

**COMPANY WITH LIMITED LIABILITY «NavEcocervis»**

**CLOSING STATEMENT  
UNDER THE CONTRACT ON RENDERING  
CONSULTATION SERVICES  
№ CS-NPS-Arctic-05/2008**

**Between**

**ESTABLISHMENT  
«EXECUTIVE MANAGEMENT OF THE RUSSIAN PROGRAM OF THE  
ORGANIZATION OF INVESTMENTS INTO ENVIRONMENT  
IMPROVEMENT»**

**COMPANY WITH LIMITED LIABILITY «NavEcoservis»**

**«WORKING OUT OF TECHNOLOGY OF  
BIOSCRUBBING OF GROUND PLOTS,  
CONTAMINATED BY OIL PRODUCTS,  
IN THE ARCTIC CONDITIONS»**



**Murmansk**

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**The name:** «Working out of technology of bioscrubbing of the ground plots contaminated by oil products, in the Arctic conditions»;

**The basis:** the Contract № CS-NPA-Arctic-05/2008 from 01.07.2008 years (further the Contract);

**The customer:** Organization «Executive management of the Russian program of the organisation of investments into environment enhancement» (EM RPOI), registered to the address: 117218, Moscow, street Krzhizhanovsky 23/5, (the mail address: 119991, Moscow, GSP-1 the Lenin avenue, 19);

**The abstract:**

The introduced report sums up works under the Contract № CS-NPA-Arctic-05/2008 from 01.07.2008 years (further Work). In a closing statement remarks and wishes of the specialists who were present at a seminar which one has gone on within the limits of V Stage of Works are allowed.

In the report are introduced:

- Results of analytical works on study of the Russian and foreign experience of bioscrubbing of soils after pollution by oil products in the conditions of low temperatures;
- Results at a choice and the equipment of exploratory range; the Plan of a location of exploratory range;
- Results of realisation of full scale observation and laboratory analysis of samples;
- Results of analytical works on treatment of results of laboratory analysis of samples;
- Results of development and submission of the project of the Management on realisation of bioscrubbing of the soils contaminated by oil products, in the Arctic conditions;
- seminar Results on discussion of the received results, and also the Management project on realisation of bioscrubbing of the soils contaminated by oil products, in the Arctic conditions and propagations of positive experience.

In the report, including conclusions about achievement of objects in view and the decision of the problems delivered within the limits of the contract are introduced.

On the basis of conclusions vision of progressing of experiment is introduced.

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## 1. Introduction

Extraction and haul of oil and oil products is concentrated on territory of the Russian Federation and develops in territory of federal districts, including possessed in the conditions of the Far North. Thus, all technogenic load from conducting the produced directions of economic activities is offset in places of an accumulation of objects on which one the circulation with oil and oil products is led. One of fields with a developing transport infrastructure of oil and oil products is the Murmansk area.

Volumes of haul, crossing and oil storage and oil products have several times increased in Murmansk area for the last 6 years. Simultaneously with growth of volumes of transported bulk-oil consignments marine, railway and motor transport odds of originating of the emergency and non-nominal situations, resulting in to extreme situations have increased.

Growth of risks of originating of extreme situations linked to oil spills and oil products (further - ES(O)) in territory of Murmansk field, and also water areas of the Kola and Kandalaksha bays, demonstrates necessity of progressing of measures on environmental safety supply in a part not only preventions, but also liquidation of the most interquartile and greatest possible ES(O).

Practice of liquidation of emergency floods of oil in the sea testifies what even in case of flood incident at essential removal from a shore and under condition of a duly response of all salvage and rescue services, pollution of offshore coastal strip and the inshore territories is imminent, threatening by ecocatastrophe.

World experience of realisation of actions for abandonment of consequences of slicks demonstrates, that in the conditions of the Arctic seas depending on a kind of oil product, remoteness of the flood from a shore and an offshore coastal strip contamination level it is possible to assemble from environment mechanically only 20-30 % of the petroleum poured as a result of an accident. The most labour-consuming is work under the tax of petroleum from offshore coastal strip. It is linked, first of all, by that the petroleum which has got to soil requires for its tax of attraction of a wide spectrum was function the different engineering and the big manpower resources. At abandonment of consequences of such accidents of technology of sweeping guess use of a mechanical cleaning with application of manual labour and a manpower considerable quantity. On reading of a capping pass of a ground (0,5-1 m), and in case of availability of large fragments of hard rocks - their withdrawal works are thus effected for realisation of treatment by means by surface active agents (further - SAA).

The basic traffic transferred through port Murmansk of oil products is massed along coast of Kola peninsula, in difficult climatic parameters, along a shore with not developed net of roads and human settlements. All these aspects complicate not only realisation of operations on localisation, but specially on liquidation ES(O). Paramount there are questions: deliveries in zone ЧС of sufficient forces and means for realisation of all works on localisation and liquidation ES(O); the organisations of exportation of the polluted ground to a place of time stowage and the subsequent salvaging.

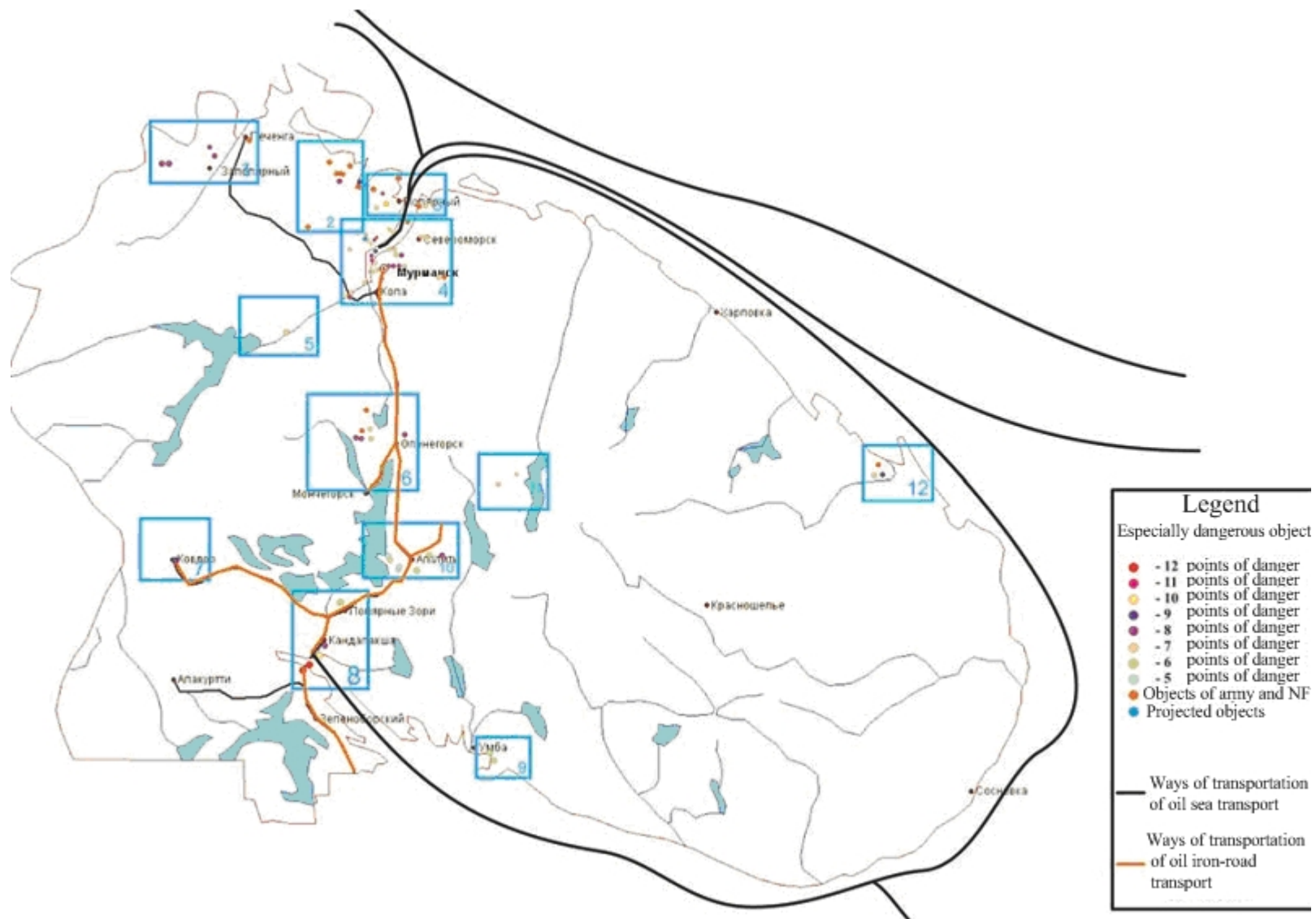
The analysis carried out within the limits of work has demonstrated, that in Murmansk and Murmansk area there are no free prepared platforms (sludge tanks), including ranges on which one it is possible to arrange the petropolluted ground or a sludge.

The analysis of number of hazardous industrial and potentially hazardous objects in territory of Murmansk area, and also their classification by significances as the most interquartile, and the greatest ES(O), have demonstrated, that focusing of objects with the max significance of flood equal regional (from 500 t to 5000 t), is greatest on water area and in an inshore part of Kola bay. The map of zones of a layout of ecologically hazardous objects in territory of Murmansk area is introduced on the picture 1.

Calculation of interquartile plotting scales ES(O) allow to draw a conclusion about impossibility to prevent hit on a oil product shore, so about necessity of looking up of the most effective and secure for environment of the technological approach to restoration of the polluted territories.

Besides recovery of territories disturbed by industrial activity was very relevant to save those plots of territories of Murmansk area which one have not tested on itself technogenic effect.

In Murmansk area the fund of objects of prirodno-reserved significance is created. The produced fund is a hull of environmental safety of region. The fund includes Especially protected natural territories (EPNT) which one ensure conservation of ecosystems, rare safeguarded kinds of animals and plants. One of reference directions of the produced work is learning of methods of drop of consequences of ecological extreme situations linked to oil spills and oil products in territories EPNT of Murmansk area.



Picture 1 Map of a layout of ecologically hazardous objects in territory of Murmansk area

In world practice, and also in territory of the Russian Federation there are different approaches to restoration contaminated by petroleum and petroleum of lands. Eurysynusic: physical and chemical (flushing of a ground of SAA, heat treatment); biological (with use of biological preparations) and the combined methods of extirpation with oil contaminations of soils and soils. Specially it is necessary to notice at that, that use of SAA in each separate event should be strictly reasonable, that neither SAA, nor products of their moulding did not become a complementary polluter of biosphere and did not render toxic effect on soil biocenosis.

Recultivation of the soils contaminated by petroleum possible as at-sight (in-situ) flood, and on special ranges (ex-situ).

Absence of specialised ranges for work with a hazwaste on territories of Murmansk field, and also remoteness of areas of interquartile oil spills and petroleum compels to pay attention to all complex of works with the petropolluted soils and soils at-sight (in-situ) of flood.

One of technological approaches perspective and harmless to environment in clearing is the biological recultivation. The approach allows not only to remove pollution in a flood place, but also to reduce risk of effect of pollutants per capita and environment during extraction, transportation and restoration of the polluted soils. Besides, the produced method does not require building and the organisation of a difficult production cycle, and allows to make works directly in a place of accident. The biological recultivation is widely enough applied in territory of the Russian Federation, including in the Moscow and Leningrad areas, Usinsk Republic Komi area, Krasnodar territory.

The biological recultivation is based on difficult chemical and biochemical processes of moulding of a hydrocarbon of petroleum to ecologically harmless substances of carbon dioxide and water. For the microorganisms participating in produced process, a hydrocarbon is the natural power supply promoting their active ability to live and active reproduction therefore there is a consumption of pollution by the introduced microflora up to its complete disappearance.

In our study following approaches in work with the polluted soils are used: biostimulation in situ (at-sight pollution) and bioaugmentation (biomeliorating).

The maiden approach is based on stimulation of the natural microorganisms naturally containing in polluted soil and potentially capable to utilise a contaminant, but not capable it to do effectively in the absence of a complete set of nutritional ingredients (nitrogen, phosphorus, potassium). In this case during laboratory researches with use of formation samples of the polluted soil instal, which additives and in what quantities should be introduced to the polluted soil to

stimulate growth of the microorganisms, capable to utilise a contaminant.

The produced campaign can be used in case potential activity of microflora of the polluted soil is high. As a rule, it is advanced by several factors, basic of which are concentration of a contaminant in a substratum and nature of pretreatment of a substratum at a technical stage.

The second approach is based on entering concerning considerable quantities of specialised microorganisms which one have been dedicated in advance from various pollution, or are genetically modified. Thus, from all spectrum choose that microorganism which one most effectively utilises the produced contaminant. The culture of microorganisms chosen thus then breeds in ферментерax in the conditions approached to conditions of polluted soil. The multiplied microorganisms in indispensable volumes are introduced to the polluted soil. Thus it is possible to introduce and nutritional additives. Bioaugmentation is expedient for using under following circumstances:

- a) the contaminant badly gives in to moulding by microflora even in the event that for it growth optimum conditions (biostimulation has appeared inefficient) are created;
- b) the contaminant has got to soil as a result of recent flood of organic compounds;
- c) physical and chemical performances of a place of pollution do impossible growth of natural microflora;
- d) there is a real possibility to accelerate time bioremediation and-or to meliorate its quality (to reach lower significances of residual concentration of a contaminant).

However, the major factor influencing activity of process of breaking down of a hydrocarbon in soil by petrooxidizing microorganisms, soil-climatic conditions are.

Keeping up of optimum and sufficient soil-climatic conditions for effective work of bacteria - one of the major problems in the decision of a question of application of a biological recultivation.

## **2. The purposes and problems, paths of their decision. The work plan**

The purpose of the held works - development of technology of water treatment of the peephole petropolluted plots, suitable for Russian and foreign parts of the Arctic region, and propagation of the received positivegoing expertise

For object in view achievement following problems have been advanced:

- Realization of the analysis of the Russian and foreign experience of bioscrubbing of



soils after pollution by petroleum in the conditions of low temperatures. A choice of biological products, optimum for use in the conditions of low temperatures of the Arctic region, on water treatment of the soils contaminated by petroleum;

- Development of regimes of increase of activity of biological products for recultivation of the petropolluted soils (soils) in high widths;
- Development of regimes of activation of habitability of native petrooxidizing microorganisms;
- Development of methods of bioscrubbing of soils after pollution by a petroleum hydrocarbon in high widths and opening-up of the project of the Management on realisation of bioscrubbing of the soils contaminated by petroleum, in the Arctic conditions;
- Realization of a seminar by results of the project and propagation of the received positivegoing expertise among interests in the form of the Management project on bioscrubbing realisation.

Within the limits of the decision of tasks in view the plan of work consisting of 5 items has been designed:

- 1) the Stage 1: the Analysis of the Russian and foreign expertise of bioscrubbing of soils after pollution by petroleum in the conditions of low temperatures.
- 2) the Stage 2. A choice and the equipment of exploratory range.
- 3) the Stage 3. Realisation of full scale observation and laboratory analysis of samples for eliciting of optimum types of biological products and regimes of their use for various types of petroleum.
- 4) the Stage 4. The analysis of the received results and development of the project of the Management on realisation of bioscrubbing of the soils contaminated by petroleum, in the Arctic conditions.
- 5) the Stage 5. Opening-up and realisation of a seminar for discussion of the received results, the project of the called Management and propagation of positivegoing expertise on bioscrubbing of the soils contaminated by petroleum, in the Arctic conditions.

### **3. The analysis of the Russian and foreign experience of the biological Water treatments of soils after pollution by petroleum In the conditions of low temperatures**

To Russia and abroad drugs of bioscrubbing of the soils contaminated by petroleum and soils are used predominantly in areas moderated and southern latitudes.

The method of bioremediation soils is based on use of the drugs produced on the basis of active cell material углеводородокисляющих of bacteria.

By present time the big material on the importance of microbiological processes of water treatment of natural habitats from a petroleum hydrocarbon is accumulated. It however concerns basically water treatments of aqueous water areas at oil spills and in much smaller extent of soils.

One of vivid examples of performance of a method of bioremediation soils are results of abandonment of consequences of petroflood in Usinsk Republic Komi area. In the course of works various biological products, methods of application, stimulating agents have been investigated and applied. The expertise received by specialists at works in Usinsk is used by us at selection of technical approaches in the conditions of the Arctic region.

