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"COMPLEX APPROACH TO THE STUDY OF SEA COASTAL ECOSYSTEMS IN CONNECTION WITH THEIR POLLUTION"

by

N.P.Morozov*, A.M.Stepanov**

Abstract

With the help of a new type of a small size vessel there has been studied the content and distribution of heavy metals in the main components of the coastal ecosystem of the Barents Sea. Special role of coastal ecosystems is emphasized as of the major part of man's habitat where the bulk of industrial polluting matters is dumped. The method of complex study of co-existing biocenoses of land and sea is being studied.

Résumé

Contribution au rapport de N.P.Morozov et A.M.Stépanov.
"Etude complexe des écosystèmes côtières en rapport avec la pollution de l'environement".

En utilisant le bateau de petite dimention du type nouveau on a étudié la teneur et la distribution des métaux lourds dans les composants principaux de l'écosystème côtière de la mer de Barentz. Il est met en relief le rôle particulier des écosystèmes côtières des mers comme la partie la plus importante de l'environnement de l'homme où on enterre la plupart de déchets industriels. On présente l'argumentation de la méthode de l'étude complexe des biocoénose adjacentes de terre et de mer.

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by

N.P.Morozov* , A.M.Stepanov**

The study of pollution of the continent and sea biocenoses by heavy metals and other toxicants are being carried on by now for many years and a large data are accumulated. However until now this research work was not integrated and the self-explaining consequences are the substantially different processes of accumulation, migration and trasportation of ways to find elements in the ground and sea biocenoses. Collaboration in the studies is to a certain extent inhibited by some bureaucratic character - by different approach, methods and terminology, units of measurements etc.

However the sea and ground biogeocenoses, being the systems of the open type, as far as the coastal area is concerned, undergo substantial mutual influence which is expressed in the cycles of mass and energy exchange. In the coastal waters and on the coasts where all three medium of life coexist, and that is ground, water and air, here there is a maximum variety of physical and chemical

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environmental conditions, the maximum variety of flora and fauna, the maximum density of ecosystems, indivisible by unit of area, and as a result their maximum bioproductivity, stability and vital capacity. Apparently the destruction of continental ecosystem not accidentally starts from their centres which nowdays are almost occupied by deserts of antropogenical origin, growing at an increasing rate.

To look at the coastal zone from ecological, economical, demographic and recreational points of view allows to single it out, as the most important habitat for homo sapiens. It is selfexplanatory that the greater part (up to 80%) of the world population lives on the coasts of the seas and oceans. It is also notable that people spend their holidays manly on the coasts where the variety and viability of both water and ground acosystems is the reproductive source of health and efficiency of the people. The recreational importance of sea coast is difficult to overestimate.

On the other hand, it is also an undisputable fact that the bigger part of pollution falls on the coastal area due to the high density of population and the accompanying allocation of industry. The volume of drainage waters annually thrown directly to the sea coastal area amounts to many thousands km^3 and accounts for different seas from 0.1 to 20% and more of the annual volume of flow of discharging rivers. It must be borne in mind that all rivers are more or less polluted and carry into the sea large quantity of toxic matters. According to some data the industrial sewage add to the natural river output twice as much mercury, 12-13 times more lead, copper, zinc, 30 times more the quantity of antimony. According to

