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RUSSIA

Technical report: Environmental impact of the BPPM and the ways of sustainable development of the economy of the Southern Coast of Lake Baikal*

Prepared for the Government of the Russian Federation
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

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CONTENT

1. INTRODUCTION

The Baikalsk Pulp and Paper Plant (BPPP) has been built in 1966 on the southern coast of Lake Baikal to produce 200 000 tons of high-quality bleached cellulose per year. The intention was to use this cellulose for the production of rayon, and finally, tyres of military aircraft. The major argument in favour of Lake Baikal as of the site of construction was the abundance of ultra-pure water. This resource made the production cheaper because it was simpler to desalt Baikal water, compared to other natural waters, prior to its use at the final stages of washing of the high-quality pulp.

However, the decision to built the plant, immediatley after it was announced, was subjected to severe criticism by citizen, journalists and scientists. Lake Baikal is a "sacred lake", a wonder of Russian wild nature, and opponents of the plant wanted to protect the lake from the intervention of pulp-and-paper industry which at that time had a very bad reputation as a major pollutant of many water bodies in Russia and abroad. The protest had a positive outcome, since the government once and forever abandoned plans to bring to Baikal other industries depending on pure water, although such plans existed. Secondly, it was decided to equip BPPP with unique and very expensive waste water purification facilities. However, the green movement failed to prevent construction of BPPP on the shore of Lake Baikal. Since that time, "the problem of BPPP" remains a major environmental concern of Russia.

The present paper gives a review of the following topics: (1) the present state of the ecological system of Lake Baikal; (2) characteristics of waste waters, exhaust gases and solid wastes of BPPP; (3) impact of BPPP upon aquatic and terrestial environment; (4) risk of envirohmental hazards associated with BPPP; (5) economic consequences of environmental legislation applied to BPPP; (6) prognosis of sustainable development of the economy of the southern coast of Lake Baikal according to different scenaria.

The authors of the present paper are convinced that the production of cellulose on the shore of Lake Baikal has to be stopped, in spite of the availability of "environment-friendly" technologies. The best argument in favour of this viewpoint may be the fact that nobody of the experts proposing renovation of BPPP would agree to recommend construction of a new pulp-and-paper plant on the shore of Lake Baikal.

2. THE PRESENT STATE OF THE ECOLOGICAL SYSTEM OF LAKE BAIKAL

2.1. Water and Bottom Sediments

Lake Baikal is the deepest (1637 m), the oldest (20 mln years) and the greatest (23 000 cubic kilometers) fresh-water lake of the world, home of 1500 endemic species. It stores 20% of liquid surface fresh water of the Earth, and this water is still of very high quality. General information on Lake Baikal may be found in the monograph by Kozhov (1963; [1]), and in an Atlas of Lake Baikal published in 1993 [2]. Table 1 shows the content of major ions and micro-elements in the water of Southern Baikal determined in 1991 by accurate modern methods [3].

Historic data and paleolimnological evidence have not revealed dramatic changes in the ecological system of Lake Baikal since the beginning of the industrial revolution of the XX century, except for accumulation of some chemicals which did not exist before they were synthesized by man, like DDT, PCBs, pesticides, etc. Fig.1 shows historic data [4-6] on the content of sulfate, a typical indicator of antropogenic pollution of lakes. It is seen that there is no trend in the concentration of this anion within the accuracy of the methods. For comparison, Fig.2 shows similar data for Lake Ontario (USA) [7] where the concentration of sulfate has significantly increased. This is not surprizing, since less than 2 million people live in the catchment basin of Lake Baikal (its area is of 500 000 sq.km, whereas some 40 million people live in the catchment basin of the Great Lakes (one of them - Lake Ontario), where industries and agriculture are much more developed. Absence of significant trends is also suggested by the identity of the concentrations of sulfate and calcium in the waters of the three basins of Lake Baikal at all depths (Fig.3) established to an accuracy of 2% by modern methods [3].

A sensitive indicator of changes in the concentrations of nutrients in lacustrine waters is the species composition of diatom algae. Thorough investigation of the uppermost layer of bottom sediments of Lake Baikal done by Flower et al. in 1992 [8] revealed (Fig.4) that the abundances of the dominating baikalian diatoms (since 1850) has changed but to a very small extent. Practically no changes occurred since 1930, i.e., since the beginning of the industrial revolution in Siberia which manifested itself in sediments of Southern Baikal by a rapid increase of the concentration

Table 1. The content of major ions and micro-elements in the waters of Southern Baikal [3].

Depth, m	Alkalinity	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	SO_4^{--}
				µmoles/ l			
4	1.089	389.0	124.6	158.2	25.7	12.1	56.4
18	1.099	390.7	-	-	24.1	-	-
23	1.102	395.2	124.6	-	23.5	-	-
47	1.105	395.5	-	-	24.9	-	-
104	1.097	394.8	123.7	157.1	24.0	12.5	59.4
172	1.091	408.9	-	-	24.2	-	-
210	1.091	399.3	126.9	-	23.3	-	-
248	1.102	396.4	-	-	23.5	-	-
288	1.096	405.9	126.7	161.1	24.0	-	57.6
336	1.094	405.0	-	-	25.8	-	-
470	1.099	405.0	126.2	-	24.7	-	-
480	1.093	419.9	-	-	24.2	-	-
478	1.094	410.7	125.4	152.0	23.9	13.0	56.4
577	1.093	405.3	-	-	23.5	-	-
674	1.102	414.7	125.3	-	24.8	-	-
871	1.090	403.3	126.0	152.8	23.6	11.2	56.4
968	1.092	409.9	-	-	23.6	-	-
1063	1.089	449.6	126.1	-	24.2	-	-
1157	1.092	401.8	-	-	23.2	-	-
1249	1.078	405.6	-	197.3(?)	28.5	-	59.4
1341	1.086	402.6	-	-	25.7	-	-
1415	1.103	-	125.8	-	23.4	-	-
1424	1.104	405.8	-	159.7	22.9	12.5	57.0