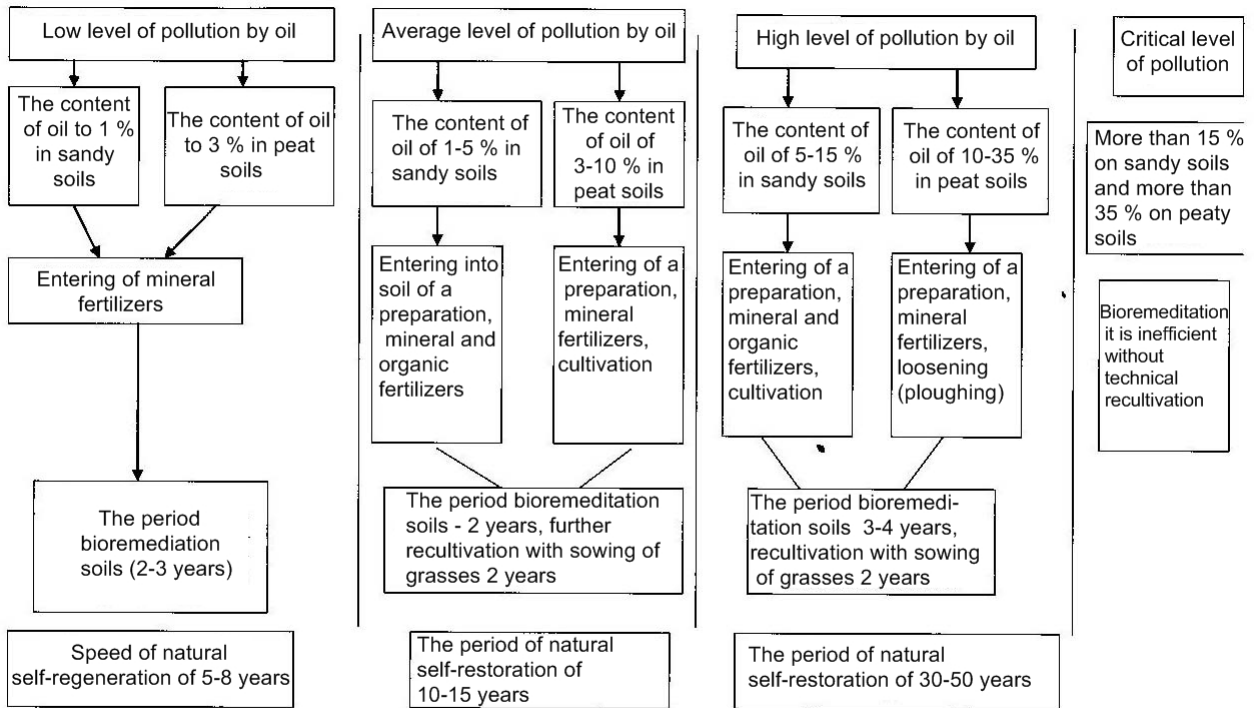
The time gap is indispensable for natural selfrecovery of sandy soils with oil pollution from 5 to 15 % in 30-50 years. While the period of bioremediation with use of biological products abbreviates this term till 3-4 years. It, in turn, detects the big outlooks of the produced method at abandonment of consequences of large scale accidents of petroleum.

Within the limits of the held works on the Stage 1 us:

- 1) effect of petroleum on soil and influencing of external factors on selfrecovery processes (item 2.1 Is learnt. The report on the Stage №1 Contracts № CS-NPA-Arctic-05/2008).
- 2) methods of bioremediation (item 2.2 Are considered. The report on the Stage №1 Contracts № CS-NPA-Arctic-05/2008).
- 3) performances of domestic and foreign biological products for sanitation of soils of petroleum (item 2.3 Are considered and compared. The report on the Stage №1 Contracts № CS-NPA-Arctic-05/2008).
- 4) Results of bioremediation soils Are analysed at abandonment of consequences of petroflood in Usinsk Republic Komi area (item 2.4. The report on the Stage №1 Contracts № CS-NPA-Arctic-05/2008).

By results of works the Schema of activation of moulding of petroleum in soil with allowance for source concentration of oil contamination and the substratum type, introduced on drawing 2 is designed.

**Picture 2 Schema of activation of moulding of petroleum in soil with allowance for source concentration of oil contamination and substratum type**



Conclusions on result of studies within the limits of the Stage of 1 works:

- In the conditions of the North use of microbial drugs more effectively in comparison with agrobiological receptions of recultivation. However, in certain conditions activation of native microflora can produce a positive effect.
- It is necessary not less 3-4th years for reception of a positive effect at sanitation of petropollution by biological methods in the conditions of the Far North.
- Biological products are necessary for picking up, being based on specificity of their development (the preparation was initially developed for what petroleum, soil-climatic conditions, in what range of concentration of pollution it is active).
- Application of biological products on the basis of native углеводородокисляющей microflorae is the most effective.

- All experiences are necessary for spending on 3-5 times (After creation of experimental installation it is necessary to advance number of repetitions of experiences. Recommendations about this question contain in the special literature [Fajn V. B, Kamenir E.A., Znaev A.S. - the Choice of optimum number of repetitions at the experiment organisation. M and E s.h-va № 10, 1980]. Normally researchers expect the number of the repetitions is minimum necessary for maintenance of the set maximum permissible error. In practice even such statement of a problem causes certain difficulties. Therefore, as a rule, experimenters accept the minimum number of repetitions  $n$ , equal to three.).
- The greatest effect is observed at double-triple application of biological products. (I.e. it agree operating instructions of application of the biological products introduced for experiment by producers of biological products, of some drugs 2-3 times) are necessary to retry depositings.
- Application of biological products most effectively simultaneously with agrotechnical receptions.
- Preliminary activization of biological products (opening-up of working slurries) is recommended.
- At a finishing stage crops of most stable of the tested grasses are recommended.
- Irrespective of a method of stimulation of substrata for the second year care of recultivated land is necessary (having sat down grasses, supplementary feeding by artificial fertilizers).
- The humidification factor is relevant. However rehumidification below zero influences growth of sowed cereals.
- Nature of sanitation of petroleum of sandy and peat substrata hardly differs.
- Entering of artificial fertilizers necessarily.
- Deoxidation of soils causes fall-off of potential of selfrecovery of soils.
- At neutralisation of soil effect on number of microorganisms is not revealed.
- The the background index pH soils is more strongly sheared in the acidic party, the substratum neutralisation (oppression of native microflora), however neutralisation of soils is less favorable is favorably mirrored in growth of recultivating grasses.
- Loosening - promotes an essential intensification of moulding of petroleum.
- Entering of a sorbent into soil succumbs to loosening reception a little.
- At impossibility of loosening (the close bedding of a frozen ground, inaccessibility of area of water treatment to engineering) is recommended entering of organic sorbents (along with biological products).

- It is necessary to expect and monitor strictly norms and doses of application of fertilizers, drugs, grasses, a kind and frequency of treatments.
- Redundant doses of artificial fertilizers cause fall-off of potential of selfrecovery of soils.

5) results of an experimental backfill of expertises with use of biological products in Murmansk in 2007-2008 of (item 2.5 Are resulted. The report on the Stage №1 Contracts № CS-NPA-Arctic-05/2008).

Analyzing results of a backfill in 2007-2008. It is possible to draw conclusions:

- About possibility and productivity of application of a method of bioremediation the petropolluted soils in the conditions of Murmansk area.
- The summer period in Murmansk area and adjoining fields is short enough and compounds only 3-4 months. This period can be insufficiently for complete course realisation биоремедиации. Besides, originating of a distress of petroflood does not depend on a season and the requirement for application of this method can arise not only in the summer. Thus defensive possibilities of the nature are not borderless. This one more of the bases for a backfill of the produced expertise on the threshold of winter.
- Skilled studies have demonstrated, that investigated bacteria have gone through winter conditions and became more active with invasion of warm days. The truth their number was abbreviated. But the fact of their survival says that at invasion of the warm period of a bacterium are capable to become more active and work on on restoration of the polluted ground. The produced conclusion is specially relevant for remote areas.
- Upon termination of the period of work of bacteria is planned to proceed restoration of soils with the help of phytoremediation which one is the final stage of bioremediation. The further monitoring of experiment will allow to draw a conclusion about influencing of vegetation on process of recultivation of lands, about productivity and an extent of this effect.

6) recommendations about the organisation of studies within the limits of the contract № CS-NPA-Arctic-05/2008 Are resulted. (Item 3. The report on the Stage №1 Contracts № CS-NPA-Arctic-05/2008).

Having analysed data on biological products, allowing for expertise of works in Usinsk and

an experimental backfill of expertises in Murmansk, it is possible to draw following conclusions:

- Because data on foreign drugs are very bounded and thus there is no information on advantages of their performance before domestic, application of the Russian drugs is preferential;
- At use of domestic biological products there are no complications with the organisation of their delivery;
- For realisation of studies drugs «Microzim «PETRO TRIT», «Roder» and «Devoroil» are recommended. Last - it is recommended by Establishment «Executive management of the Russian program of the organisation of investments into environment enhancement» and, in turn, it was applied in 2007 to recultivation of the polluted soils on Archipelag ZFI;
- Drugs «Devoroil» and «Microzim «PETRO TRIT» are polybacteria preparations, drugs which one compound includes some species strains microorganisms. It allows to speak about their possibility to destruction various fractions. Besides, both drugs have wide ranges of working temperature and acidity of soils. They are easy in application, do not require special installations for activation of bacteria. The produced drugs are widely applied in Russia (including to water treatment of soils along tracks);
- In turn the drug «Devoroil » has capacity to complex moulding both dissoluble, and indissoluble fractions in water.

The basic advantages of drugs «Devoroil » and «Microzim «PETRO TRIT» consist in the following:

- Drugs are polybacteria preparations with high титром, hence, have wider adaptable and ecological possibilities at abandonment of oil contaminations, than the biological products created on the basis of one штамма of microorganisms.
- Drugs are economic in disbursing that is economic aspect at their purchase.
- Drugs save activity at low positivegoing ambient temperatures (5°C), that is specially relevant at remediation soils in northern regions.
- Drugs are capable to work in a wide range pH (from 4,0 to 9,0).
- Have high performance of water treatment (90-99 %).
- Are nontoxic, nonpathogenic, are ecologically sefe.

## **4. A choice and the equipment of exploratory range**

For realisation of actions for opening-up of range and an expertise backfill following works are held:

- A. A choice of a place for range housing;
- B. Range construction;
- C. The technical equipment of range;
- D. Development of the plan of work of biorange;
- E. A backfill of soils and the soils contaminated by petroleum and petroleum;
- F. Realisation of the primary analysis of samples of soils and earths;
- G. A backfill of expertise (biological products);
- H. Experiment accompaniment.

### **4.1. The range organisation**

The organisation and work on creation and the equipment of range has required, first of all, learning standard and a legal side of the manipulation with a material the contaminated petroleum, formed on territory of the Russian Federation.

In work federal acts of the Russian Federation in sphere of the circulation with waste metal (only 6 documents), communal requests to the circulation with waste metal (only 9 documents), documents on activity licensing under the manipulation with a hazwaste (only 4 documents), documents on a standardization in the field of the manipulation with waste metal (only 5 documents), documents under the state account and responsibility in the field of the manipulation with waste metal (only 4 documents), documents on economical regulation in the field of the manipulation with waste metal (only 7 documents) are analysed. The legislative base is introduced in the Appendix № 4 to the Report on the Stage №2 under the Contract № CS-NPA-Arctic-05/2008.

At work for choice places of position of range have been learnt to a request to places of time stowage of a hazwaste.

The experimentally range is possessed in range solid waste territory in the settlement Drovyanoe. The choice of a place of position of experimental range is caused by following conditions:

- a) Ranges are arranged outside of cities and other human settlements. The size of a sanitary

buffer from a residential construction to boundaries of range of 500 m (SNiP 2, tab. 12). Besides, the size of a sanitary buffer is updated at account of gaseous atmospheric emissions. Zone boundaries are installed on an isoline 1 maximum concentration limits if it leaves limits of a standard zone. Reduction of a zone less than 500 m is not enabled.

- b) Hydrometeorological. The choice of the locations of ranges is led with allowance for wind roses.
- c) Hydro-geological. On hydro-geological conditions the best are plots with глинами or clay loams and the groundwater possessed on depth more 2 m.
- d) Sanitary-and-epidemiologic. On the basis of materials of geologic and hydro-geological surveys organs of wildlife management and sanitary-and-epidemiologic supervision of a city (area, field, edges) issue the concluding about operability of the chosen plot under the range TBO system.

Complementary data on the held actions are introduced to subitem 1.2 - 1.3. The report on the Stage №2 Contracts № CS-NPA-Arctic-05/2008.

Development of the project of experimental range, and also work on construction was led according to rules and norms of the Russian Federation.

In cooperation with company Orko-Invest the experimental range by a total area 87 м<sup>2</sup> has been created. The range has engaged 2 parts: the basic and engineering. Both parts of range are broken down into the meshes (boxes), each mesh in the size 1 м<sup>2</sup> and contains volume of the polluted ground 0,5 м<sup>3</sup>. Thus, the number of meshes in both parts of range cumulatively compounds 87 pieces. The plan range solid waste and a plot under range building №2 Contracts № CS-NPA-Arctic-05/2008 are introduced in the Appendix 1 to the Report on the Stage.

Range members are introduced in Picture 3: the basic (a bookmark of expertises in natural conditions) and engineering parts (with application of a complex of technical decisions for preheating and compulsory soil aeration).

For realisation of building of range following works have been held:

- a) the schema of a backfill of range (Picture 4) Is designed;
- b) the choice of materials (the enclosure 2 to the Report on the Stage №2 Contracts № CS-NPA-Arctic-05/2008) Is effected;
- c) the choice of dodges Is effected.

The soil surface on which one the range is installed, has been covered by a hydroinsulating material. The inner surface of boxes was выстлана a hydroinsulating material that has allowed to

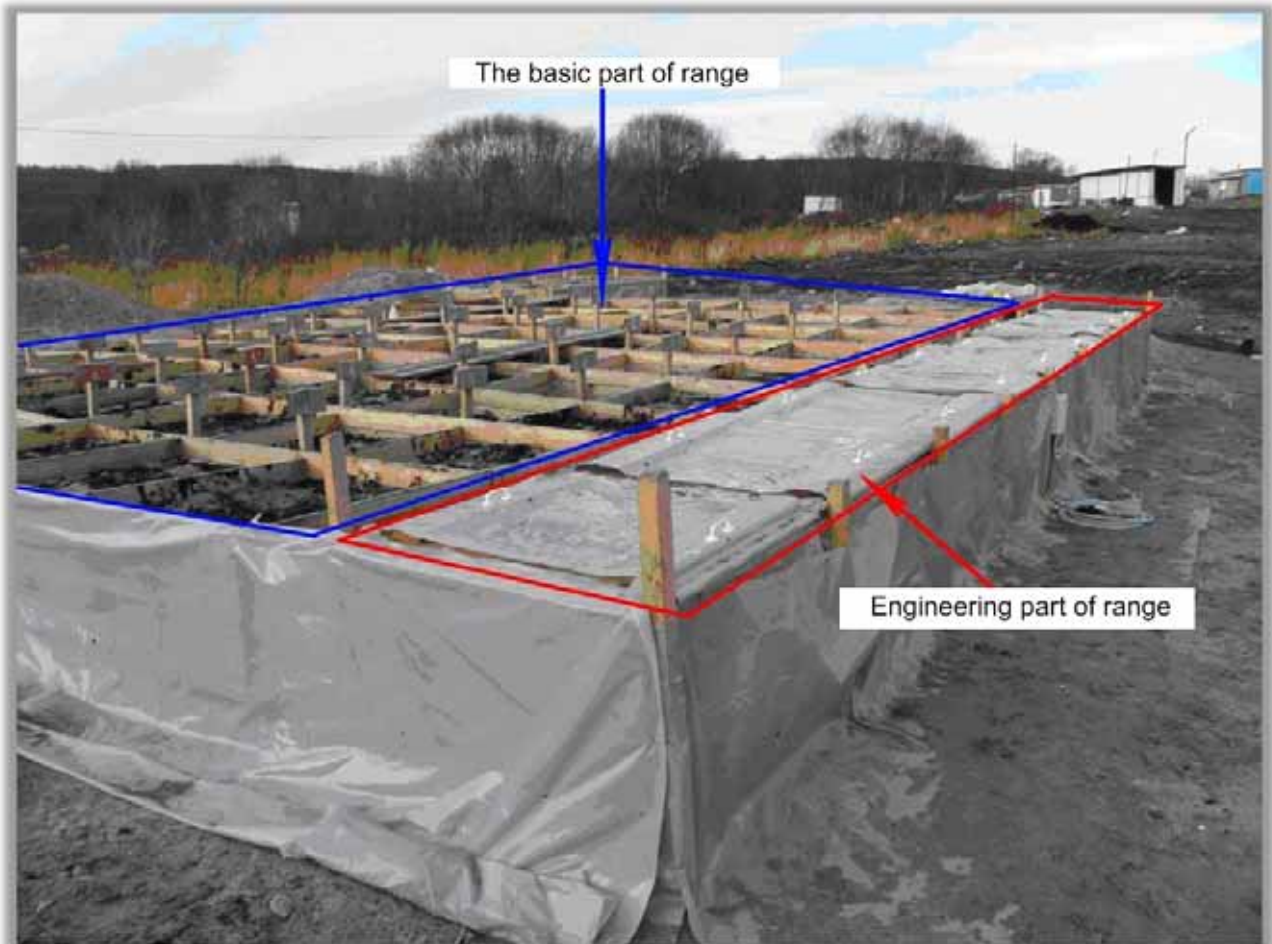


avoid infiltration of petroleum and the introduced biological products for limits of boxes.