UNESCO every year together with the river waters more than 320 mln.t of iron, 2.3 mln.t of lead, 6.5 mln.t of phosphor get to the seas. Moreover, the rivers carry a great deal of oil products, pesticides, phenyles, detergents and other pollution materials. The observations of the pollution and assimilation of rivers in some industrially developed areas of the world showed that the processes of assimilation secure the destruction and neutralization of only 1/3 of the arriving pollution. Consequently, the oil products, detergents, phenyles and other matter thrown into the rivers have not sufficient time to mineralize within river flows and come to the coastal area. In the marine medium the pollution disperse, transform and finally dump in the sediments. This occurs under the influence of complex processes of physical and chemical, hadrodinamic and hydrobiological character. The transit of pollution from the water to the ground in the process of normal life activities of hydrobionts is mainly realized through the functioning of filtrators and sedimentators. Absorbing from the water large quantity of suspension they transport it to the ground in the form of excrement bits which go down to the bottom. However of much greater importance is the formation by the animals of pseudo excrements - the bits of filtrates that are not swollowed. Besides that the filtrators and sedimentators discharge into the water mucus which contributes to the coagulation of suspensions, as a result the sea water becomes lighter in colour.
The importance of this quality of hydrobionts in assimilation of sea water from suspension is comparable with their filtration capacity. Very important for biological assimilation

is also the water stirring function of filtrators and sedimentators. The stirring of water caused by the above accelerates the process of mineralization of organics and that of the biological detoxication of pollution. Due to the aggregate filtration activities of bivalve mollusca, crustacea, ascidian. echinodermata, larvae of various animals and other hadrobionts in the waters off sea coasts appears an unusually massive belt of biofilter through which in many cases every 24 hours all waters of lythoral and sublythoral zones are pumped. Extremely significant is biosedimentation connected with the going down to the bottom of dead organisms. The toxic substances and other sources of pollution are dumped adequately with the aggregate forms of hydrological sedimentation.

All hydrobionts in some way are capable of destructing or neutralizing different toxic sources. The leading role here belongs to microorganisms. Many kinds of bacterial, yeasts, mushrooms and one-cell seaweeds in the process of their life activities destroy oil products, pesticides and neutralize some toxic heavy metals.

As a result of all indicated processes in the seas especially in the coastal waters takes place an enormous by its scale the process of lightening of waters and maintaining its quality on a certain level. The coastal zone of the sea characterized by intensive processes of sedimentation and transformation of the substance under the influence of abundantly developed biota represent the natural biochemical barrier on the way of the substance coming from the continent to the sea medium.

This very property of coastal ecosystems - to be zone of removing toxicants from biosphere - put them into the advantageous position in the biosphere and distinguishes them as the vital part of people's habitat, the fact which until now escaped the attention of ecologists and other experts on the preservation of the environment.

However the assimilating capacity of marine bodies of water is not unlimited. The existing scale of supply of different sewage into the marine medium is already adequate to or surpasses the capacity of marine ecosystems to assimilate. The modern level of pollution of many seas and especially their coastal regions measured by all controlled values markedly exceeds the admitted level. According to S.A.Patin (1979) the minimum values of actual (toxic and threshold concentrations of the most popular polluting substances which is true not only regionally but also universally. Foe some substances (oil, DDT , polychlorbypheniles, mercury, copper) the minimum values of their content in pelagic area of the ocean and threshold concentrations are lower than these ranges practically in 100% of the cases (fig.1).

The one-cell seaweeds are among the most vulnerable to the action of pollution factors groups and forms of hydrobionts which are proposed by Patin to be calles "Targets of Toxic Factors", their photosyntesis is inhibited at lower concentrations of various toxicants in the medium and also some types of microzooplankton filtrators and the earlier stages of ontogenesis of benthos and necton organisms (especially within the biothope of hyponeuston and benthos where the increased concentration of all polluting matters is to be observed (Patin, 1979).

The acologic action of polluting matter influences the levels of organisms, population and biocenosisand biosphere. There is a lot of examples of destructive influence of pollution on the coastal ecosystems of the seas. More than others suffer from pollution the Irish, North, Baltic, Javan, Terreinian and Mediterranian seas as a whole.