Depth, m	Sr	Li	Ba	Rb	U
			nmoles/ l		
4	1.37	291	75.6	7.09	1.80
18	1.35	290	75.4	7.09	1.80
23	1.34	299	76.8	7.11	1.77
47	1.30	305	74.9	6.79	1.73
104	1.37	290	75.8	7.17	1.83
172	1.34	297	75.4	7.15	1.78
210	1.31	301	76.0	6.88	1.78
288	1.35	294	76.5	7.17	1.86
336	1.31	295	72.4	6.89	1.73
470	1.29	286	73.9	6.81	1.73
480	1.29	296	74.8	6.92	1.62
478	1.29	297	74.2	6.77	1.70
577	1.35	301	75.5	7.16	1.75
674	1.34	305	74.5	7.30	1.67
774	1.31	291	74.6	7.02	1.44
871	1.32	293	73.4	7.09	1.77
968	1.32	295	74.2	7.09	1.65
1063	1.40	305	73.5	7.40	1.62
1157	1.38	295	73.6	7.33	1.58
1249	1.37	307	73.4	7.80	1.89
1341	1.37	299	73.7	7.68	1.85
1415	1.35	294	73.1	7.16	1.73
1424	1.44	295	67.2	7.56	1.77

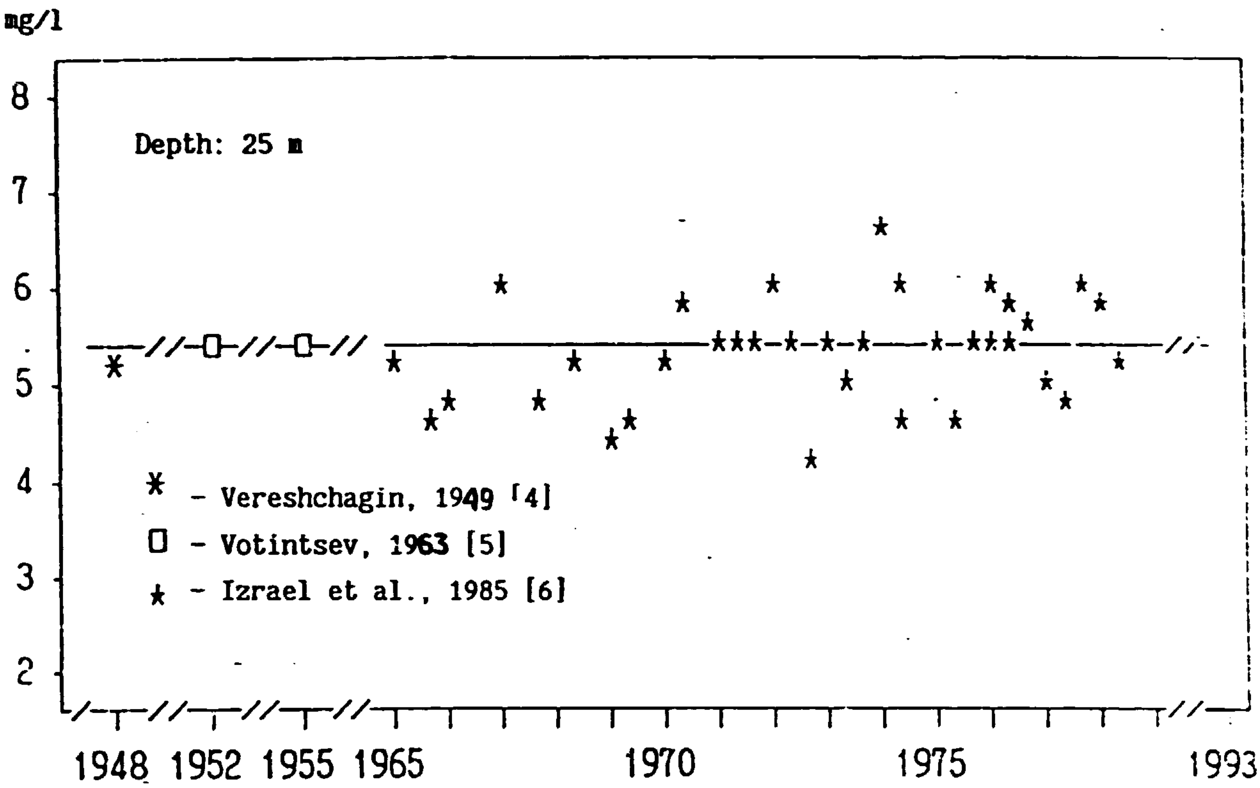

Fig.1. Concentrations of sulfate in surface waters of Lake Baikal (mean values for deep-water stations).