During held earlier within the limits of the Maiden Stage of works of the analysis of an overall performance of biological products and their performances, achievement of the minimum sufficient conditions for a life, growth of bacteria, and also their effective work became a prime problem in the organisation of work of range during the cold period of year.

Us the technical decision of the produced problem was offered.

**Picture 3 General view of range**



The technical decision represents a self-reacting complex on heating and soil aeration. The complex engages use of following mechanisms: compressor installation, the diesel engine-generator, the heating cable, the punched hose, the thermostat, a thermal detector (Picture 5 a,b,c,d).

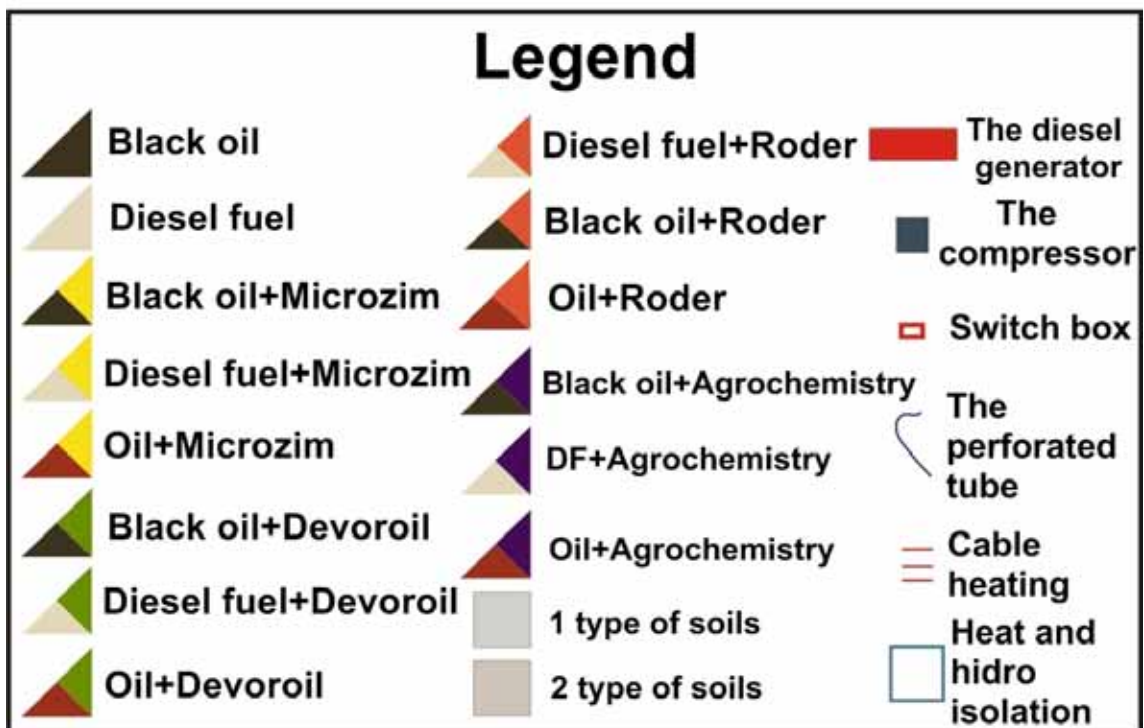
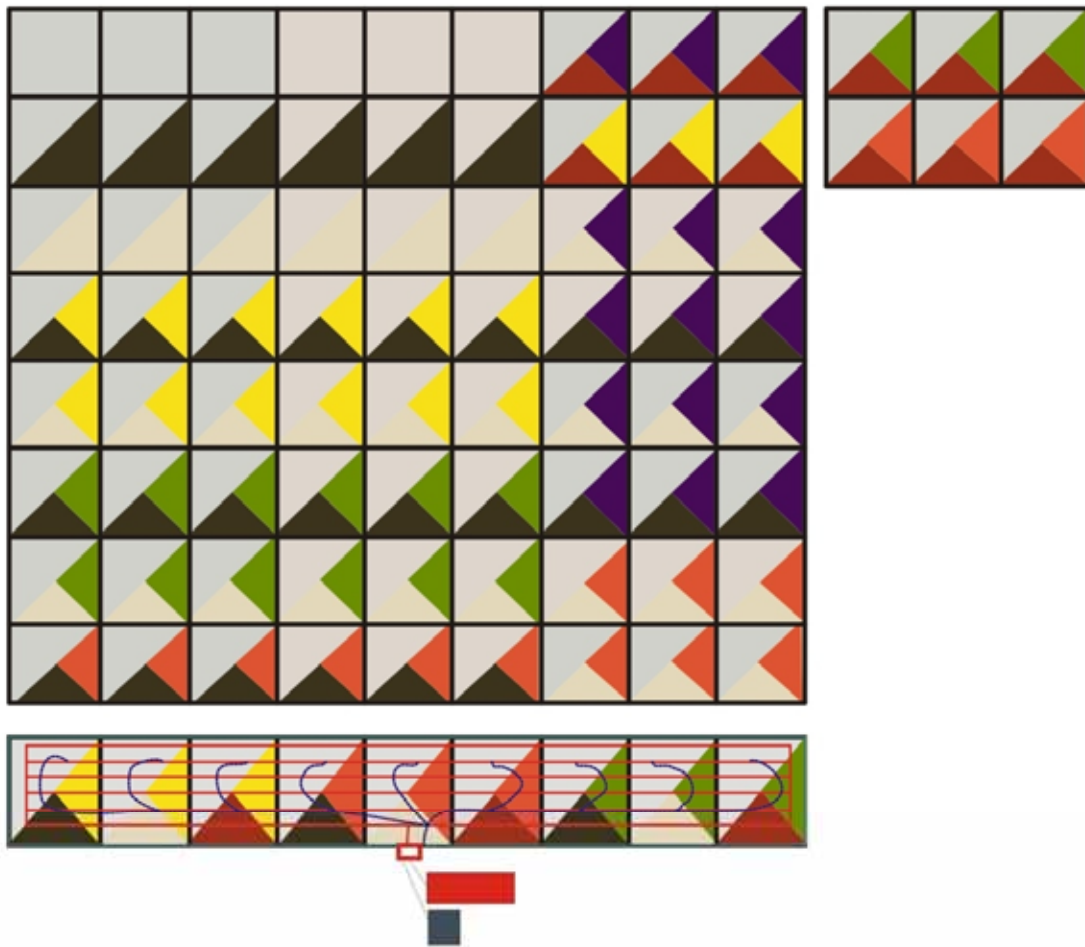
For effective work of all system some decisions in an engineering part of range have been made, namely: an inner part of the rigid body of an engineering part covered a complementary stratum of a hydroinsulating material, and also a stratum of a heat-insulating material. All meshes are barred by rigid caps, from an outer side hydroinsulating, and with inner - a heat-insulation layer.

As the complex operates:

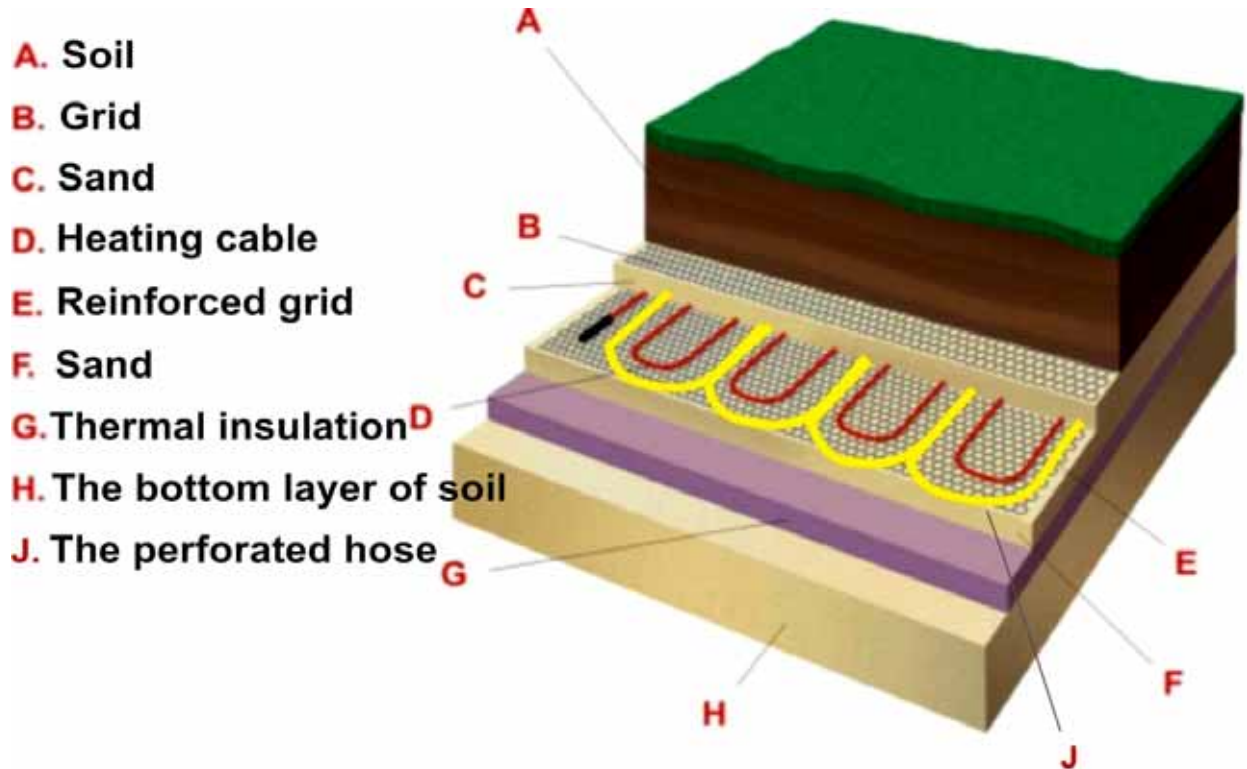
The generator gives voltage sufficient for functioning of compressor plant and a heating cable simultaneously, with allowance for operations in the conditions of low temperatures. Made on a desired shape the heating cable and the punched handsets going from the compressor, make heating and air intake to the polluted ground. The thermal detector fixed on an inner surface of boxes in a complex with the thermostat gives the chance to inspect cable heat.

**Picture 4**

## The scheme of a backfill of experimental range



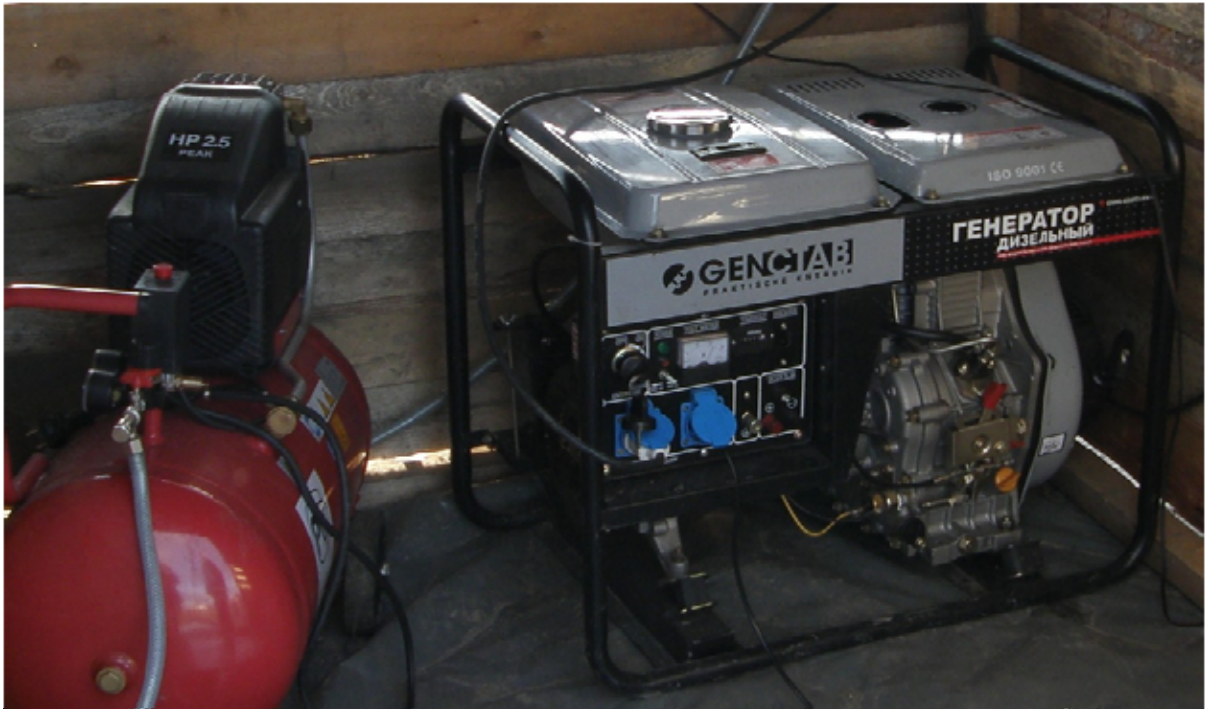
Picture 5a the Schema of a backfill of heating system and aeration in a ground



Picture 5b equipment Adjustment for range



**Picture 5c the Compressor and a diesel engine the oscillator**



**Picture 5d organisation System thermal insulator and dewaterings of meshes in an engineering part of range with stacking of a net of perforated pipes for soil aeration**



## 4.2. A soil backfill

The soil mantle of Murmansk field is characterised by the big diversity and integrated approach that is linked to variability of conditions of soil formation in the intercepted land forms. According to the Contract № CS-NPA-Arctic-05/2008 from 01.07.2008 and on the basis of data of the map of types and biogenesis soils (the Ecological atlas of Murmansk field), two kinds of the soils most typical for Murmansk region. On the map the predominating type of soils in a soil mantle within the dedicated outlines (Picture 6) is demonstrated.

Soils of Murmansk field on them biogenesis are partitioned on three groups:

I. Soils with low biogenesis,  $BS < 2$ : primitive and illjuvialno-gumusovye tundra soils, and also illjuvialno-ferruterous.

II. Soils with mean biogenesis,  $BS = 2-8$ : forest-tundra illjuvialno-gumusovye, gumusovo-ferruterous wood soils, illjuvialno-mnogogumusovye wood, torfjano-podsolic illjuvialno-gumusovye, torfjano-marsh riding, mountain.