In the Baltic Sea,according to not fuly comprehensive data, about 40 thousand km^2 is devastated which corresp_onds to 10% of the total area. As it was pointed out at the colloquium of representatives of 17 Mediterranean countries (Monaco), if the pollution of the coastal waters of the sea by industrial and household sewage would go on as before, at the same rate as at present, in 10 years the northern part of the sea may prove to be dead. The decrease of the biomass and of the productivity of the sea animals under the influence of the pollution is noticed in many seas, especially in the coastal waters and bays the assimilating capacity of which would inevitably go down. Relying on the direct observations of sea flora and fauna J.Cousteau (1971) makes an assumption that during the last 30 years as a result of pollution "the intensity of life" in the seas and oceans decreased over 30% and more. Not only the decrease in "the intensity of life", but also the development of morbific microbes is the result of ecological nonbalance under the influence of excessive quantity of the pollution elements the coastal ecosystem cannot cope with. In many places of the Mediterranean coast the bathing in the sea water is risky in terms of infection.

Heavy metals, pesticides and many other toxic elements not only influence badly hydrobionts but also accumulate in them reaching dangerous concentrations. For this reason in

many parts of the world fishing is prohibited. For instance in Japan the fishermen are deprived of the possibility to earn their living on the grounds with the total area of 2,000 km^2.

In many countries of the world the protection of coasts is confirmed legally. In Sweden the general protection extends to 100 m off and into the coast and if necessary may be widened to 300 m. It is stated in the Common Market countries' Council of Ministers' resolution that the problems of maintaining ecological balance, the protection of landscapes and reproduction of resources of coastal regions must be dealt upon simultaneously with the recreational targets and protection of the regions adjoining to the coast by means of internationally united efforts. Among the measures to safeguard the coasts are mentioned: the inventory of the coastal resources, measures on sea fishery regulation, the control of motor transport, the arranging of natural reservates, national parks and organized rest areas, taking measures as to the protection of sea coast from abrasion, introduction of the necessary security during throw into the sea of any kind of waste or substance which may cause the pollution of the coast and the effective control on pollution.

A lot of attention is given to the protection of the sea media in the USSR and COMECON countries, where this problem is dealt upon by a large number of scientific bodies.

The working out of many water protection programs is inhibited by the lack of scientifically justified approach to the problem of protection of sea coastal area. The central point of this problem in our opinion is the

evaluation of the degree of stability of ecosystems to different anthropogenic influences, one of then the capacity to assimilate. The overestimation of this possibility invariebly leads to destruction of biocenoses and to the expansion of areas where pollution is spread. That is what practically is happening in the coastal area of many seas today where to a lot of industrial agricultural and household sewage of the coastal factories and cities is thrown away sometimes without any refinement. Actually, the whole problem of modern pollution of the sea basins is the result of overestimation of their assimilating ability. On the other hand the underestimation of this capacity can bring to exessive expenditures on the refinement of drainage waters. Insofar as the assimilation capacity of different seas and their separate regions is not even which reflects the variety of climate, hydrological, hydrobiological and other conditions the problem of maximum admissible level of waste of certain substance should be always considered individually. Depending on a given situation (density, character of production of coastal industry, capacity, the state and efficiency of refinement installations etc.) the throw away of the pollution matter may be evaluated for each enterprise separately or for the whole coastal housing and industrial complex as a whole with the following rate of waste determined for each water user, being the relationship of the quantity of the substance thrown into the sea to the quality of this substance in the drainage waters before their refinement. Thus, the above mentioned functional peculiarity of the coastal zone of the sea - the final stage of migration cycle of toxicants in the biosphere - should be the central research point of

ecologists in the modern times. Which is not done until now. The coastal area of the seas lying on the boundary areas of research made in the open sea and on the ground is obviously studied insufficiently. This is to a larger extent determined by the complications in getting the representative samples. In particular, as far as the boundary zones: coast-sea, river-sea are concerned, the main difficulties are attributed to the inaccessibility of these areas for conventional vessels and also to the high probability of the pollution of samples by the inevitable throws away from the vessels (the particles of soot, paint, oil products, vessel sewage etc.). Not of minor importance is the necessity to work from the high board. These are the main reasons which stipulate the negligiable number and the fragmentary character, sometimes even contradiction of the available data as compared with the actual level of pollution of the coastal sea waters. As a whole, the coastal zone of seas in a sense could be called as a "white mark" in the oceanology.