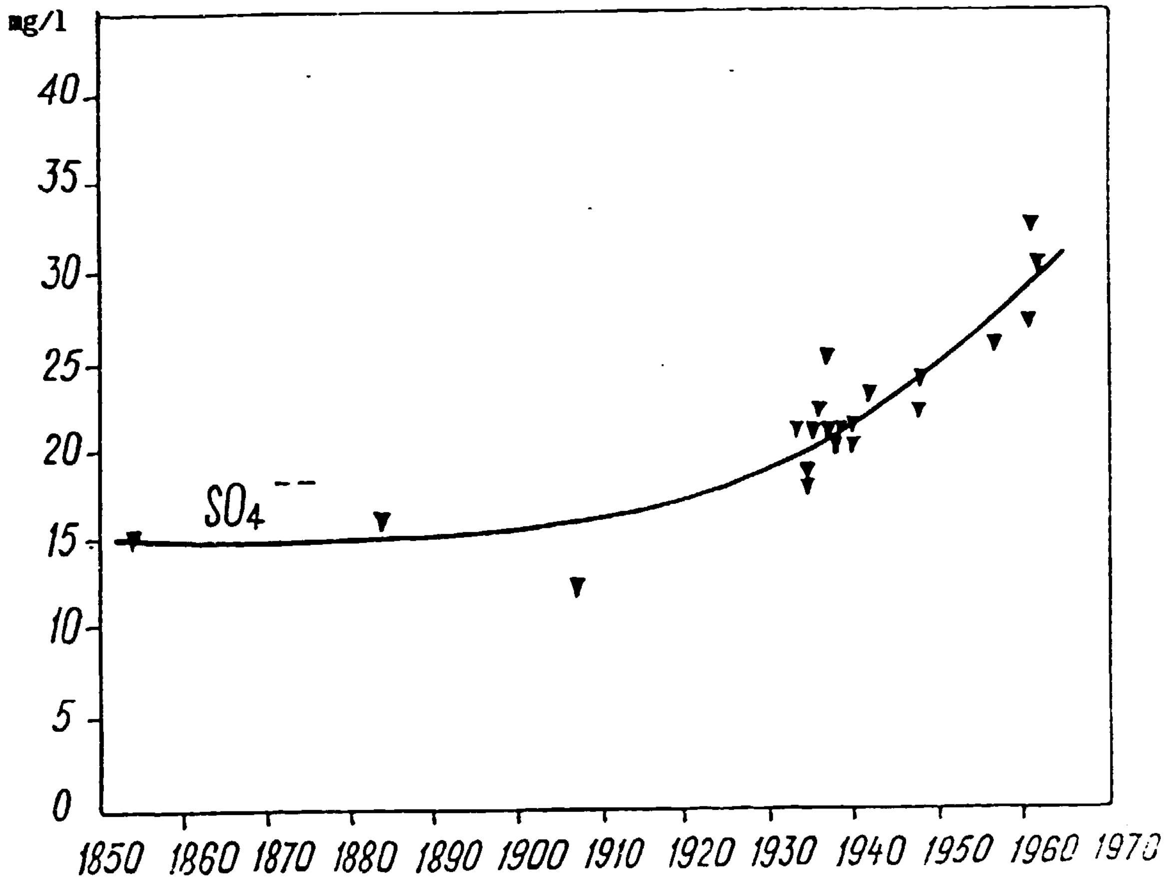

Fig.2. Concentrations of sulfate in Lake Ontario [7].

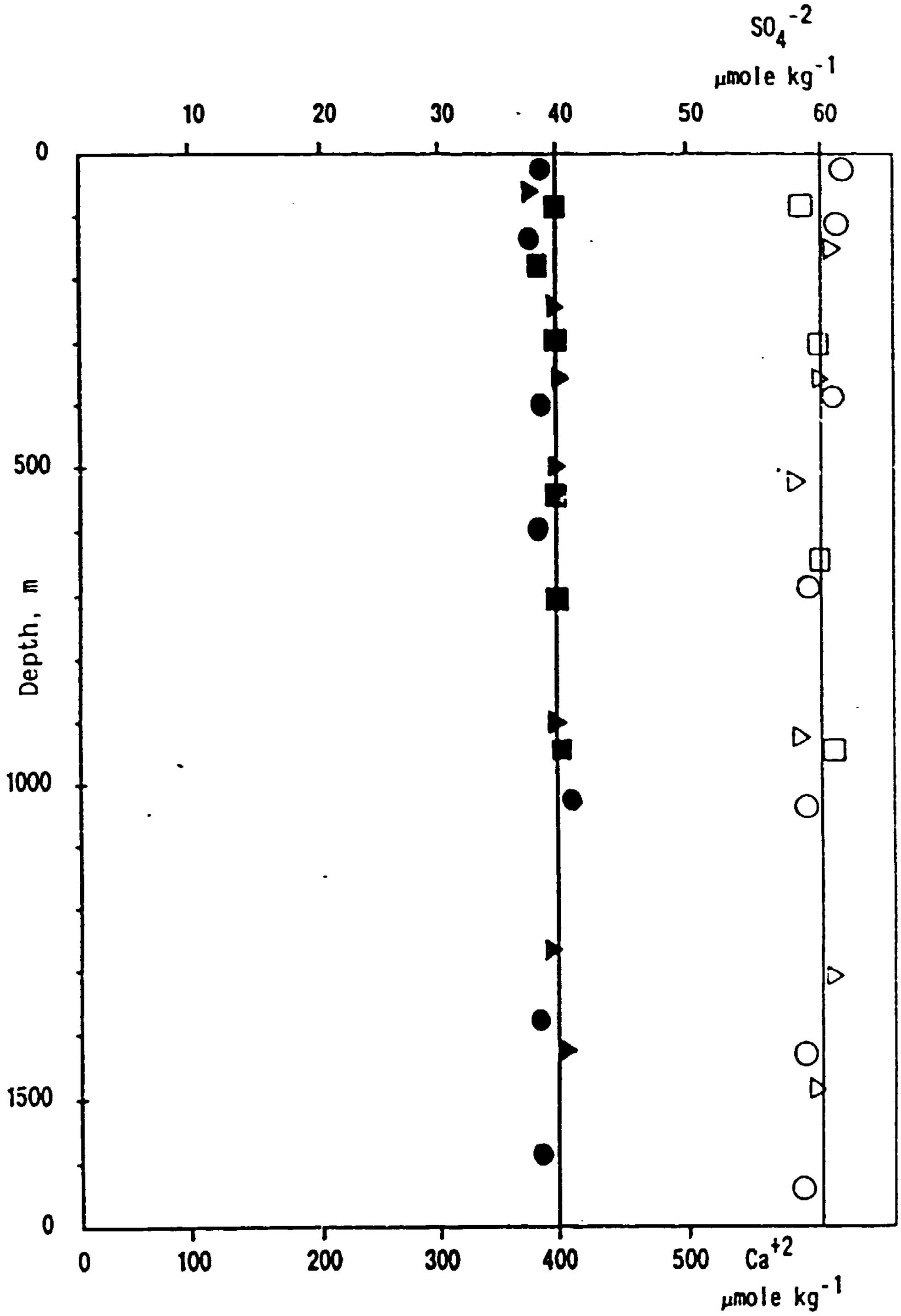

Fig.3. Concentrations of sulfate (open simbols) and calcium (black symbols) in different basins of Lake Baikal. Triangles - Southern Baikal; circles - Central Baikal; squares - Northern Baikal [3].

of carbonaceous particles (Fig.4) produced by high-temperature combustion of organic fuels in furnaces of power stations (such particles are not produced in furnaces of railroad steam engines). The most probable reason of the weakly expressed trend with diatoms seen on a longer time scale is change of climate.

It is seen in the same Fig.4 that since 1930 there took place a slight increase in the abundance of lead - a pollutant delivered into the environment due to combustion of fossil fuels, and by automobiles. Much stronger pollution occurred with the sediments of Lake Michigan (*Fig.5*; [9]).