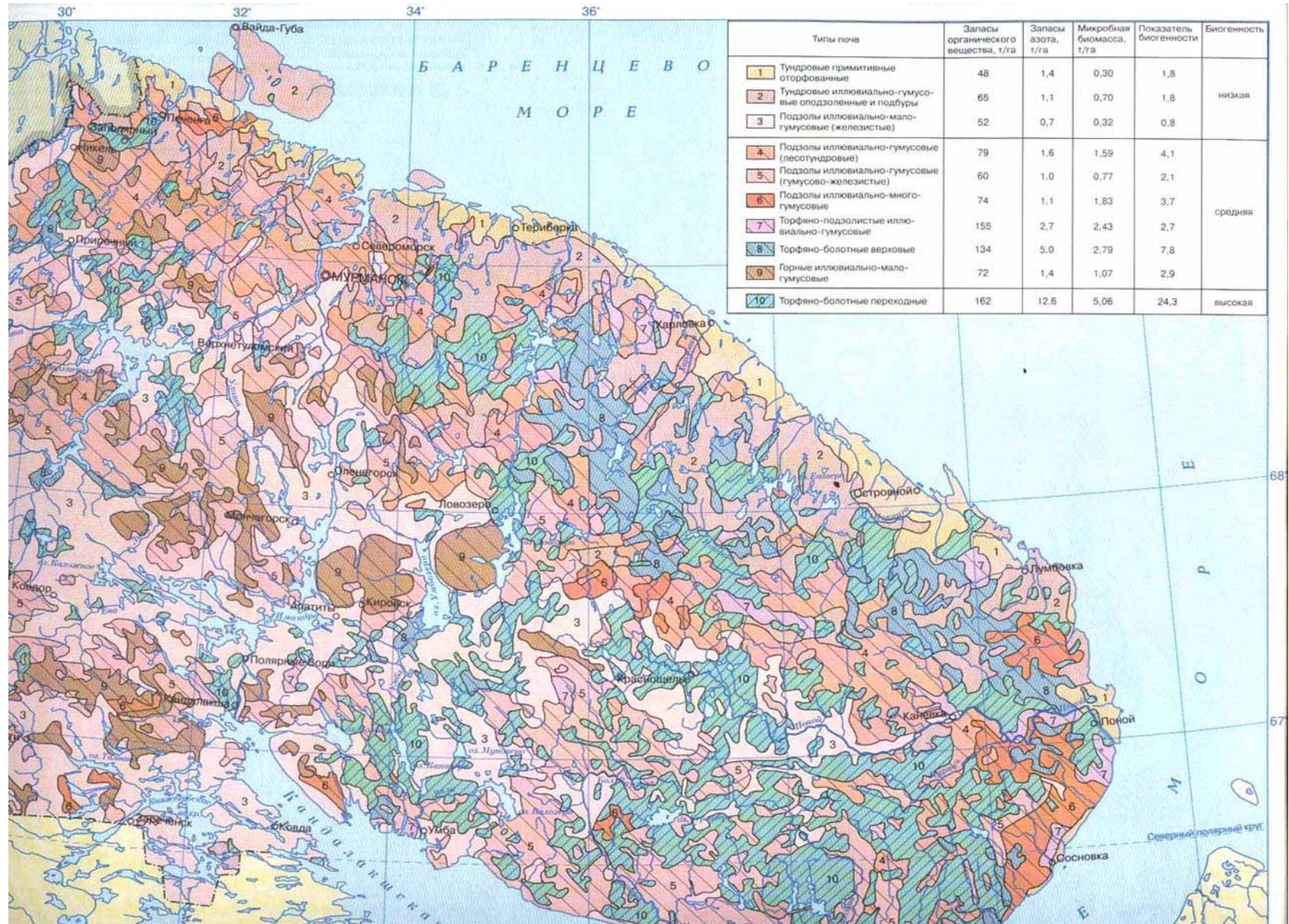
III. Soils with high biogenesis,  $BS > 8$ : the torfjano-marsh transitive.

The types of soils used in experiment are referred to I group and have low biogenesis ( $BS < 2$ ). It allows to speak about their low self-purging capacity and necessity of application of artificial methods of water treatment from oil contaminations.

In a range main body (meshes №№ 1-78) the method of application of frequency of expertises (each alternative of a bookmark contains 3 frequencies) is applied.

For study we had been chose the soils polluted by following petroleum: Boiler oil, diesel fuel, petroleum. The mass of the soil introduced to each mesh, has compounded about 480 kg.

**Pictures 6 Types and biogenesis soils of Murmansk area**



### **4.3. The contents of petroleum in soil on the beginning of works**

At application of a method of a biological recultivation of soils it is necessary to expect norms of addition of biological products. The quantity of an introduced biological product is advanced depending on a level of pollution of soil by petroleum.

In August, 2008, after work on range loading by the polluted soils, soil sample drawing on the contents of petroleum has been held.

Sample drawing and contents definition in them of petroleum are executed by specialists FGU «the Center of laboratory analysis and technical measurings on Murmansk area» (further - «CLATM on Murmansk area»). Copies of the Certificate of accreditation and the Appendix to it are resulted in the Enclosure 1 in the Report on the Stage 4 Contracts № CS-NPA-Arctic-05/2008. Hallmarks were sampled by a sampler from five various dots of each mesh, carefully stirred and acted on opening-up and the immediate analysis (pic. 7).

Results of analyses of the contents of petroleum in soil on the beginning of works are resulted in Report Table 2 on the Stage 4 Contracts № CS-NPA-Arctic-05/2008. Copies of protocols of definition of the contents of petroleum in hallmarks - in the Enclosure 2 to the Report on the Stage 4 Contracts № CS-NPA-Arctic-05/2008. On the basis of the received data the mean contents of petroleum in soil has compounded ~ 4-5 %.

**Picture 7. Sample drawing by specialists CLATM on Murmansk area**





#### **4.4. Calculation of norms of entering of biological products**

The cost of biological products settles up proceeding from a soil level of pollution at the beginning of works. A soil level of pollution (Report item 2.2 on the Stage 4 Contracts № CS-NPA-Arctic-05/2008) has compounded ~4-5 %, that is 40-50 g petroleum on 1 kg of soil.

Norms of the cost of biological products expected according to operating instructions of producers (Report item 2.3 on the Stage 4 Contracts № CS-NPA-Arctic-05/2008).

**Picture 8. Entering of biological products**



#### **4.5. Calculation of norms of entering of artificial fertilizers**

For effective work of biological products creation of a favorable nutrient medium is necessary, i.e. soils should be sufficiently enriched mineral members: nitrogen, phosphorus and potassium.

Entering of artificial fertilizers at a biological recultivation of soils ensures stimulation of natural microflora and creates a nutrient medium for petrooxidizing bacteria.

Works on account of norms of entering of artificial fertilizers since their defect will below zero affect growth of colonies of petrooxidizing microorganisms have been held, and the overabundance will lead acidification soils.

The factor acidification (on expertise of abandonment of emergency in Usinsk Republic Komi area) does not render negative effect on progressing of petrooxidizing bacteria, however, below zero affects a stage phytoremediation.

According to biological product directions for use «Roder», entering of mineral (Nitrogen-phosphorus-potash) fertilizers in the ratio C:N:P:K = 1:0,1:0,01:0,003 per unit of hydrocarbon pollution soils (g/kg) is recommended.

Types of soils used in experiment have low biogenesis (item 2.1. The report). For magnification of a saturation of soils by microelements, the norm of application of fertilizers has been augmented to agronomic norms.

During works the complex of the nitrogen-phosphorus-potash manures ensuring a nutrient medium for petrooxidizing microorganisms, containing in biological products has been picked up. Artificial fertilizers «Azofoska» and «ammonia caliche» used. Fertilizers are introduced in the ratio N:P:K=10:1:1

Fertilizers are prepared by specialists of lab GU «Murmansk UGMS» on analytical scales with a margin error  $\pm 1$  g.

**Picture 9. addition of artificial fertilizers**



#### **4.6. Actions for a backfill of biological products and artificial fertilizers**

On August, 14th, 2008 on a backfill of biological products and artificial fertilizers works have been held to skilled meshes of range.

Within the limits of actions works were held on:

- To soil humidification, gauging of temperature of soil substrate
- Activatings of biological products
- To depositing of artificial fertilizers
- To depositing of biological products
- Soil aeration

Before depositing of biological products into soil introduced artificial fertilizers (except for the meshes planned for depositing of a drug «Roder» where fertilizers are introduced directly to slurry).

According to the designed schema (picture 4) in meshes biological products were introduced. All biological products used in studies were exposed to pre-award activization that abbreviated time of transferring of microorganisms in an active phase at entering into the polluted soil.

According to operating instructions on biological products «Microzim «PETRO TRIT» and «Roder» have effected repetitive entering.

- «Microzim «PETRO TRIT» it was introduced repeatedly in 25 days after 1st entering;
- «Roder» - it is triple with a gap in 14 days between depositings.

«Microzim «PETRO TRIT» it is introduced by a method described in item 2.5.2 of the Report on the Stage of 4 Contracts № CS-NPA-Arctic-05/2008, in 25 days after the maiden entering. The drug«Roder »was introduced is triple in a gap of 14 days between depositings.

According to the work schedule on service of biorange the soil carefully stirred after each depositing of biological products (picture 10).

In detail actions are introduced within the limits of the Report on the Stage 2, and also to item 2.5. The report on the Stage 4 Contracts № CS-NPA-Arctic-05/2008.

**picture 10. Soil loosening**



## **5. Realisation of full scale observation and laboratory analysis of samples**

Within the limits of the third Stage of works on range actions have been executed on:

- To creation of the graph of service and range supply;
- The organisations a shift of a method of works on range.
- To check behind soil temperature;
- Having watered and to soil stirring;
- To compiling of graphs of sample drawing;
- To sample drawing by different subcontractors;
- To check of purity sample drawing;
- The organisations of protection of range;
- To a curbing of territory of range.

The complex of works on the third stage of the Contract has engaged:

- Work on progressing of experiment and keeping up of its purity;
- Sample drawing realisation on the contents of petroleum in soil, and also the microbiological analysis (the contents of the native and introduced bacteria);
- Realisation of laboratory analysis of the sampled samples of the soils polluted by petroleum and petroleum with introduced biological preparations;
- Work on technical and technological accompaniment of experiment.

Works on biorange it was led according to the graph.

According to Official body «Murmansk control on hydrometeorology and environmental monitoring» (further - HC "Murmansk UGMS") indexes of meteorological conditions were daily fixed: air temperature (in each 4 hours), quantity of settling out sediments, air humidity etc. (the enclosure 4 to the Report on the Stage 4 Contracts № CS-NPA-Arctic-05/2008). The graph is introduced in picture 12.

Gaugings of temperature of soil were effected by the soil thermometer of 1 times in two weeks (picture 11).

During all term of work check of work of the oscillator in an engineering part of range that has ensured keeping up of constant positivegoing temperature of soil was carried out.

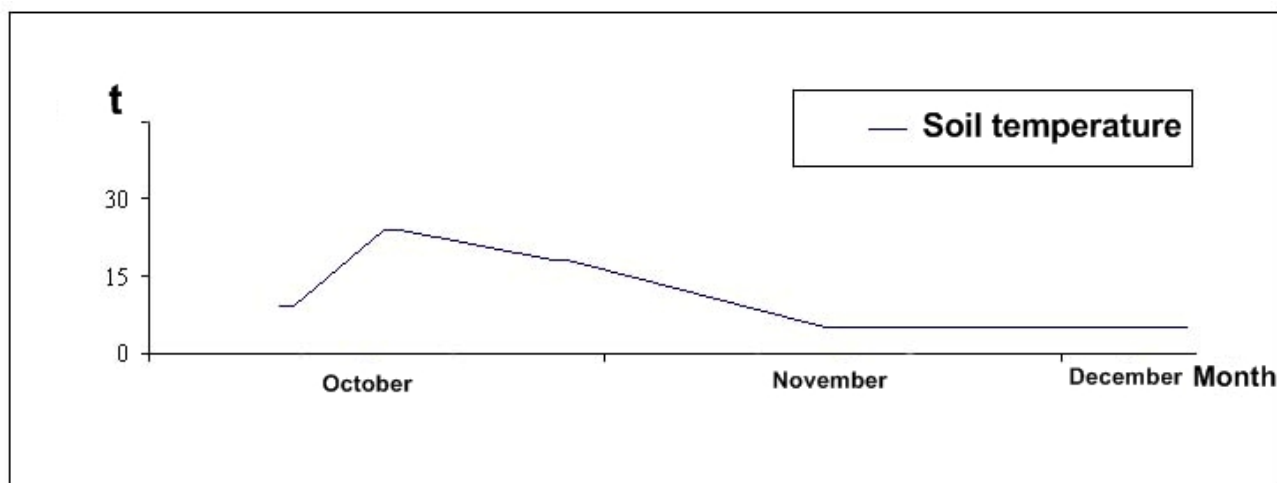
Throughout all period of studies loosening and soil humidification, to the optimal arguments recommended by producers of biological products was held

Sample drawing on the microbiological analysis was executed by specialists of lab of microbiology FGU «Murmansk CSM». Sample drawing was carried out according to GOST 17 and GOST 17.

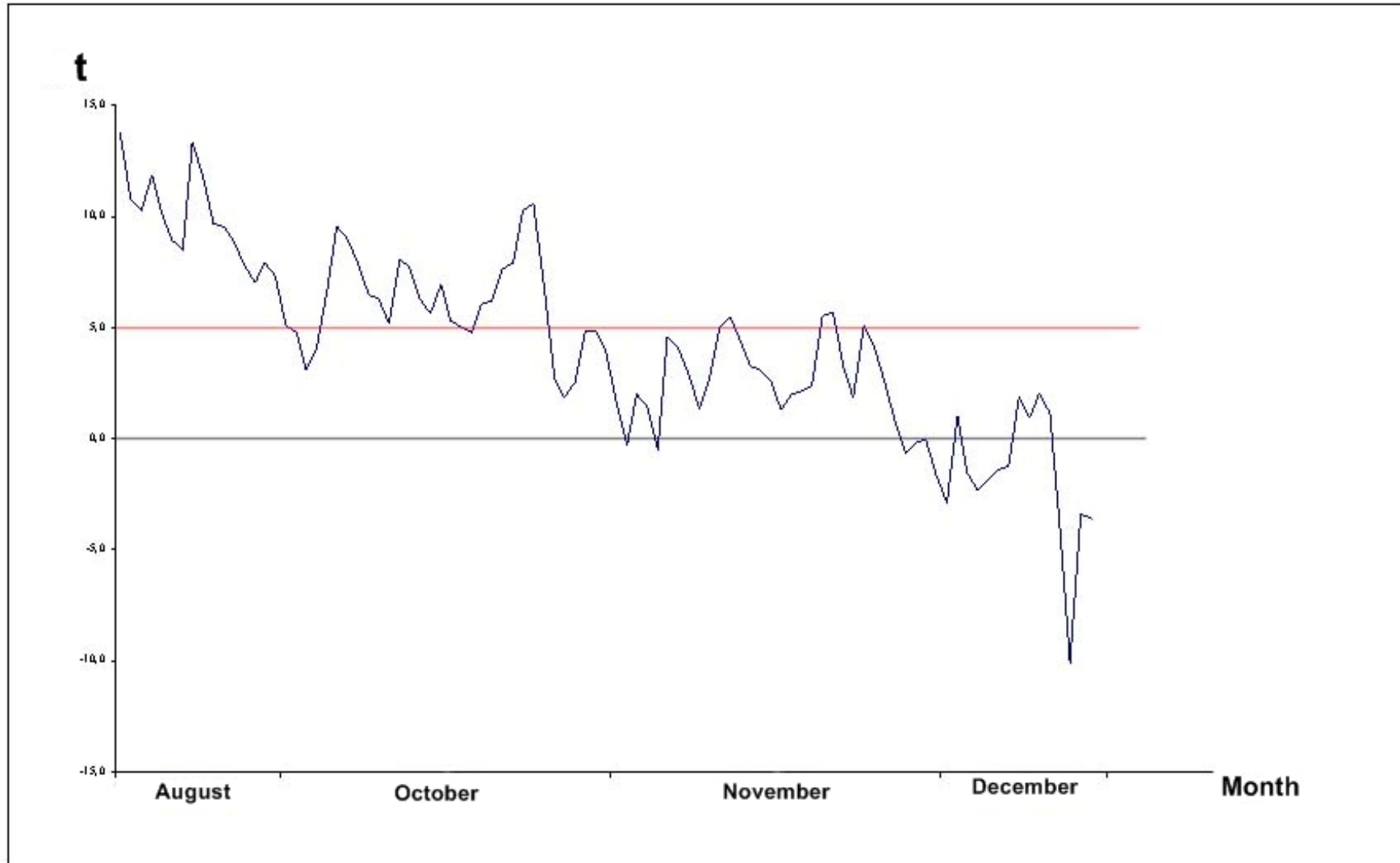
**picture 11. Measurement of temperature of soil**



**picture 12a. Dynamics of temperature of soil**



picture 12b. Dynamics of temperature of air



## **6. The analysis of the received results**

### **6.1. The analysis of the contents of oil products in soil**

Upon termination of the third stage of works under the Contract samples of soil for chemical analysis realisation on the contents of oil products (November, 2008 - in the basic part of range, December, 2008 - in an engineering part of range) have been repeatedly selected.

Results of analyses of samples on the contents of oil products in soil are shown and introduced in Report Table 4 on the Stage 4 Contracts № CS-NPA-Arctic-05/2008).