In our opinion the complex research of the coastal zone apart from the traditional hydrological, hydrochemical and hydrobiological studies should include the following directions of <u>biogeochemical investigations</u>: the study of the quantity and qualitative composition of the substance supplied into the sea; the transformation of their finding methods in the marine medium: the ways of migration of the toxicants in the coastal ecosystems and their distribution among its biotic and abiotic components; the accumulation of the pollution substance in the organisms of various systematic groups and taxanomic levels taking into account the enrichment during the movement along the trophic chains;

the revelation of the organism-concentrators by separate groups of toxicants, the balance values of supply and removal of toxicants from the ecosystem. In this case beside the sea water, suspended material, organisms and benthic sediments also the atmospheric precipitation, aerosols, the surface microlayer of the sea water, foam, fog and the organisms of hyponeuston, epineuston and pleuston should be investigated for the content of toxicants.

Very important and until now not worked out is the question about criteria of evaluation of the condition of coastal ecosystems and the degree of their infringement under the influence of toxicants. A great help in this respect, as well as in respect of studying the migration of toxicants and their accumulation by various hydrobionts, could be provided by an ecological modelling under the circumstances maximum close to the natural.

It should be stressed that the complex investigations of the coastal area should be directed not only to the disclosure of the most endangered areas and elaboration of the corresponding recomendations, in particular the evaluation of the maximum admissible throws-away of the polluting elements in the drainage waters of the coastal industry, but also to the choice of regions suitable for observations of the background state of the biosphere.

To effect the suggested complex studies in the coastal zone of the seas it seems expedient the usage of vessels of new type - sailing and oar driven polymaran "Octopus", constructed in our country (Raikennen, 1978). This vessel due to the peculiarities of its construction - the distribution

in space of the separated elements of floating - obtained new properties - the increased stability and resistance to covering by waves that allows not only to cruise autonomously in the coastal shallow waters among the reefs and surfing roughness, whereas the conventional small vessel (motorboats, oar boats) practically continually are on the edge of an accident but also it can land to the shore during the surf wave of 1.5-2m. The absence on the "Octopus" of the sources of pollution makes it principally the ideal vessel to study the pollution of the coastal zones of the sea, hardly accessible both from the coast and from the board of large research vessels.

The polamaran "Octopus" was used for the first time with its inventor taking part, by the authors of this report for the investigation of coastal area of the Japan Sea in 1977 and in the coastal area of the Barents Sea in 1978. The unique characteristics of the vessel and especially its capability to land during surf roughness (and to take the vessel out of the water) allowed for the mass selection of probes of biospheric substance in a wide assortment. Some of the results of these investigations giving an example of such complex approach are represented on figure 2 and table 1.

In a way one can state that precisely this new type of vessel pusjed towards the realization and formulating the complex principles of investigations of the coastal zones of the sea - the situation rather typical than exceptional for any sphere of science.

At the fig. and table 1 first of all is notable a relatively high content of investigated metals in the rain water. To obtain full data on local cycle of carry over of

microelements along with wetness turnover, we have evaporated sea water in laboratory. The analysis of the distillate, as it could be expected, showed the contents below the analytic ability of measurements, i.e. lower than 10^{-10} - 10^{-11} g/ℓ for all the studied metals. Judging by this result metals supply with rain water may be referred to atmospheric transfer of polluting substances.

All land waters including the ground ones have approximately the same metal content which may be explained by availability of close permafrost. Accumulation of zinc in puddles and zinc, iron and lead in snow is quite pronounced. Concentration growth in snow is likely to happen due to its sublimation in spring and summer.

Continental vegetation displays distinct concentrational ability. The best concentrators are scum lichen which accumulate metals at ratio 1 : 100 000 - the quality putting them into the group of pollution bioindicators.