Studies done by Russian [10, 11], American [12], and Japanese [13] scientists have shown that some chloroorganic compounds, especially DDT, are present at very high concentrations (up to 100 ppm) in the blubber of Baikal seals. The sources of these compounds are not exactly known, they may be both distant and local. Seal is the uppermost member of the pelagic food web of Lake Baikal. As for the lower members of this web, and Baikal water itself, they contain much smaller concentrations of chloroorganic compounds (e.g., the concentration of Σ DDT in Baikal water is equal to $87 \cdot 10^{12}$ grams per liter; this is 1 billion times smaller than that in cells blubber [12]).

A good illustration of purity is the certificate of the quality of bottled deep water of Southern Baikal issued by an independent German certifying institution - Fresenius Institute (*Annex 1*). It is important that this water, taken at a depth of 400 m near the outlet of Angara River has not been subjected to any purification before bottling except for thorough filtration. Purity of the water of Lake Baikal suggests that its biota has not yet lost the capacity to remove alien organic compounds.

2.2. Hydrobionts

It is necessary to consider the unique endemic complex of organisms living in Lake Baikal in order to understand the present state of this ecosystem. Firstly, there is no indication in scientific literature about recent extinction of any of the endemic species of Lake Baikal (e.g., see Atlas [2]). This does not mean that the numerical abundance of organisms of these species remains constant - on the contrary, this abundance is subject to significant, e.g., seasonal changes, like in any natural ecosystem. Polluted lakes, on the other hand, have totally lost many aquatic

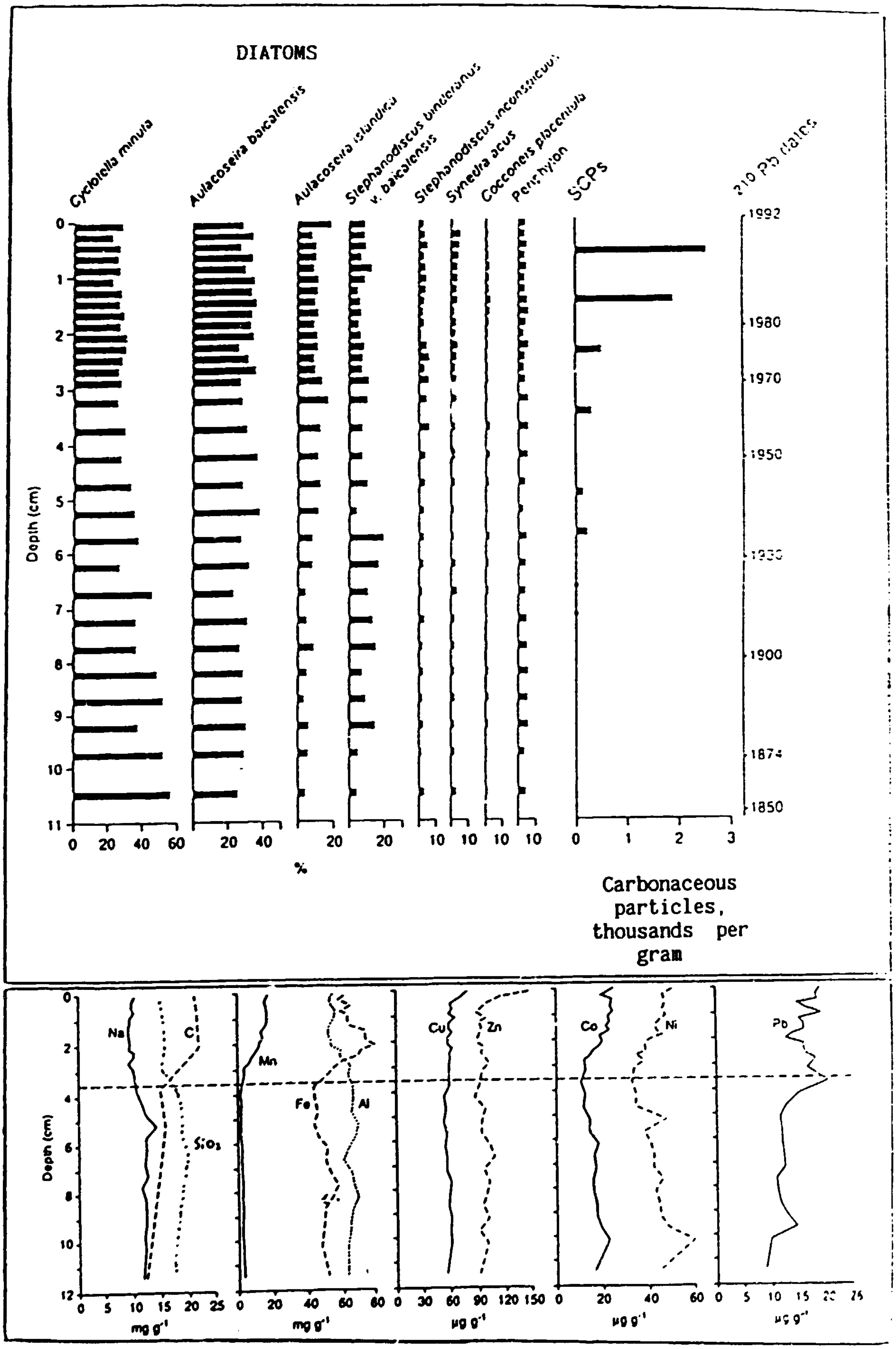

Fig.4. Changes in the ecological system of Lake Baikal since 1850, as revealed by studies of the uppermost layer (11 cm) of bottom sediments taken in Southern Baikal at a depth of 1420 m near the outlet of Selenga River [8].