#### **By results of the received data it is possible to draw following takeouts:**

- The percent of weeding of soil of control cells (variants with the polluted soil without entering of biological products and artificial fertilizers) fluctuated within 0,0-0,6 %. It speaks about low self-cleaning ability of soil.
- At stimulation of native petrooxidizing microflora at the expense of entering of artificial fertilizers the result of decrease in the contents of oil products has made 0,7-2,1 % that speaks about possibility of application of agrotechnical receptions of recultivation of soils at low concentration of pollution (to 1-2 %).
- Application of biological products accelerates process of weeding of soil from petrocontaminants.
- At the cultural operations polluted by black oil, the greatest purification efficiency of soil the biological product «Roder» (has shown 4,5-5,3%). At pollution by solar oil - «Devoroil» (4,8-5,9%), petroleum - «Microzim (tm) «PETRO TRIT» and «RODER» (6,7%). The centre percent of weeding of soil with application of biological products has made 5,4 %.
- Black oil most hard gives in to process of biomolding. It is connected with its high viscosity. At hit in soil the produced contaminant does not permeate soil, and forms lumps. Oil product balling up has worsened an overall performance of biological products and has complicated process of creation of optimum conditions for work of microflora of soils (complexity of agitation, non-uniformity of distribution in soil). Attempt of agitation of the polluted substrate by means of a drill has not brought positive result.

- With a peat layer disintegration of oil products has passed in soil more effectively (on the average on 1,4 %). Peat has played a role of a natural sorbent and organic fertilizer is simultaneous.
- In an engineering part of range, at the expense of maintenance of constant positive temperature of soil (5+15°C), biological products have shown the big degree of moulding of oil product (average value - 9,9 %). The best result on weeding of soil from black oil and solar oil has shown a drug «Microzim (tm) «PETRO TRIT», petroleum -«Devoroil».
- To draw unequivocal takeouts in favour of this or that biological product by the received results it is inconvenient. The difference in a purification efficiency of soil depending on an applied biological product fluctuates on the average in limits  $\pm 1,6\%$ .

On the basis of the received results of researches of the contents of oil products in soil, it is possible to draw a takeout, that the biological recultivation with application bio biological preparations considerably increases velocity of weeding of soils from oil products, and application of engineering technologies allows to prolong and intensify this process.

The centre percent of weeding of soil of the basic part of range has made 5,4 %, an engineering part of range - 9,9 %.

For complete restoration of soils after oil contamination continuation recultivation works is necessary: repetitive additions of biological products and artificial fertilizers at invasion of a warm season with the subsequent phytoremediation.

The range has been mortgaged in the middle of August, 2008. Duration of the warm period has made 1-1,5 months. In case of work from the beginning of the warm season, the produced period in the Arctic conditions will make about 3 months.

On the basis of experience recultivation works in averages and southern latitudes of the Russian Federation, experience of abandonment of consequences of petrooverflow in Usinsk area of Republic Komi and with allowance for the results received during made researches, it is possible to assume, that for complete recultivation of soil at a level of pollution of 5 % 3-4 years is required.

That has formed the basis to such forecast of purification. First of all, it is necessary to recognise, that a season chosen for realisation of experiment, was unrepresentative. Average daily temperatures of air were in limits 7-9°C. The soil temperature was essentially below summer. Thus, the purification efficiency of soil from oil products without application of technology of preheating,



fluctuated limits of 5-6 % for 1,5 months until temperatures favoured to activity of bacteria. If to take for a basis of account of annual percent of purification of soils an index of 5-6 % it is possible to ascertain, that the chosen path will be erroneous, i.e. we do not consider work of bacteria in warm summer months.

Important was to show, whether realisation of weeding in the conditions of the marginal north is possible, but be used thus owes all warm period of year. Understanding it, we had been carried out the analysis of soil-climatic conditions of the summer period on which we have outstripped, that the centre temperature of soil during the summer period on Kola peninsula is similar to temperature corridor synthetically created by us in an engineering part of range. The soil purification efficiency in an engineering part has made order of 9,6 %. These indications us were are taken as mid-annual in the conditions of Murmansk area. Thus, with allowance for 3-4 months in a year of favorable for work of bacteria, the anticipated period of purification of the polluted ground can lay within 3-4 years (picture 15).

Having received total figures (3-4 years), having compared them with the Russian experience, including in Usinsk Republic Komi area, we can say with confidence that have received result with the sufficient degree of reliance, corresponding with results of other experiments and works in biological recultivation sphere.

It is necessary to notice, that the period of moulding of such pollution in natural conditions (without application of any methods of weeding) makes 10-15 years.

## **6.2. pH and soil moisture**

The analysis pH and dampness of soil substrates was executed by experts of laboratory of microbiology FGU «the Murmansk centre metrology and certification Standardizations» (further - FGU «Murmansk SCM»).

Significances pH soils were advanced on the universal ion metre with glass and silver-chlorid electrodes. Significances pH, close to neutral (7.0), are optimum for growth on a hydrocarbon of the majority of bacterial microorganisms. Significances pH the soils advanced during researches, are introduced in Report Table 5 on the Stage 4 Contracts № CS-NPA-Arctic-05/2008.

Reference samples of 1st type of soil had a neutral reaction of mediuum, 2nd type - close to neutral, that is the positive factor for ability to live of a microbiota and cultivation of plants.

In other variants the depressed level pH was observed. Further pH mediums in cells with addition of artificial fertilizers has a little grown, however sharp jumps it was not observed. In control cells pH mediums it was depressed. The produced fluctuations have not rendered effect on growth of colonies of bacteria-destructorov of petroleum.

Results of moisture determination of soil are introduced in Report Table 6 on the Stage 4 Contracts № CS-NPA-Arctic-05/2008.

At primary sample drawing the increased soil moisture (the optimum makes 40-70 %, the actual significance fluctuates within 64-82 %) that is caused by plentiful sediments in a sampling run is installed.

Further significances of humidity have approached the optimum. In cells with 1st type of soil higher indexes of humidity, than in cells with 2nd type are mainly noted. It is connected with the increased water-absorbing ability of the peat which is a part of 1st type of soil.

### **6.3. Microbiological researches**

The microorganisms decomposing petroleum, are natural representatives of soil microflora and fall into to bacteria of sorts *Micrococcus*, *Brevibacterium*, *Rhodococcus*, *Acinetobacter*, *Pseudomonas*, *Bacillus*, *Nocardia*, *Corynebacterium*, *Arthrobacter*, to mushrooms of genres *Actinomucor*, *Aspergillus*, *Penicillium*, *Streptomyces*, yeast *pp. Candida*, *Torulopsis*, *Rhodotorulla*, *Cryptococcus*, *Trichosporon*. From the transferred microorganisms of a bacterium of genres *Pseudomonas*, *Arthrobacter*, *Rhodococcus* and mushrooms of genus *Penicillium* are characteristic inhabitants of northern soils.

The microbiological analysis of samples is executed by experts of laboratory of microbiology FGU «Murmansk CSM».

In experiment used three kinds of bacteria preparations: «Devoroil», «Roder», «Microzim (tm) «Petro Trit».

Vegetative cells of not pathogenic strains of cultures *Rhodococcus* enter into a biological product compound «Devoroil» *sp.* Piece 367-2, *Rhodococcus maris* piece 367-5, *Rhodococcus erythropolis* piece 367-6, *Pseudomonas stutzeri* piece 367-1, *Candida lipolytica* piece 367-3.

The drug is active in temperature range from +5 to +40eC on a surface of an oil film and in a stratum of petroleum bed, is adapted for substrates by salinity to 150 g/l and is effective in a range

pH mediums 5,5-9,5. Products of biological degradation of petroleum and oil products do not render negative effect on ecosystems. It is delivered in the form of a dry powder with fine-crystalline inclusions of inorganic salts and biologically active admixtures. Drug action increases at application together with it of the artificial fertilizers containing nitrogen and phosphorus.

The biological product «RODER» represents a concentrate of the dehydrated not pathogenic, viable and active cells of bacteria-destructorov of the hydrocarbon evolved from soil - *Rhodococcus ruber* piece Ac-1513D and *Rhodococcus erythopolis* piece Ac-1514D.

The drug acts at a level of pollution petroleum and oil products to 25 %, but is most effective at low level of pollution (1-0,5 %). Efficiency of a drug is observed in wide temperature range from +8 to +30°C. An optimum pH 5. Working suspension of a biological product before entering dress mineral ingredients (nitrogen, phosphorus, potassium). Treatment is led during the summer period, frequency rate of treatments depends on a contamination level. At oil contamination high levels it is recommended to apply a biological product during 2-3 seasons.

The biological product of "Microzim" (tm) «PETRO TRIT» represents association from 12 strains oxidizing microorganisms.

The association includes bacteria of sorts: *Bacillus*, *Rhodococcus*, *Arthrobacter*, and also yeast, mushrooms. All of them are typical representatives of soils. These are nontoxic, not pathogenic and genetically not modified saprophytic oxybiotic and facultatively anaerobic microorganisms. The drug represents a homogeneous dry powder of yellow colour, contains biogenic elements and the additional power supply in the form of a corn flour. To apply a drug it is recommended at temperature of air from +10 to +50°C. Admissible pH soils in limits from 5 to 9.

The biological product is intended for bioscrubbing of soil, reservoirs, sewage from petroleum and oil products.

#### *Technique of definition of heterotrophic microorganisms*

Heterotrophic bacteria fall into to group of the bacteria consuming ready organic matter. The produced kind concern, including, and native oxidizing bacteria.

Number of heterotrophic bacteria of soil was advanced on fish-pepton a broth (FPB).

Sowings became a method of limiting delutings.

Cultivation microorganisms carried out at temperature 20°C within 3 days.

The availability of growth was observed on turbidity of medium.

The quantity of bacteria was advanced by method NVCH under the table Mac Kredy.

Studying culture properties microorganisms made after a subculture on a nutritious agar.

*Definition technique oxidizing microorganisms*

Number oxidizing bacteria was advanced on mineral medium of a following compound (г/л дист. Waters):  $K_2HPO_4 \cdot 3H_2O$  - 1,  $NH_4Cl$  - 2,  $MgSO_4 \cdot 7H_2O$  - 05,  $NaCl$  - 05,  $CaCO_3$  - 1,  $FeSO_4 \cdot 7H_2O$  - traces, solar oil (summer) - 1 about. %.

Shots of salts dissolved in water separately and mixed before sterilisation. Then lead up pH mediums to preset values (pH 7,0-7,2).

Sowings were made by a method of limiting delutings.

Cultivation microorganisms carried out at temperature 20°C within 1 month.

The availability of growth was observed on turbidity of medium or filming on boundary «diesel fuel-environment».

Quantity of bacteria advanced method NVCH under the table Poppy Креды.

Studying properties made after a subculture on agarlike mineral medium of the same compound with 1,7 %-s' contents of an agar.

***Dynamics of number of heterotrophic microorganisms of the basic part of range***

Sample drawing was manufactured for realisation of microbiological researches once a month during all period of researches to soil freezings.

Soil samples were selected before biological product entering that has allowed to analyse dynamics of growth of number of microorganisms.

Also it is single-pass (16.10.2008) sample drawing of soil after entering of biological products is made.

The produced bleeding has shown actual quantity of the bacteria which have reached of soil substrate, as a result of entering of biological products.

The partial destruction of microorganisms can be caused effect of an adverse external environment in the course of entering (for example, the depressed temperature of air, etc.). Also partially bacteria could remain on walls of the bottle used at entering.

Data of results of the analysis of number of heterotrophic microorganisms are tabulated the Report on the Stage 4 Contracts № CS-NPA-Arctic-05/2008.

Control variants at definition of growth of number of bacteria are cells of range without entering of bacteria preparations and artificial fertilizers (№№ 55-60), and also cells with background samples of soil (№№ 61-66).

Dynamics of number of heterotrophic microorganisms is introduced in the form of diagrams to subitem 3.3.4. The report on the Stage 4 Contracts № CS-NPA-Arctic-05/2008. Initial number of heterotrophic bacteria in variants without entering of bacteria preparations is identical. These significances more low, than in variants with the introduced microflora that is caused by entering of additional mass oxidizing microorganisms which also are heterotrophs. Further there is a slow accretion of number of heterotrophic microflora, the maximum will be reached in September.

Thus, it is possible to draw a takeout on adaptation of the most resistant kinds of bacteria to pollution conditions. The interval of growth of number of bacteria in control variants and in variants with the introduced artificial fertilizers fluctuates within one order.

Laws of growth of native heterotrophic microflora at the expense of entering of artificial fertilizers it is not revealed.

As a whole, the greatest number of bacteria is marked in cells with a drug of «Microzim «PETRO TRIT».

Without dependence from types of soil substrate and oil product the growth maximum is recorded in a month after entering -  $2,5-7 \times 10^8$  kl/g.

The quantity of heterotrophic bacteria at entering of drugs «Roder» and «Devoroil» remains close to each other during all period of observation.

As a whole, throughout all experiment, against decrease in temperatures of air and soil in cells with biological products there was a decrease in number of heterotrophic microorganisms and, hence, rapprochement of number of bacteria of the introduced biological products and control significances.

Falloff of number of bacteria in 3 months after the beginning of researches is caused by freezings of soil substrate (soil temperature more low  $0^{\circ}\text{C}$ ).

Against chilling effect of air and substrate freezings it is necessary to notice, that in cells with artificial fertilizers and a control variant there was no falloff of number of bacteria - all alterations fluctuate within one order.

It is connected by that own microflora of soil is more adapted for seasonal alterations of temperature and does not react to them jump of quantity of microorganisms.

Supplementary data on dynamics of number of heterotrophic microorganisms of the basic part of range it is introduced within the limits of the Report on the Stage 4 Contracts № CS-NPA-Arctic-05/2008.

*Dynamics of number hydrocarbon-oxidizing microorganisms of the basic part of range*

Data on dynamics of number hydrocarbon-oxidizing microorganisms are introduced in Report Table 8 on the Stage 4 Contracts № CS-NPA-Arctic-05/2008.

Dynamics of number hydrocarbon-oxidizing microorganisms is introduced in the form of diagrams to subitem 3.3.4. The report on the Stage 4 Contracts № CS-NPA-Arctic-05/2008.

Being based on the received data, it is possible to notice, that concentration hydrocarbon-oxidizing microorganisms in a control variant and in cells with artificial fertilizers more low, than in cells with biological products (as well as in an event with heterotrophic microorganisms).

During all period of researches number hydrocarbon-oxidizing bacteria in control cells and in cells with fertilizers are close to each other, and regarding cells it is identical.

In two events initial number of bacteria is close to control - cells №№ 13-15 with a drug «Devoroil» ( $6 \times 10^3$  kl/g) and №№ 7-9 with a drug «Roder» ( $6 \times 10^3$  kl/g). The produced fact can be connected that at hit in an inhabitancy new to them for activation of the activity some time (the adaptation period) is necessary for cells of bacteria.

Number hydrocarbon-oxidizing bacteria in cells with drugs remained high during all period of skilled works.

Maximum of significances of number will reach in 2 months after the experiment beginning. During the produced period most favourable conditions for development hydrocarbon-oxidizing bacteria are reached.

After 3 months of observation at freezings of soil number of bacteria falls (as well as in an event with heterotrophs).

Owing to environment chilling effect the following is noted:

- The drug of «Microzim «PETRO TRIT» in a variant «2nd type of soil + black oil» has slightly reduced the titre, and in a variant« 2nd type of soil + solar oil »remained at former level;
- A caption of drugs «Roder» and «Devoroil» in a variant «1st type of soil + black oil» has not changed.

It is important to notice, that the number native hydrocarbon-oxidizing bacteria in the control and in variants with artificial fertilizers after ground freezings has not decreased. It testifies to the increased stability of natural microflora of soils of the North to the depressed temperatures.

As a whole, it is possible to draw a takeout, that all drugs have shown accretion of number of microorganisms during the warm period of temperatures.

Further droop of number of bacteria is observed.

Studying of dynamics of number hydrocarbon-oxidizing microflorae, owing to the short period of researches, does not allow to evolve a priority biological product for uses.

Supplementary data on dynamics of number hydrocarbon-oxidizing microorganisms of the basic part of range it is introduced within the limits of the Report on the Stage 4 Contracts № CS-NPA-Arctic-05/2008.

***Dynamics of number heterotrophic and hydrocarbon oxidizing microorganisms of an engineering part of range***

Data on dynamics of number heterotrophic and hydrocarbon oxidizing microorganisms of an engineering part of range are resulted in tables 9, 10 Reports on the Stage 4 Contracts № CS-NPA-Arctic-05/2008., and also are displayed in the form of diagrammes in subitem 3.3.4. The report on the Stage 4 Contracts № CS-NPA-Arctic-05/2008.