Distribution of all metals depending on the distance from the shore has a noticeable maximum at 200 m which we found in both the studied basins. For comparison of curves of different metals mean contents of all metals in coastal marine waters were standardized to 50 units, their generalized profile is given in fig.2. The iron and manganese curves that have clear mirror distribution are marked in fig.2 together with the generalized curve. This regularity had been earlier discivered by us for the north Atlantic waters (Morozov and others, 1974).

The best concentrators in different groups of the studied hydrobionts were Spongia among protozoa, Bogeuvielea among molluscs, Pfilota among macrophytes. Their accumulation rates

are 10^3 - 10^5. Pronounced strontium accumulation by hydrobionts attracts special attention. Strontium as analogue of calcium and a more active substance is likely to replace the latter in hard parts of marine organisms.

There should be pointed out to conclude that the developing pollution of the coastal zones as of the most important area of toxicants' dumping endangers the assimilation ability of coastal ecosystems and there is an urgent need of special attention to the study of processes in this part of biosphere. This task is a complex and pressing one.

Content of transitory and heavy metals in the components of the coastal ecosystem of the Barents Sea, July 1978 (for water in mkg/l; for land vegetation and hydrobionts in mg/kg of raw weight).

Object \ Metal	Fe	Mn	Zn	Cu	Ni	Co	Pb	Cd	Cr	Sr
Lichen	1913.3	14.2	24.05	9.25	4.1	1.12	6.79	0.31	1.68	2.4
Moss	894	19.3	14.8	5.58	2.54	0.96	2.31	0.6	0.57	15.25
Florals	99.6	31	25.8	8.67	1.73	1.03	0.47	0.82	0.35	32
Bushes	128.5	127	55.2	5.07	2.46	1.49	4.03	0.6	0.6	11.71
Rain water	40.5	9.95	24	9.95	0.22	0.17	0.08	0.2	-	-
Snow water	157	0.72	194	3.5	0.34	0.27	0.44	0.2	-	-
Brook water	55	20.5	85.3	3.44	0.17	0.28	0.13	0.4	-	-
Puddle water	61.4	0.33	303	2.7	0.2	0.19	0.13	0.1	-	-
Ground water	62	0.4	3.6	8.6	0.1	0.6	0.15	1.4	-	-
Sea water 1000m	5.3	0.19	7.34	1.52	0.2	0.22	0.14	0.3	-	-
-"- 500m	2.3	0.24	13.2	2.9	0.3	0.18	0.18	0.16	-	-
-"- 200m	3.2	0.44	112	1.28	0.15	0.23	0.8	0.18	-	-
-"- 100m	7.25	0.42	56	3.14	0.2	0.18	0.19	0.14	-	-
-"- 50m	11.35	0.32	5.8	1.42	0.26	0.42	0.18	0.17	-	-
from the shore	3.3	0.55	10.2	1.9	0.27	0.23	0.16	0.3	-	-
$\Sigma/6$	5.45	0.36	34	3.52	0.21	0.25	0.27	0.21	-	-
Macrophytes	318	13.2	93.2	7.3	7.52	3.46	1.75	2.03	3.14	475
Porifera	400	22	38.3	4.6	28	16	20	3.4	10.1	1200
Polychaeta	278	14.4	278	9.4	4.4	2.2	2.2	0.78	3.4	111
Coelenterata	1000	28.1	105.7	21.7	11.1	18.2	7.4	1.25	5.9	331
Echinodermata	69	11.25	6.75	3.35	6.5	6.9	14.2	1.01	5.75	351.2
Crustacea	235	26.8	82.4	12.25	9.6	14.7	33.8	2.41	12.41	1397
Molluscs	226.2	30.5	54.9	10.63	24.9	17.8	47.9	2.8	15.4	929
Fishes	57.9	8.8	102	6.85	3.35	4.75	4.05	0.8	2.51	151