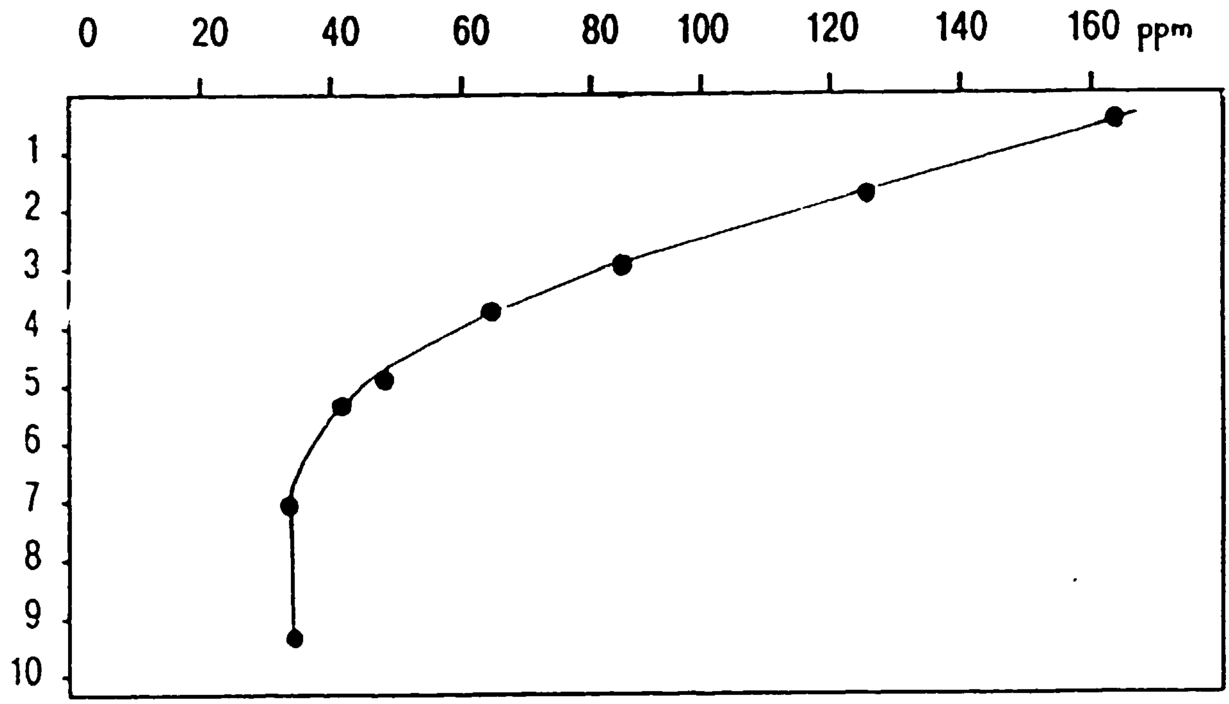

Fig.5. Concentrations of lead in the uppermost layers of bottom sediments of Lake Michigan [9]. Ordinate - depth below sediment surface, cm; 10 cm of sediment correspond to a time interval of 170 years.

species. A classical example are acidified lakes of Scandinavia, Canada and USA where many fish species disappeared completely. Many fish species have disappeared from the Great Lakes [7], presumably, due to intended and occasional introduction of new species; some commercially important fish stocks have completely lost their economic value. Such deep changes have not yet happened in Lake Baikal. Species introduced occasionally by man, like fish *Perccottus glehni*, canadian *elodea* alga, etc., cannot yet adapt to the deep and cold waters of open Baikal, and inhabit only near-shore shallow waters [14, 15].

An example of biological pollution of Lake Baikal is the disease of Baikal seals which has killed in 5-6 thousands of them of the total number of 70-100 thousands in winter of 1987-88. It is firmly established [16-18] that the disease was due to canine distemper virus, and did not have any direct connection with chemical pollution.

Great attention is attracted by the problem of "omul diminution" - decrease of the size of omul (*Coregonus autumnalis migratoris* Sars) - the major commercial fish of Lake Baikal. A two-fold decrease of the average weight of omul specimens since that typical of the 1930-ies has happened, although the total biomass of the fish in Baikal remained approximately the same [19]. This could be due to the ban of its commercial catch issued for five years in 1969, to intensive delivery of artificially fertilized omul larvae, and to over-catch of yellow-winged sculpins - the most valuable food of adult omul. Intensive feeding of the small-sized omul on *Epischura baicalensis* pelagic crustacean may be the reason of the decrease of the concentration of the biomass of this organism in Southern Baikal [20] (which is doubted by some authors [21]).

Surface waters of Southern Baikal near settlements are polluted with *Escherichia coli* of fecal origin [22].

2.3. Atmosphere

Let us now consider the state of the atmosphere over Baikal. A good integral indicator of antropogenic pollutiuon of the atmosphere is fallout of sulfate. Many years of measurements of the concentrations of sulfate in snow collected in March have shown that fallout of this pollutant equals to 0.1-0.4 tons of S per square kilometer per year [23] on the major part of the territory of the Baikal region .For comparison: fallout of sulfate in Europe over a major part of its territory is 10-70 times greater. Un-