Initial number of heterotrophic bacteria in cells of an engineering part of range slightly differs from each other in all variants.

In first two weeks number of bacteria did not change. Further the tendency to titre decrease is observed. It can be connected with temperature lowering in cells during adjustment of temperature indexes. It is necessary to notice, that the similar behaviour of bacteria was not observed in cells without additional preheating.

Sharp jumps of number of bacteria basically are caused by repetitive additions of drugs.

After 4 weeks the quantity of heterotrophic bacteria starts to grow again. Presumably, for this time microbial population could adapt for new conditions of existence and has started to rebuild initial number.

The best result has shown a drug of «Microzim «PETRO TRIT» in a variant «2nd type of soil + petroleum». Here the titre was kept at a high level within 2 weeks -  $1,1 \times 10^9$  kl/g.

Sharp jump of number is marked in 2 weeks, and the titre in all variants has grown on some orders.

The maximum titre has shown a drug «Roder» in variants «2nd type of soil + black oil"and"2nd type of soil + petroleum» -  $1,1 \times 10^{10}$  kl/g, and also a drug of «Microzim «PETRO TRIT» in a variant «2nd type of soil + solar oil»- also  $1,1 \times 10^{10}$  kl/g.

Further the temperature sensor of an engineering part has been installed on temperature schedule maintenance in a range 5-15°C.

Owing to temperature schedule decrease lowering of a titre of drugs was observed. The drug titre «Devoroil» in a variant «2nd type of soil + solar oil» was most continuously depressed.

In 4 weeks, as well as in an event with heterotrophs, number increase hydrocarbon oxidizing bacteria (possibly, in view of adaptation of microorganisms to the installed conditions) is marked.

By the end of observation the greatest number hydrocarbon oxidizing bacteria is marked in cells with a drug of «Microzim «PETRO TRIT» in all variants ( $7 \times 10^8$  kl/g).

Supplementary data on dynamics of number heterotrophic and hydrocarbon oxidizing microorganisms of an engineering part of range are introduced within the limits of the Report on the Stage 4 Contracts № CS-NPA-Arctic-05/2008.

#### **6.4. The analysis of alteration of number of microorganisms depending on temperature of free air and soil temperature**

On pic. 13 a, b, c, d in the form of the diagramme are introduced data of average daily temperature of free air and indexes of dynamics of growth of petrooxidizing microflora of soil of the basic part of range.

Data of meteorological observations during realisation of research works are introduced in the enclosure 4 Reports on the Stage 4 Contracts № CS-NPA-Arctic-05/2008.

The analysis of graphs shows:

##### **- August - September:**

Significances of temperature of air positive (the minimum significance +1,8°C, the maximum significance +13,8°C).

*The resistant tendency of growth of petrooxidizing microflora of soil in all variants of experiences is marked.*

##### **- October:**

Significant fluctuations of temperatures are observed. Lowerings of temperature with transferring more low 0°C are marked. The minimum significance -0,7°C, maximum +5,7°C.



*To the middle of month active growth of petrooxidizing microflora proceeds. Further temperature lowering that is accompanied by droop of number of bacteria is observed.*

The exception is made by control variants and variants with application of agrotechnical receptions recultivation. Here a maximum of number of petrooxidizing microorganisms also will reach in the middle of October, however, unlike variants with application of biological products, stable number of bacteria irrespective of chilling effect is preserved. Possibly, it is connected with stability of native petrooxidizing microflora to alterations of temperature of air and soil.

**- November:**

Temperature mainly below zero of degrees (the maximum significance +2,1eC, minimum-11,2zS).

*Tendencies of second half of October are preserved: decrease in number of the introduced petrooxidizing microflora and stable number of the native.*

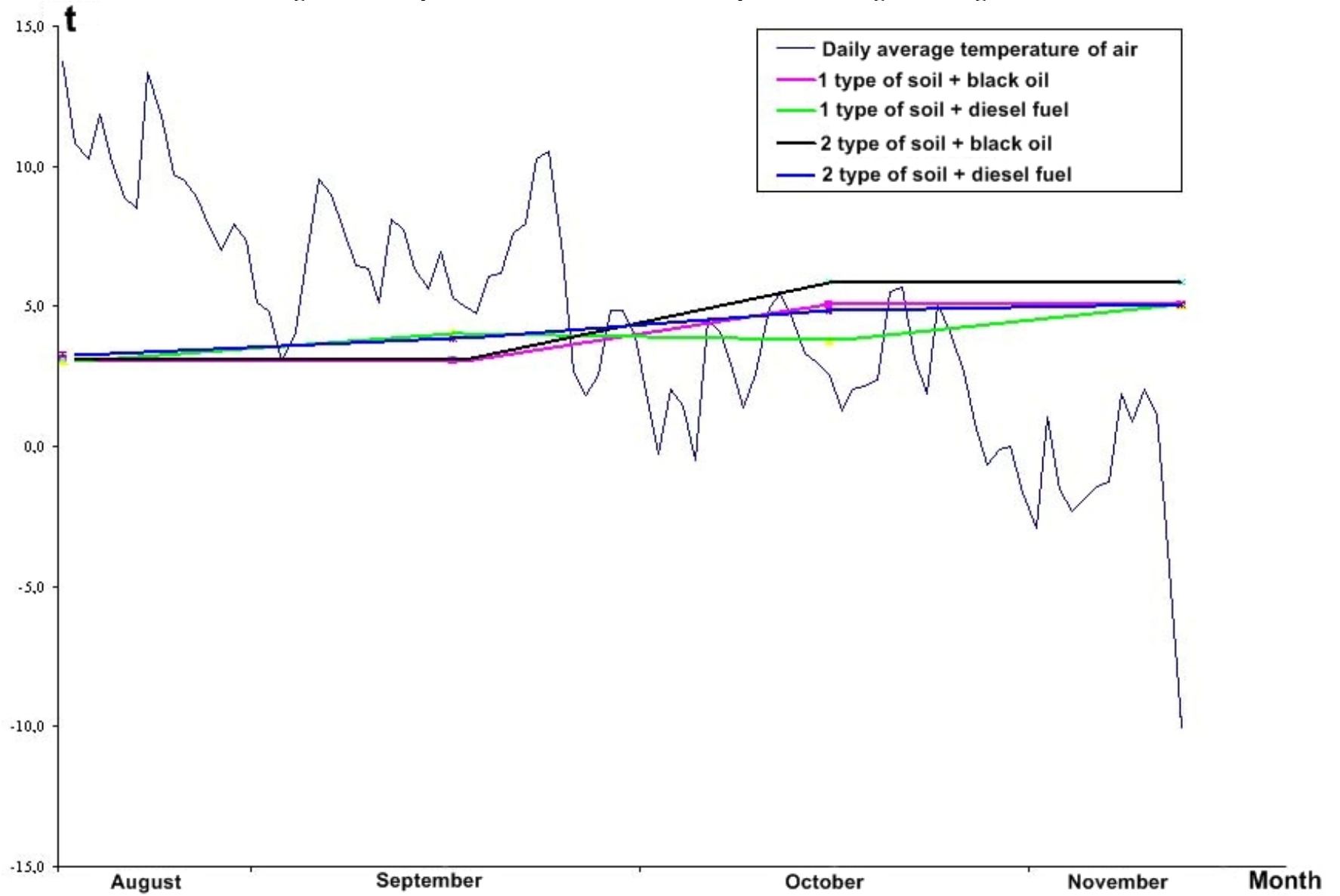
On fig. 14 and, in diagrammes of temperature of soil and indexes of dynamics of growth of petrooxidizing microflora of soil in an engineering part of range are introduced.

Significances of temperature of soil of an engineering part of range during researches are resulted in Report table 11 on the Stage 4 Contracts № CS-NPA-Arctic-05/2008

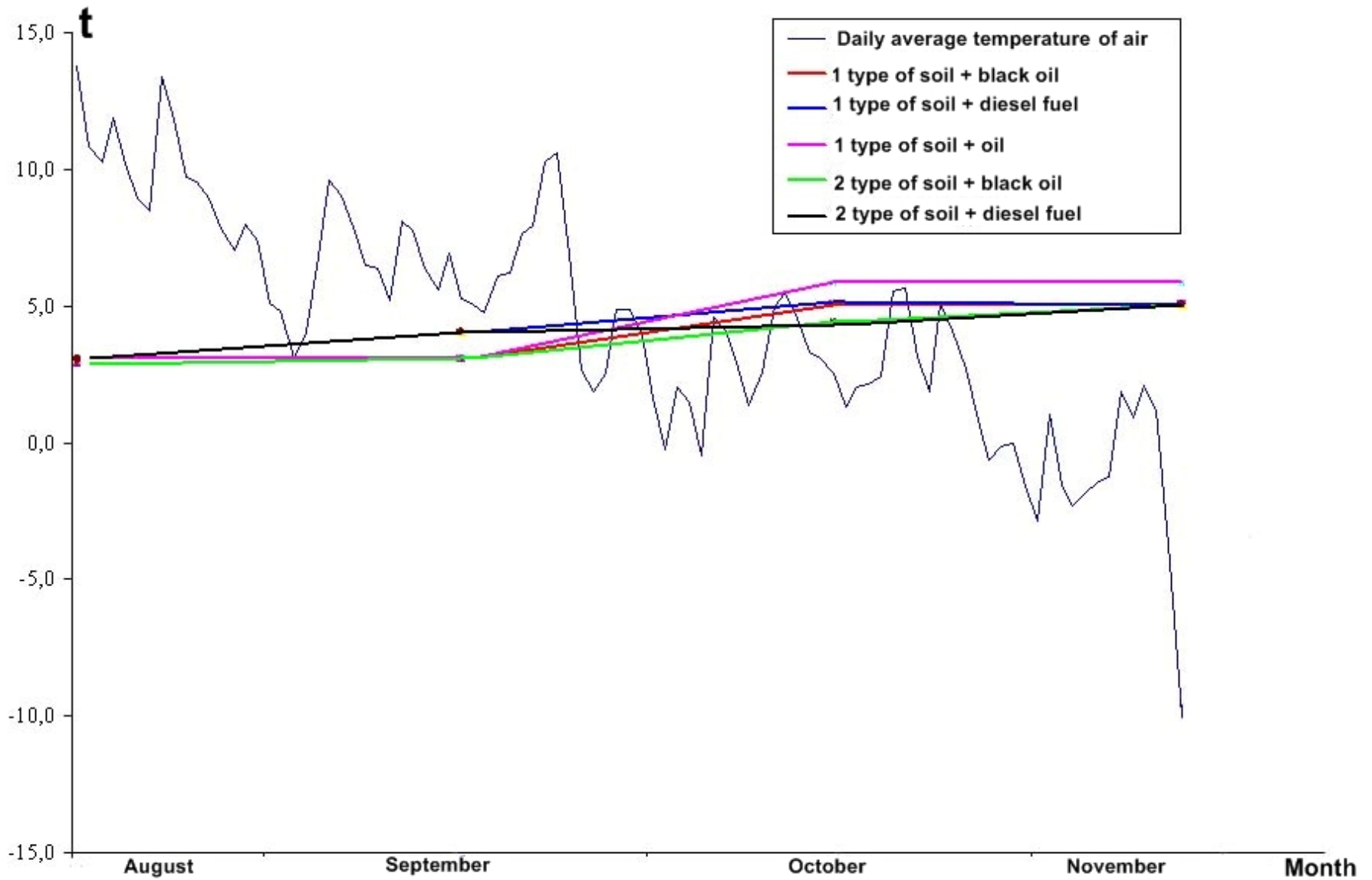
Analyzing diagrammes it is possible to note following tendencies of behaviour of petrooxidizing microflora of soil:

- As a result of approach of heating environments to an optimum of operating temperature of bacteria (18-25°C) active growth of number of microorganisms is observed;
- At chilling effect to 5°-15°C there is a droop of number of petrooxidizing microflora;
- At maintenance of a fixed level of temperature (5°-15°C) again there is an increase of number of bacteria. Possibly, it is connected with adaptation of microflora of soil to a temperature schedule.

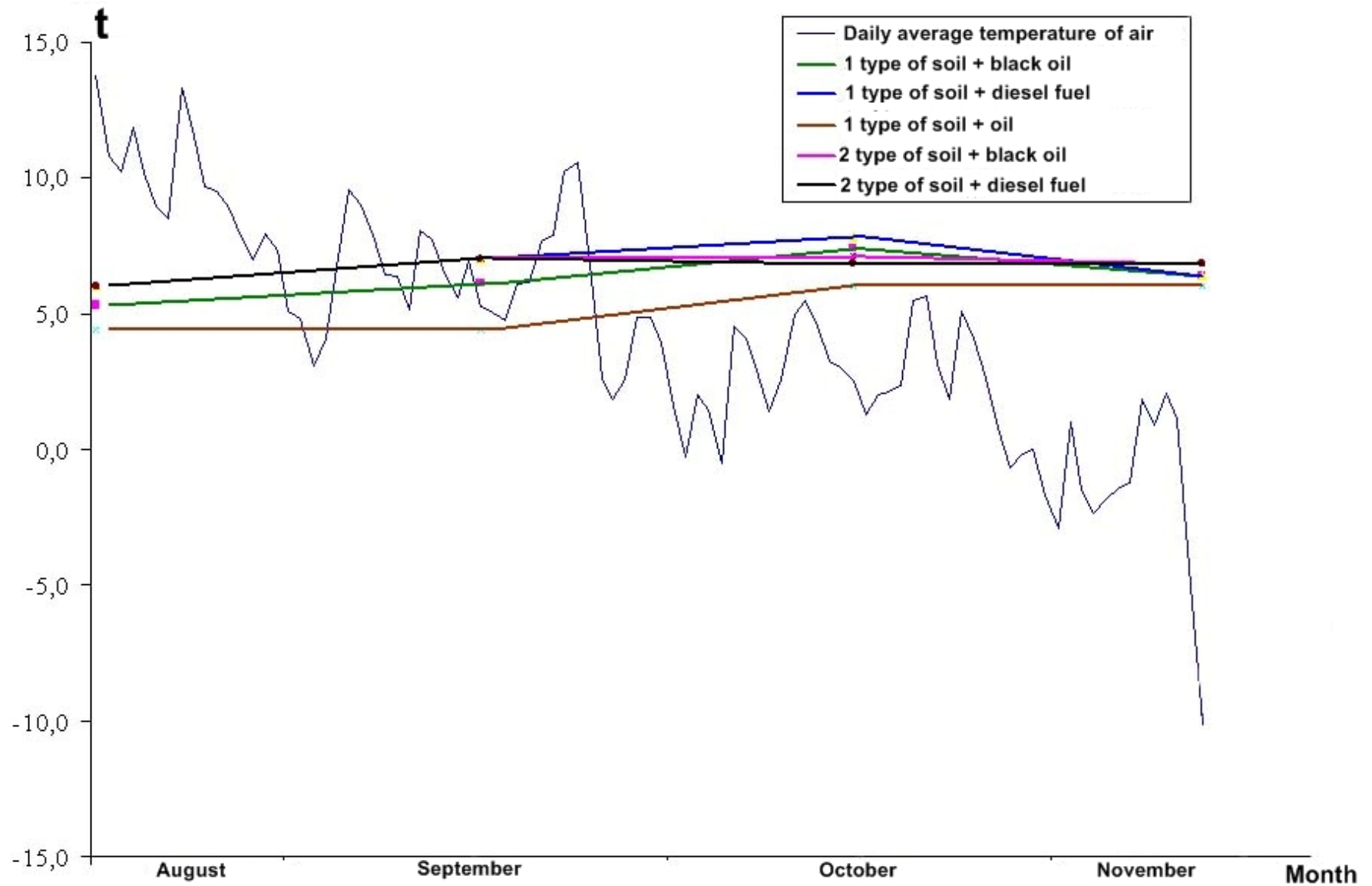
**Picture 13a the Diagram of temperature of air and number of petrooxidizing microorganisms in control treatments**