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Legend for figures

Fig. I Range of toxic (rectangles) and threshold concentrations (thick lines) of Hg,Cu,Cd,Pb and Zn in the environment for main groups of marine organisms and concentration rates in euphotic layer (portions without shading -areas of toxic concentrations for early stages ontogenesis).Toxic concentrations are limit rates of concentration in the environment with which the measured parameters ,biological in the first place, display more than 50% reliable decrease, in comparison with test experiments, the duration being not less than 2-4 days. Threshold concentrations are minimum rates of content in the environment with which the measure parameters (biological and physiological -biochemical) fall to 50% of the value it used to be in test samples comparable with ontogenesis of the given organism by duration (according to Patin S.A.(2)

Fig.2 Fe content in different components of coastal ecosystem of the Barents Sea. Distribution of Fe,Mn in surface waters depending on the distance from the shore. - generalised distribution profile for all investigated metals.

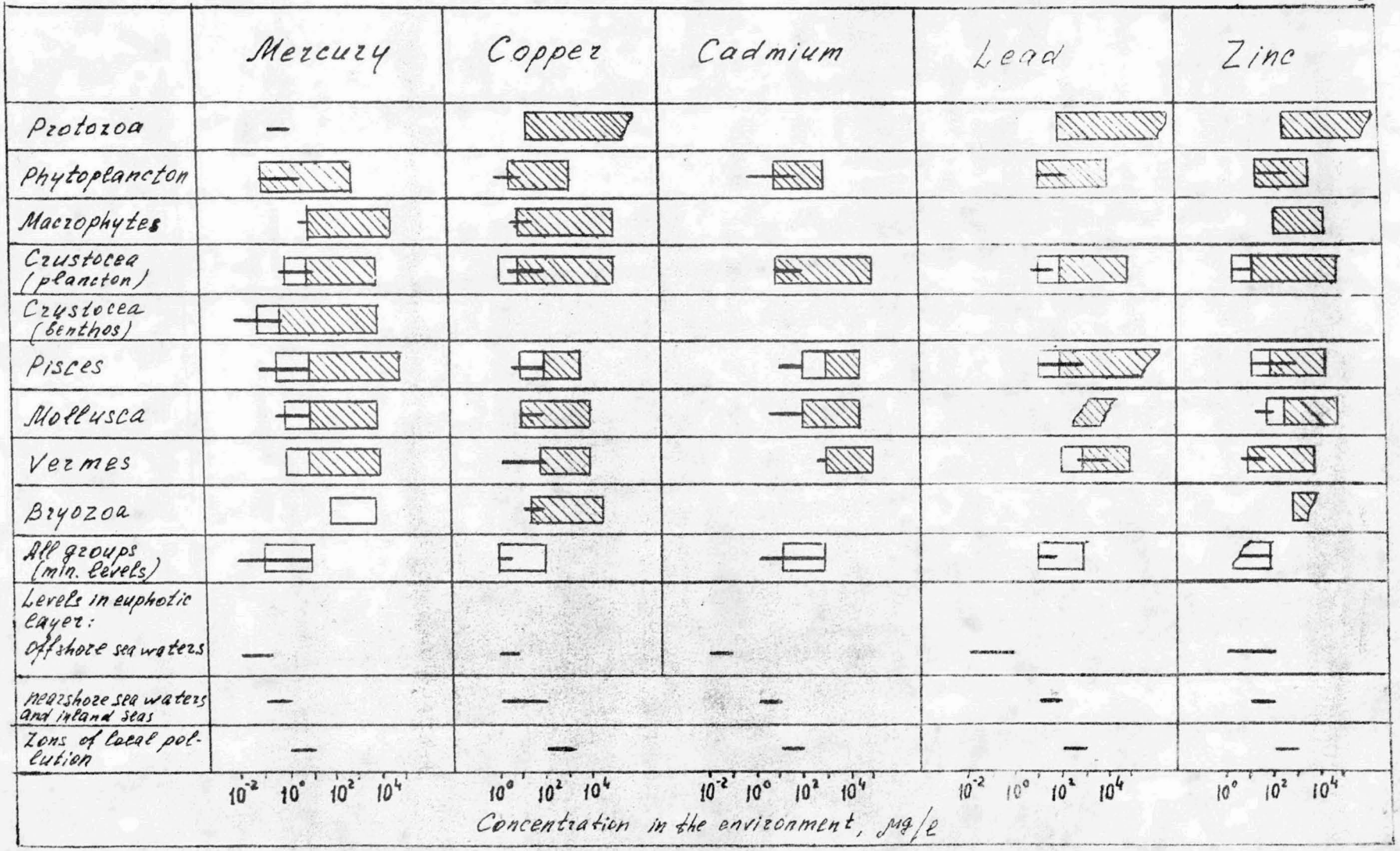
Mercury
Copper
Cadmium
Lead
Zinc
Protozoa
Phytoplancton
Macrophytes
Crustocea (plancton)
Crystocea (benthos)
Pisces
Mollusca
Vermes
Bryozoa
All groups (min. levels)
Levels in euphotic layer:
offshore sea waters
nearshore sea waters and inland seas
Zons of local pollution
10^{-2} 10^{0} 10^{2} 10^{4}
Concentration in the environment, µg/ℓ

