/kg
Disinfection (please specify which product)	kg/a	€/kg
Reagents for laboratory (costs only)		€/kg
Levies for discharge		
Other costs		
Current emission standards: CSB/BSB ₅ , Ntot, (NH ₄), Ptot (PO ₄), SS (suspended solids)		

(Near) Future emission standards: CSB/BSB₅, Ntot, (NH₄), Ptot (PO₄), SS (suspended solids)

Russian Questionnaire for plants “upgraded soon” Part I (similar questionnaires for the categories “new plant” and “upgrade soon”),

начало действия станция на настоящей момент:	год
начало действия будущей станции:	год
расчетная производительность станция на настоящей момент:	единиц населения (ен)
расчетная производительность будущей станции:	ен
бывшая нагрузка	ен
токовая нагрузка	ен
	1 единица населения (ен) 60 г биологическое потребление кислорода (бпк) в день или: 110 г химическое потребление кислорода (хпк) в день или: 11 г N (азот) в день или: 1,7 г P (фосфор) в день
средний суточный объем притока станция на настоящей момент:	кубических метров в день
средний суточный объем притока будущей станции:	кубических метров в день
концентрация притока:	
бпк	миллиграмм в литр (мг/л)
хпк	мг/л
N (общий)	мг/л
Аммоний NH ₄	мг/л
P (общий)	мг/л
Фосфат PO ₄	мг/л
фактическая концентрация стока:	
бпк	
хпк	
N (общий)	
Аммоний NH ₄	
P (общий)	
Фосфат PO ₄	
взвешенные твердые частицы	
степень очистки углерода (C)	%
степень очистки азота (N)	%
степень очистки фосфата (P)	%
описание конфигурации настоящей и будущей станции - ступени очистки:	
инвестиции (сумма) на станцию на настоящей момент:	€
затраты на строительство (если известно)	€
затраты на машинное и электрическое оборудование	€
инвестиции (сумма) на будущую станцию:	€
затраты на строительство (если доступный)	€
затраты на машинное и электрическое оборудование	€

Russian Questionnaire for plants “upgraded soon” Part I

расходы по эксплуатации:	сейчас:	будущие:		
среднее получение осадка сточных вод			тонн сухой массы (см) в год	
концентрация азота в осадке (N)			г/кг см	
концентрация фосфата в осадке (P)			г/кг см	
тип обезвоживания осадка				
тип удаления осадка				
расходы по обращению осадка станции на настоящей момент:				
расходы при обезвоживании осадка		€/тонна см		
расходы при сбросе осадка		€/тонна см		
расходы при сжигании осадка		€/тонна см		
расходы при сельскохозяйственном применении осадка		€/тонна см		
другой способ обращения осадка и связанные с ним расходы		€/тонна см		
потребление электричества до модернизирования:		кВт-ч./год		
цена электричества с модернизировании:		€/кВт-ч.		
обращение биогаза с септиктенков:	сейчас:	будущие:		
количество биогаза			кубических метров в год	
эффективность использования энергии системы совместного производства теплоты и электроэнергии			%	
производство теплоты и электроэнергии			кВт-ч./год	
продукция электричества			€	
затраты на систему совместного производства теплоты и электроэнергии	сейчас:	будущие:		
число занятых на станции			€ в месяц	
средняя зарплата персонала			€ в месяц	
средняя зарплата в секторе строительства				
химикалии	сейчас:	будущие:	сейчас:	сейчас:
полимеры			кг/год	€/кг
осадитель (какой продукт?)			кг/год	€/кг
дезинфицирующее средство (какой продукт?)			кг/год	€/кг
реагенты в лаборатории (только цену)			кг/год	€/кг
налог на сток				
другие расходы				
настоящие допустимые концентрации в стоке:				
бпк		мг/л		
хпк		мг/л		
N (общий)		мг/л		
Аммоний NH ₄		мг/л		
P (общий)		мг/л		
Фосфат PO ₄		мг/л		
взвешенные твердые частицы		мг/л		
будущие допустимые концентрации в стоке:				
бпк		мг/л		
хпк		мг/л		
N (общий)		мг/л		
Аммоний NH ₄		мг/л		
P (общий)		мг/л		
Фосфат PO ₄		мг/л		
взвешенные твердые частицы		мг/л		