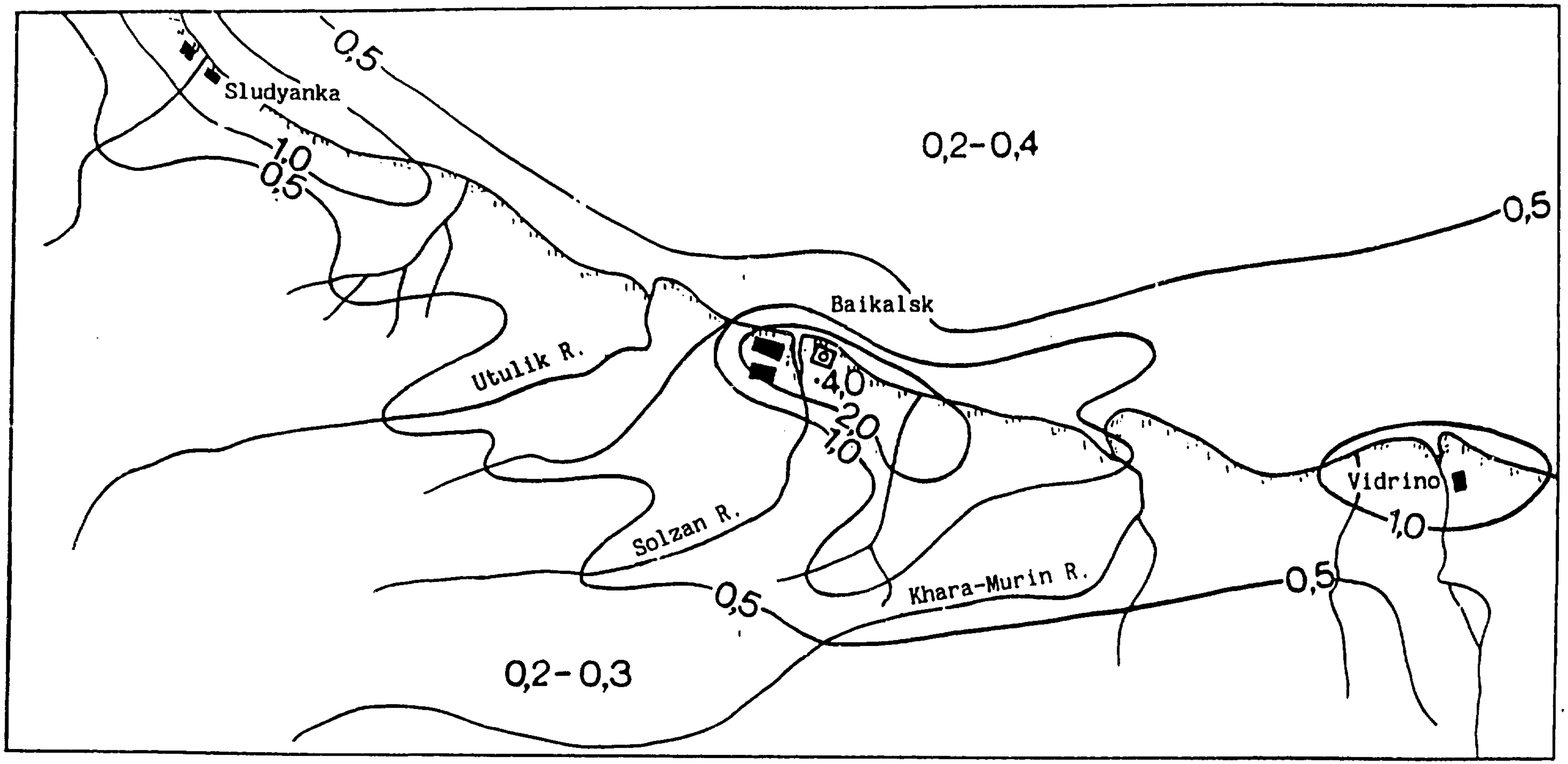

Fig.6. Fall-out of sulfate on the southern coast of Lake Baikal, tons of sulfur per square kilometer per year (extrapolated from the data on the content of sulfate in snow collected in March in 1986 - 1990) [23].

fortunately, high fallouts occur at some locations, one of them BPPP (Fig.6).

2.4. Landscapes

Natural landscapes of the soutern coast of Lake Baikal are heavily deteriorated. They suffered significantly for the first time in the end of the XIX century during the construction of the Trans-Siberian Railroad. A lot of shacks, ruins and garbage are typical of the setllements of Kultuk, Slyudyanka, Vidrino, Babushkin, Posolsk, etc. No special measures have been ever taken to plan and to protect these landscapes, even in the beginning of 1990-ies, when a new high-voltage electric line was built for the delivery of energy from Irkutsk District to Republic Buryatia. The contribution of BPPP to deteroration of landscapes will be discussed in another section. However, it may be mentioned here that of all the sites mentioned only its high stacks are seen from the lake surface at a large distance.

Forests of the southern coast of Lake Baikal have been seriously changed by human activity. Their intensive cutting took place during the construction and the first decades of work of the Trans-Siberian Railroad, during the construction of the highway, of electric power lines, of numerous settlements and "dachas". Forest fires happen here every year. Till the middle of the 1980-ies, these forests were subject to major cutting for industrial purposes - such cutting is at present prohibited. A significant contribution to conservation of the forests of the southern coast has been given by the Tankhoi Reserve.

2.5. General Remarks

Considering the state of the ecological system of Lake Baikal in general, it has to be mentioned that the state of landscapes received little attention, whereas the extent of pollution of waters was exagerrated, especially in publications for laymen. For example, academician G.I.Galazy presents the following calculations in his book "Baikal in Questions and Answers" [24]: "BPPP has discharged 1.5 billion cubic meters of polluted wastewater during the time of its operation; these wastewaters affect the behaviour of fishes after 10 000 times dilution; hence, spoiled is 15 thousand cubic kilometers of Baikal water, more than half of the total volume of the lake". This calculation does not take into account decomposition of biologically active compounds, their removal from the water body into the atmosphere and burial into the bottom sediments, concentration by biota.

Much misunderstanding is due to the use of inaccurate methods for the analysis of Baikal waters. For example, paper [25] claims that waters of Southern Baikal are totally polluted by sulfate-anion, although this conclusion is not confirmed by more accurate methods [3]. Paper [26] considering the results of analysis of sulfate in Baikal during the time interval from 1950 to 1980-ies gives an average concentration of this anion equal to 4.85 mg per liter, but the 95% confidence interval is between 4.42 and 6.28 mg per liter. This means that the methods could not be used to monitor trends of sulfate concentration in the waters of Lake Baikal. Indeed, a 1 mg per liter increase of the concentration of sulfate in Southern Baikal would need a delivery of this pollutant equal to 5.6 million tons. It would take BPPP 300 years to discharge this amount of sulfate.

3. CHARACTERISTICS OF WASTE WATERS, EXHAUST GASES AND SOLID WASTES OF BPPP

3.1. Waste waters

The State Service for Hydrometeorolgy and Environmental Monitoring of Russian Federation reports (Annex 2) that BPPP has discharged 57.2 mliion cubic meters of waste waters in 1994. This volume is equal to that of waste waters of a city with some 500 000 inhabitants, (e.g., Ulan-Ude). BPPP has discharged with these waters 9 700 tons of sulfate, 6 200 tons of chloride, 2 800 tons of hardly-oxidized organic compounds, 530 tons of easily-oxidized organic compounds, 200 tons of suspended solids. Concentrations of these compounds in waste waters are many times greater than those in the waters of Lake Baikal (Table 2).