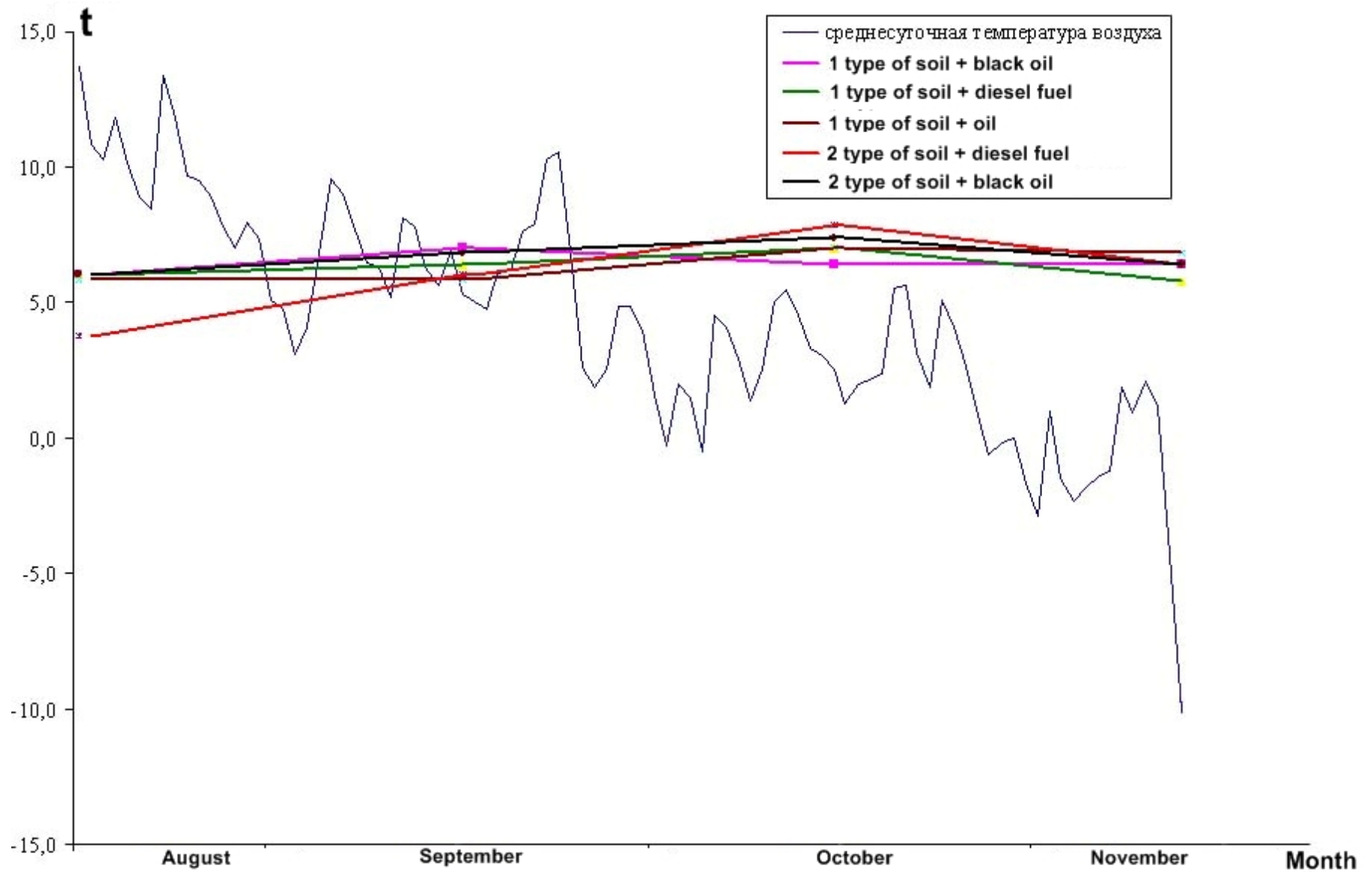
Picture 13b the Diagram of temperature of air and number of petrooxidizing microorganisms  
In treatments with application of agrotechnical receptions



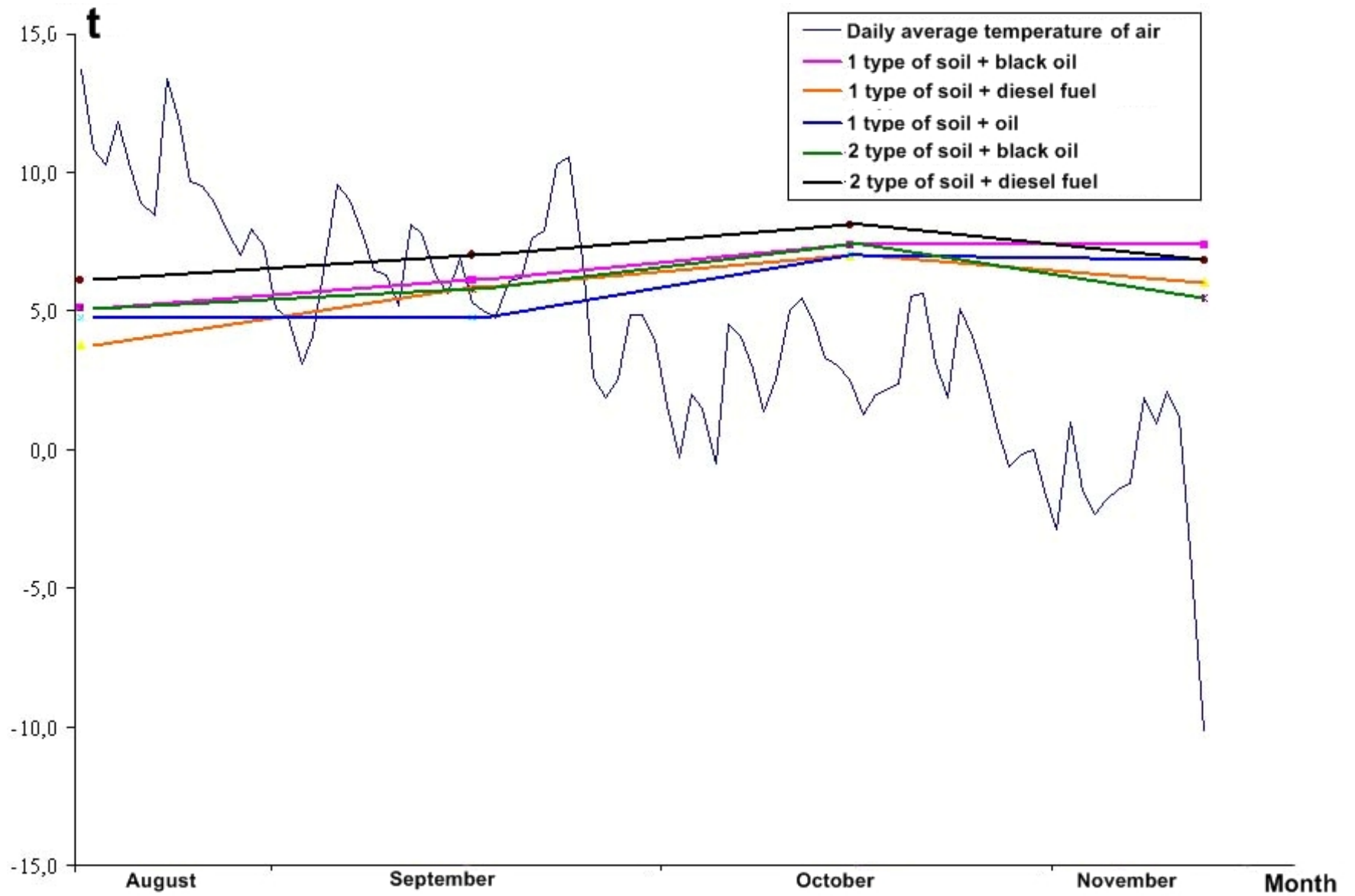
**Picture 13c the Diagram of temperature of air and number of petrooxidizing microorganisms  
In treatments with application of a drug of «Microzim «PETRO TRIT»**



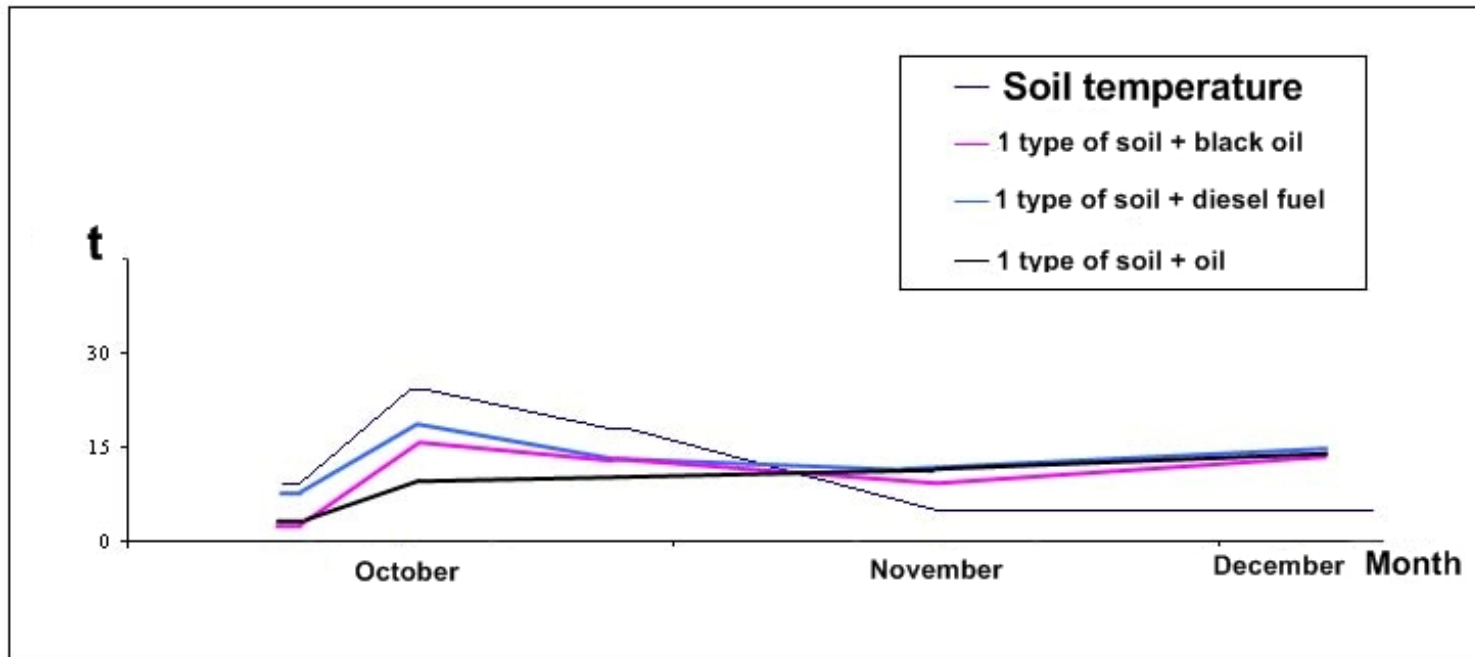
**Picture 13d the Diagram of temperature of air and number of petrooxidizing microorganisms  
In treatments with drug application «Devoroil»**



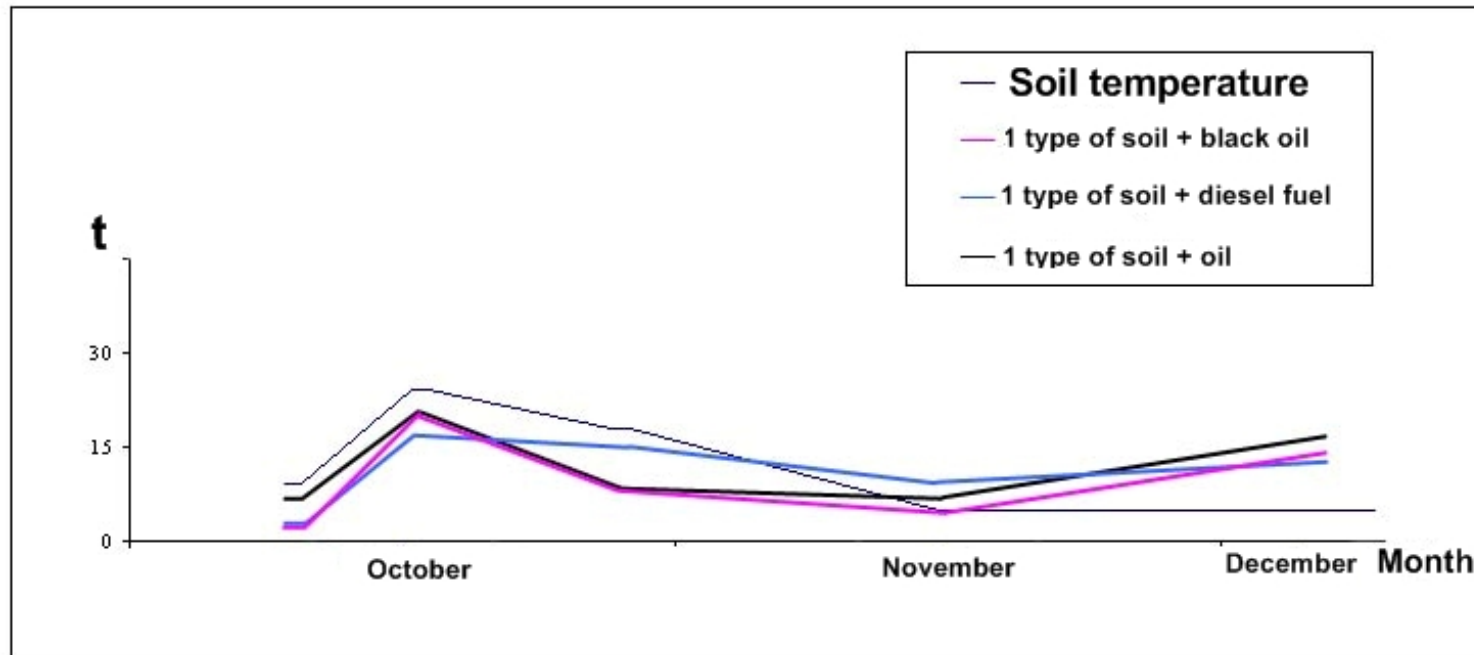
Picture 13e the Diagram of temperature of air and number of petrooxidizing microorganisms  
 In treatments with drug application «Roder»



Picture 14a the Diagram of temperature of soil and number of petrooxidizing microorganisms  
Engineering part of range with a drug of «Microzim «PETRO TRIT»

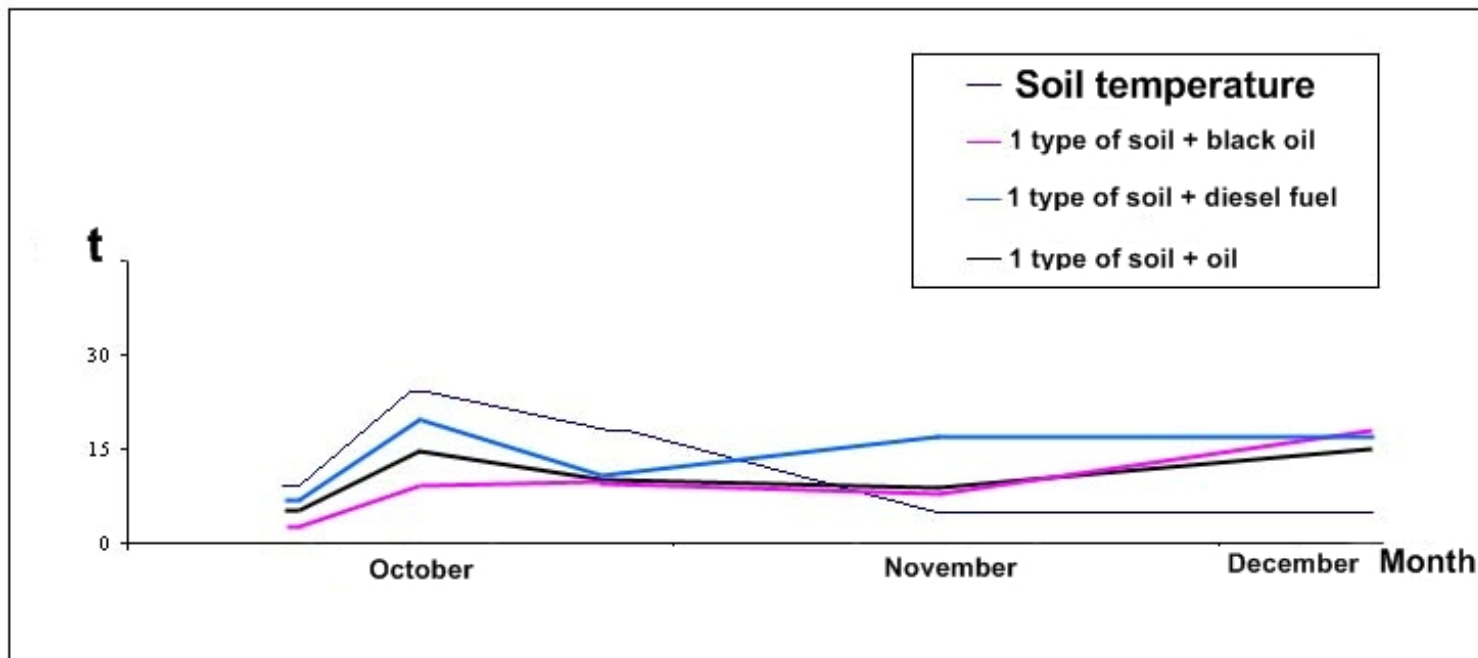


**Picture 14b the Diagram of temperature of soil and number of petrooxidizing microorganisms  
Engineering part of range with a drug «Devoroil»**





Picture 14c the Diagram of temperature of soil and number of petrooxidizing microorganisms  
Engineering part of range with a drug «Roder»



On the basis of the received data and considering the short period of researches, it is possible to draw following pre-award takeouts on dependence of development of number of bacteria on an environment temperature schedule:

- The best result of growth of number of bacteria is noted in positive environment temperatures, thus the maximum is marked at achievement of optimum temperature of work of bacteria (18-25°C);
- At temperature not more low +5°C tendencies of gradual growth of petrooxidizing microflora of soil are noted;
- As a result of temperature jumps (towards lowering) droop of number of bacteria is marked;
- As a result freezings of soil substrate there is a sharp droop of number of petrooxidizing microorganisms;
- Stability of natural (native) petrooxidizing microflora of soil to temperature alterations is noted;
- Takeouts about number and ability to the further development of the introduced petrooxidizing microflora of soil after the winter period are possible only at achievement of a following warm season.