Fig. 1

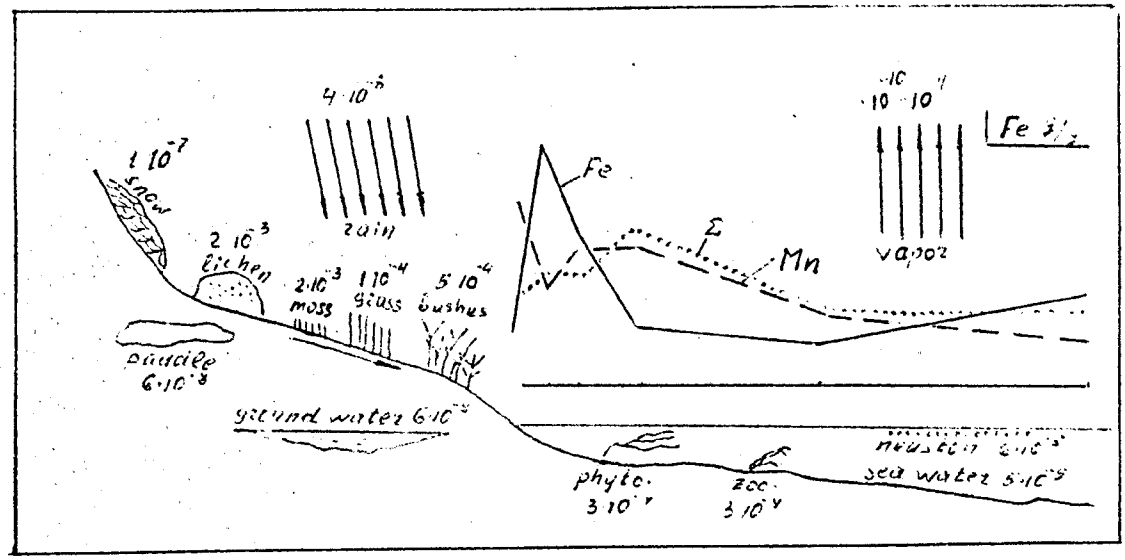
4·10⁻⁶
rain
1·10⁻⁷
snow
2·10⁻³
lichen
2·10⁻³
moss
1·10⁻⁴
grass
5·10⁻⁴
bushes
boulder
6·10⁻⁸
ground water 6·10⁻⁵
Fe
Mn
Σ
·10 ·10⁻⁷
vapor
Fe 3·10⁻⁷
phyto.
3·10⁻⁷
zoo.
3·10⁻⁷
sea water 5·10⁻⁵

Fig. 2