Waste waters contain toxic components. The most dangerous of them are believed to be chloroorganic compounds formed from lignin during the bleaching procedures. According to the official report of 1994 (Annex 2) based on the data of the Baikalsk Institute of Ecological Toxicology, BPPP has discharged into Baikal 76 tons of TOCl. Low molecular weight chloroorganic compounds have been found by means of HPLC in purified waste water, and in bile of fishes kept in diluted purified waste water of BPPP (fishes rapid-

Table 2. The planned (according to the project of 1964) and permitted characteristics of the purified waste waters of BPPP.

Characteristics	Project of 1964	Permitted characteristics 1971	1972	1977	1979	1982	1985	Baikal, background
pH	6.3-6.8	6.5-7.5	6.5-7.5	6.5-7.5	6.5-7.5	6.5-7.5	5.3-9.8	7.2-7.6
Oxigen demand, mgO/l.	160-210	100	-	-	-	-	-	-
BOD_5, mgO/l	5-7	6	6	2.5	2.0	2.5	3.0	0.5-1
BOD_{compl}, mgO/l	-	-	-	-	-	-	15	-
COD, mgO/l	180-230	150	100	65	55	60	65	5-10
Dissolved salts, mg/l	345	750	600	650	550	645	610	95-105
Suspended solids, mg/l	5-10	10	5	5.5	6	6	6	0.2-0.3
Colour	No colour	<100	100	75	65	70	75	No colour
Dissolved O_2, mg/l	4-6	>4	6	6	6	6	>6	10-12
Sulfurorganic compounds, mg/l	0.5	0.05	0.05	0.05	0.05	0.16	0.25	0.03-0.24
Sulfate, mg/l	-	-	-	-	-	-	300	4.8
Chloride, mg/l	-	-	-	-	-	-	100	0.56
Volatile phenols, mg/l	-	<0.1	0.02	0.015	0.01	0.02	0.015	0.001-0.018

ly die in non-diluted waste water). The concentrations of some chloroorganic compounds in purified BPPP waste water are the following: trichloroguaiacol - 1.4; tetrachloroguaiacol - 0.03; tetrachlorocatechol - 0.7; pentachlorophenol - 0.25 μg per liter [27].

Priority toxicants of pulp-and-paper industry, resin acids, have been also found in purified waste water by means of HPLC; for example, the concentration of dihydroabietic acid was 0.4 μg per liter, [27].

Purified waste water contains phenols (5 - 60 μg per liter), compounds of divalent sulfur, e.g., dimethylsulfide (6 - 109 μg per liter), aluminium (80 μg per liter), mercury (0.6 - 7 μg per liter), and many other components [28].

Tests with yeasts and bacteria have shown that purified waste water of BPPP has a significant mutagenic activity [29]. Purified waste water contains live fecal microorganisms [22] due to the contribution of municipal waste waters of the town of Baikalsk; the latter are purified together with the industrial waste waters, but are not desinfected, because they are mixed with industrial waste waters only after their active chlorine present in the the effluent of bleaching has been neutralized by compounds of the effluents of the cooking, evaporation, and drying plants [30].

An additional source of pollution of Baikal are underground waters. The latter are believed to be contaminated over a front which is 6.5 km long. The volume of waters draining through rocks under the area of BPPP is 17 500 cubic meters per day (Annex 3). The extent of pollution of these underground waters is not exactly known.

3.2. Exhaust Gases

Table 3 shows the composition and the planned amounts of pollutants which BPPP was going to discharge into the atmosphere in 1994, on an agreement with the environment protection committee of Irkutsk District [31]. It will be mentioned that plans of this type are usually fulfilled by BPPP; it has reached a high extent of removal of solid compounds and some other substances, but does not efficiently remove malodorous compounds of divalent sulfur - their discharge into the atmosphere was planned to be equal to 300 tons in 1994 [31]. There are no reliable data on the discharge of polychlorodibenzodioxines - super-ecotoxicants which are without any doubt formed during the burning of lignin slime, and thrown out into the atmosphere.

Table 3. Planned discharges of BPPP into the atmosphere, 1994. Tons per year.

Component	MPD*	TAD**
Inorganic dust	740.8	1500
Wood dust	1.1	-
Fly ash	2447.5	3355.6
Sulfur dioxide	2308.0	-
Hydrogen sulfide	18.3	194.8
Methyl mercaptan	0.3	70.1
Dimethyl sulfide	10.8	38.2
Dimethyl disulfide	15.3	-
Terpentine	36.5	46.4
NO_x	1171.0	3526.4
CO	937.0	-
Aerosol of alkali	14.0	-
Chlorine dioxide	5.7	-
Chlorine	3.1	-
Phenols	0.4	-
Methanol	0.001	-
Vanadium pentaoxide	0.5	-
Benzo(a)pyrene	0.0023	-

* MPD - maximum permitted discharge

** TAD - temporarily agreed discharge

3.3. Solid Wastes

The total amount of solid wastes of BPPP in 1994 was equal to 121 000 tons [31]. These were majorly fly ash of the coal-burning energy plant. Ash is collected by electrostatic filters and removed by the wet method, mixed with the black slime of green liquor (precipitate which is formed during the preparation of the cooking liquor from the melt produced by soda regeneration plants), and buried in ash storage ponds. It will be mentioned that the most dangerous component of the ash storage facilities is alkali - pH of their supernatants is more than 12. The source of alkali is slime of green liquor; the discharge of this slime is equal to 7 000 tons per year [32]. Minor amounts (200 tons) of solid wastes are formed during the burning of concentrated lignin slime - i.e., of the residue formed at the waste water treatment plant [31].

4. ENVIRONMENTAL IMPACTS OF BPPP

4.1. Chemical Contamination of Water

The hydrochemical methods used do not give reliable information on the size of the zone of water pollution around BPPP. Areas of contamination published by different authors are different (Table 4; [33]). The publications on this topic [34-36] usually do not present protocols of measurement, crude data and experimental errors. This remark concerns both scientific publications, and official reports.