By results of microbiological soil analyses it is possible to draw following takeouts:

### ***The basic part of range***

- 1) Concentration hydrocarbon oxidizing bacteria in 1st type of soil fluctuates from  $1,1 \times 10^3$  kl/g in the beginning of experience to  $2,5 \times 10^7$  kl/g in the end of experience, in 2nd type of soil - from  $7 \times 10^2$  kl/g in the beginning of experience to  $7 \times 10^6$  kl/g in the end of experience.
- 2) the highest concentration hydrocarbon oxidizing bacteria in the experience beginning is noted at entering of drugs of «Microzim «PETRO TRIT» and «Devoroil»-  $1,1 \times 10^6$  kl/g.
- 3) Most intensively develop hydrocarbon oxidizing microorganisms at drug entering «Roder».
- 4) hydrocarbon oxidizing and heterotrophic microorganisms intensively develop at temperature of substrate from 8-14°C within 2 months, their quantity sharply falls after substrate chilling effect.

- 5) the Maximum number of bacteria was observed in a variant «2nd type of soil + solar oil» with a biological product «Roder» -  $1,3 \times 10^8$  kl/g.
- 6) Entering of additional mineral supplementary feeding has not led to active development own hydrocarbon oxidizing soil microflorae.
- 7) it is not revealed accurate dependence between growth (or decrease) numerositys hydrocarbon oxidizing microorganisms, type of soil and a kind of a petroleum contaminant.
- 8) Number native hydrocarbon oxidizing bacteria after freezings of substrates has increased in all variants that can testify to the increased stability of natural microflora of soils of the north to the depressed temperatures.

### *Engineering part of range*

- 1) the highest concentration hydrocarbon oxidizing bacteria in the experience beginning is noted at drug entering «Devoroil» -  $6 \times 10^7$  kl/g.
- 2) develop hydrocarbon oxidizing microorganisms at entering of drugs «Devoroil» and «Microwzim «PETRO TRIT» More intensively.
- 3) the Maximum number drugs «Roder» and «Microwzim «PETRO TRIT» in variants have shown «2nd type of soil + black oil» and «2nd type of soil + solar oil» ( $1,1 \times 10^{10}$  kl/g), and also a drug «Devoroil» in a variant «2nd type of soil + petroleum» ( $1,1 \times 10^{10}$  kl/g).
- 4) Repetitive additions of drugs have led to one-stage increase of number hydrocarbon oxidizing microorganisms.
- 5) Maintenance of optimum temperatures for ability to live hydrocarbon oxidizing microorganisms (18-25°C) has led to sharp increase of their number.
- 6) At stabilisation of temperature of soil not more low +5°C stability and gradual growth of number of petrooxidizing microflora of soil is marked.

## **7. Development of the project of the Management on realization of bioscrubbing of the soils contaminated by oil products, in the Arctic conditions**

Working out of the design of a management has engaged work on generalisation of the experience received in Murmansk area in 2007-2008, work experience on recultivation in Republic Komi territory (UDC 502.656:504:054:622.323 (470.13)), and also as a result of made within the limits of the Contract №CS-NPA-Arctic-05/2008. Experiment. By working out of the design of the

Management the wishes designated by participants of meeting, the natural management which has passed in Committee and ecology of Murmansk area also have been considered on June, 16th, 2009. The meeting has been held concerning presentation of results of works under the Contract №CS-NPA-Arctic-05/2008.

In the Management design requests of producers of biological products to technologies of activation and entering of biological products are considered. Also experience and Open Society "Lukoil" requests together with FGUP «Research design and survey institute "Komimeliiovodhozproekt"» to planning and work on recultivation polluted by petroleum and oil products of lands in the conditions of the North is considered.

In the Management are resulted:

- 1) Technological approaches to a biological recultivation of soils;
- 2) Possible methods of recultivation (in natural conditions or with application of the engineering technologies, allowing to maintain constant positive temperature of soil and to ensure its aeration), and also recommendations for choice a method of recultivation;
- 3) Planning, and also constructive requests to a platform under range;
- 4) To equip range with means;
- 5) technology of application of the biological products, engaging the description of conditions of the medium necessary for successful work of drugs, sequence of works at entering of biological products, and also the analyses made during works on recultivation.

On the basis of the data received by results of researches, to application in the conditions of the North biological products of «Microzim «PETRO TRIT», «Devoriol», «Roder»<sup>TM</sup> are recommended. But technological approaches to recultivation polluted by petroleum and oil products of soils and the soils, the Managements resulted in the design, do not exclude possibility of application of other preparation-destructors of petroleum hydrocarbons. For inclusion of others destructors realisation of skilled works in similar with Arctic the soil-climatic conditions is necessary.

Characteristics, preparation for application and technology of entering of the above-stated biological products, with allowance for the experience received during researches, are led in the Appendix to the Management.

The appendix also contains conditions of application of biological products, norms of their discharge rate, the recommendation about entering of artificial fertilizers, safety requirements at work with biological products, rules of their transportation and storage.

The experience received within the limits of the Contract №CS-NPA-Arctic-05/2008. And also introduced to the Management design, it is approved by Committee of a natural management and ecology of Murmansk area.

## 8. CONCLUSIONS

On the basis of the received results it is possible to draw following takeouts:

- 1) the soil compound, characteristic for northern widths, is not toxic and not pathogenic;
- 2) the soils most typical for northern widths, have low biogenesis owing to what are of little use to independent remediation;
- 3) stability of natural microflora of soils to chilling effect is marked;
- 4) activation of native microflora can produce a positive effect only in events with low concentration of pollution (to 1-2 %);
- 5) at treatment of soils of the basic part of the range, polluted by black oil, the greatest purification efficiency of soil the biological product «Roder» (has shown 4,5-5,3 %), solar oil - «Devoroil» (4,8-5,9 %), petroleum - «Microzim «PETRO TRIT» and «RODER» (6,7 %).
- 6) in an engineering part of biorange, at the expense of maintenance of constant positive temperature of soil, biological products have shown higher degree of moulding of oil products in comparison with the basic part. The best result on weeding of soil from black oil and solar oil has shown a drug «Microzim «PETRO TRIT» from petroleum -«Devoroil».
- 7) in the Arctic conditions use of microbial drugs more effectively in comparison with agrotechnical methods recultivate;
- 8) biological products have positive effect on magnification of biological activity of soils and, as consequence, accelerate process of moulding of oil contaminations;
- 9) pre-award activization of biological products (preparation of working suspensions) that reduces the period of activation of bacteria in soil is recommended;
- 10) the peat containing in soil, executes functions: the natural sorbent reducing infiltration of petroleum deep into of soil; the water-retaining substance promoting maintenance of soil

moisture necessary for bacteria; the natural organic fertilizer promoting an intensification of processes in soil;

- 11) it is necessary strict account and the control of norms of application of fertilizers and drugs, superfluous doses of artificial fertilizers cause protoxide soils that reduces potential of restoration of the polluted soil substrates;
- 12) the factor of maintenance necessary is important (40-70 %) soil moisture, soil rehumidification can affect on soils;
- 13) soil aeration (loosening, milling etc.) promotes uniform distribution hydrocarbon oxidizing microflorae in a stratum of soil, aeration and, as result, intensifications of biomolding of petroleum;
- 14) at impossibility of realisation of aeration by loosening or milling (the close bedding of a frozen ground, inaccessibility of area of purification to engineering), besides biological products, is recommended entering of natural sorbents (peat, sawdust, a moss, etc.) in soil;
- 15) the greatest intensity of action of biological products is noted at positive temperatures;
- 16) data of microbiological analyses allow to draw a takeout that bacteria continue to work and at chilling effect, up to soil freezings. However, their activity drops in process of lowering of temperature of soil;
- 17) stage application phytoremediation at a finishing stage of biorecultivation (seeding of plants, stable against oil contaminations) is recommended;

For realisation of a complete cycle of biorecultivation of soils (at a level of pollution of soil of ~5 %) it is necessary order of 4th years.

## 9. THE CONCLUDING

Results of the made researches allow to speak about perspective of application of a method of a biological recultivation of the petropolluted soils in the Arctic conditions. It is confirmed with results of meeting by results of the executed works under the Contract №CS-NPA-Arctic-05/2008., the natural management which has passed on June, 16th, 2009 in Committee and ecology of Murmansk area.

One of the basic achievements of the produced work are served by application special technological approaches and technical decisions to biorecultivation process that allows to continue process of a fermentation of oil products within all calendar year.

Experiment has confirmed laws of work of biological preparations with reference to the Arctic conditions.

The limited period of researches does not allow to draw definitive or unequivocal takeouts on advantage of this or that biological product with reference to a kind pollution in the Arctic conditions. Difficult definition of a termination date of a complete cycle of process bioremediation also is represented. Presumably, on the basis of the received results, regenerative process of soils on range can take from two to four and a half years, depending on a choice of the technological approach, under condition of observance of all technical specifications on use of biological products and works on recultivation of soils in the Arctic conditions (picture 15).

The stage phytoremediation should be a definitive stage of a biological recultivation. The stage engages: selection of recultivation grass, account of norms of seeding, sowing and the control of growth of seeds and growth of grass. Depending on a level of pollution and soil-climatic conditions, realisation of repetitive sowing of grass is necessary.

Existing methods phytoremediation allow to manufacture afterpurification of soil to admissible residual significances petroleum and oil products.

One of the questions which have arisen by consideration of experience of work on recultivation in territory of other subjects of the Russian Federation, the establishment of specifications for soils of Murmansk area is. Absence of specifications obliges to make works on recultivation to complete weeding of soil with a remaining content of petroleum and oil products equal to zero, that in the conditions of the marginal north to become a problem.

The developed design «Managements on realisation of bioscrubbing of the soil polluted by oil products, in the Arctic conditions» is the first in territory of Murmansk area the document

regulating realisations of a biological recultivation, including with allowance for technical novations.

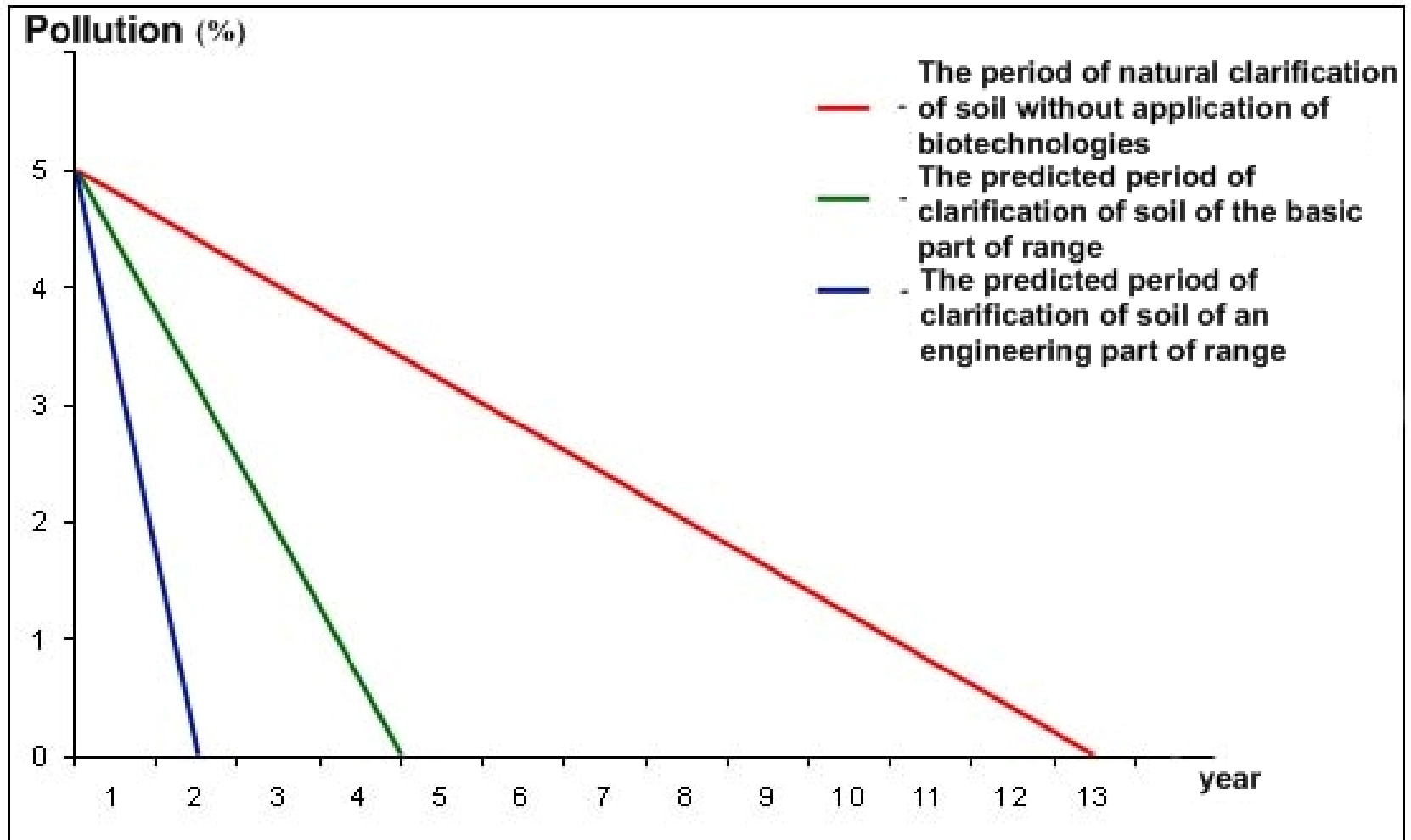
The Management design is recommended persons, organize actions for abandonment of consequences of oil spills on soil and a soil biological recultivation.

In development of the design of the Management with allowance for experience of realisation of similar works in Republic Komi territory, and also other Regions it is necessary to consider as action for abandonment of the emergency oil spill or oil product, and its consequences, till the input moment in an economic cycle recultivated lands.



picture 15. The forecast of dynamics of a fermentation of petroleum and oil products

Within the limits of the organised experimental range



All participants of meeting by results of the executed works under the Contract №CS-NPA-Arctic-05/2008, the natural management which has passed on June, 16th, 2009 in Committee and ecology of Murmansk area, and representatives of Committee state wishes on continuation of works and their transferring on following trial, or demonstration level of research.

Realisation of the further works on recultivation of the petropolluted soils within the limits of range is interfaced to financing, however company "NavEcoservis", leaning against own means, has continued works on recultivation. On June, 2nd, 2009 loading of biological products «Roder», «Devoroil» and «Microzim «PETRO TRIT» in the basic and engineering parts of range has been manufactured.

**Now company "NavEcoservis" in common with experts of group of companies "EcoCenter" schedule the further works on recultivation polluted by petroleum and oil products of soils and soils, including within the limits of experimental range.**

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