Questions arise even when data are published in reviewed scientific journals. For example, Lomonosov et al [37] claim that "during the period of studies, cases of significant increase of the concentrations of sulfate were recorded, majorly near the outlet of waste waters of BPPP". However, plots and tables presented in this publication show that these authors observed not only an increase, but also a significant decrease of the concentrations of sulfate "near the outlet of waste waters of BPPP", i.e., at stations within 1 km off the outlet. It is seen in one of the figures that the concentration of sulfate was permanently smaller than that found in Baikal, and varied between 0 and 4 mg per liter. Table 1 of the same publication presents minimal concentrations equal to 1.4-1.5 mg per liter. It is difficult to imagine a mechanism which would lead to a decrease of the

Table 4. A. The estimated areas of pollution near the outlet of the waste waters of BPPP [33].

Estimate of:	Indicator	Area, sq.km	
		Water body	Bottom sediments
Irkutsk University	Hydrobiological	Non-detected	0.1
Institute of Applied Geophysics	Hydrochemical (major ions)	2.0	-
Hydrochemical Institute	Hydrochemical (sulphur organic compounds, terpentine, methanol)	17 - 35	2.3 - 2.7
Limnological Institute of the Academy of Sciences of USSR	Electric conductivity, microbiology, organoleptic	› 50-60	› 3

B. The estimated areas of pollution in, or via the atmosphere.

Pollutant or indicator	Area of the polluted zone, sq.km	Estimated by:
Carbon disulfide	150	Hydrochemical Institute
Organic carbon	335	Hydrochemical Institute
Sulfur dioxide	40	Institute of Applied Geophysics
Heavy metals in snow	400	Laboratory for the Monitoring of Climate and Environment
Insoluble solid particles	300	Institute of Ecological Toxicology
State of lichen	230	Tartu State University
State of forests	50	Irkutsk Agricultural Institute

concentrations of sulfate near the outlet of waste waters of BPPP in the upper layer of Baikal water which is 25 - 200 m thick; evidently, these results are erroneous.

Presumably, inadequacy of the methods used to measure the concentrations of major ions is the reason for which data on their content on the constantly monitored 35 sq.km area near BPPP are not given in official documents (Annex 2).

Fedorov [38] attempted to estimate the area of contamination of Baikal water near BPPP with sulfate by measuring $\delta^{34}S$. Unfortunately, experimental data [38] do not confirm the conclusion that the area is equal to 45-60 sq.km. Fedorov found the following $\delta^{34}S$ values over the presumed "contaminated zone": 3.9; 3.3; 5.6; 4.1 $^{o}/oo$. The values for open Baikal are higher: 13.9; 9.6; 10.6 $^{o}/oo$. Waste water exhibited $\delta^{34}S$ values of 5.6 - 6.4 $^{o}/oo$, i.e., greater than those found in the contaminated zone. Hence, the conclusion is either due to erroneous measurements, or to the fact that the author did not take into account the effect of the waters of the small tributaries of Lake Baikal, Osinovka River, and Khara-Murin River, whose mouths are near the outlet of the waste waters of BPPP.

Discharge of excess major ions into Baikal at first glance does not seem to be dangerous, since they are not toxic. However, this discharge is in fact a matter of concern, in terms of stability of the ecological system of Lake Baikal over long time intervals. For example, the concentration of chloride in the waste water of BPPP is 140 times greater than that in Baikal. This anion is not buried in bottom sediments. The time of the exchange of waters of Southern Baikal is 200-300 years. Hence, all the chloride delivered by BPPP into the lake is "used" exclusively to increase its concentration. The presence of sources of chloride which are even greater than BPPP does not matter, since, if these are natural sources, they are in a secular equilibrium with the waters of Baikal. During the 30 years of work of BPPP, the concentration of chloride in Southern Baikal should have increased some 5%; unfortunately, the methods of monitoring applied were not able to trace such a small increase. The contribution of BPPP alone will result in a large-scale transformation of its ecosystem due to increase of salinity already in a few decades - a time which is very short on the geological time scale. Remarkably, the discharge of chloride by BPPP is approximately the same as that consumed by all the inhabitants (1.5 mln people) of the catchment basin.

It may happen that the increased concentrations of major ions in the zone of contamination near BPPP occurs near the bottom - this possibility is discussed in the above mentioned official report (Annex 2). The reason of such distribution may be increased density of the warmer, but more mineralized mixture of the diluted waste waters, compared to waters of Baikal. A similar phenomenon was observed near the Frolikha vent in Northern Baikal where an anomaly of temperature and salinity was traced down the underwater slope to a depth of 700 m near; thermal waters are discharged at a depth of 450 m [39].

Presumably, most reliable information on chemical pollution of Baikal near the outlet of waste water of BPPP could be obtained by measuring the concentrations of compounds specific for the waste water. Unfortunately, the sensitivity of the methods and instruments which are practically applied for this purpose by official organizations is too small for this purpose. For this reason, specific chloroorganic compounds were not found on the standard 35 sq.km test area (Annex 2, annual report, p.4). Data on the contamination of a 3 -14 sq.km area with non-sulfate sulfur mentioned in the same document (annual report, p.3) do not seem to be reliable, since this value is often found to be equal to zero even in non-diluted waste water (Annex 2, report on the fourth quarter of 1994, Table 3).

4.2. Microbiological Contamination of Water

The most reliable data on the large-scale impact of BPPP on the water body of Lake Baikal have been obtained by microbiological methods. The concentrations of heterotrophic microorganisms were measured near the outlet of waste water of BPP over an area of 30 sq.km on a grid of stations 600 x 600 m [40]. Maximal concentrations of these microorganisms in the background regions were 9 colony-producing cells per liter in winter, and 237 cells per liter in summer. Maximal concentrations in the polluted zone were 237 and 2390 cells per liter in winter and summer, respectively. The size of the polluted area was 4 sq.km. Almost the same area (5 sq. km) for saprophite microorganism has been reported later [41].

Different workers have found high concentrations of allochtonous pathogenic microflora - mainly *E.coli* - near the outlet of BPPP waste water (e.g., [22, 42]). Fig.7 shows the distribution of the concentrations of *E.coli* over a large area. This dangerous pollutant is found near BPPP even at great depths.

Official report (Annex 2) gives an area of pollution as indicated by

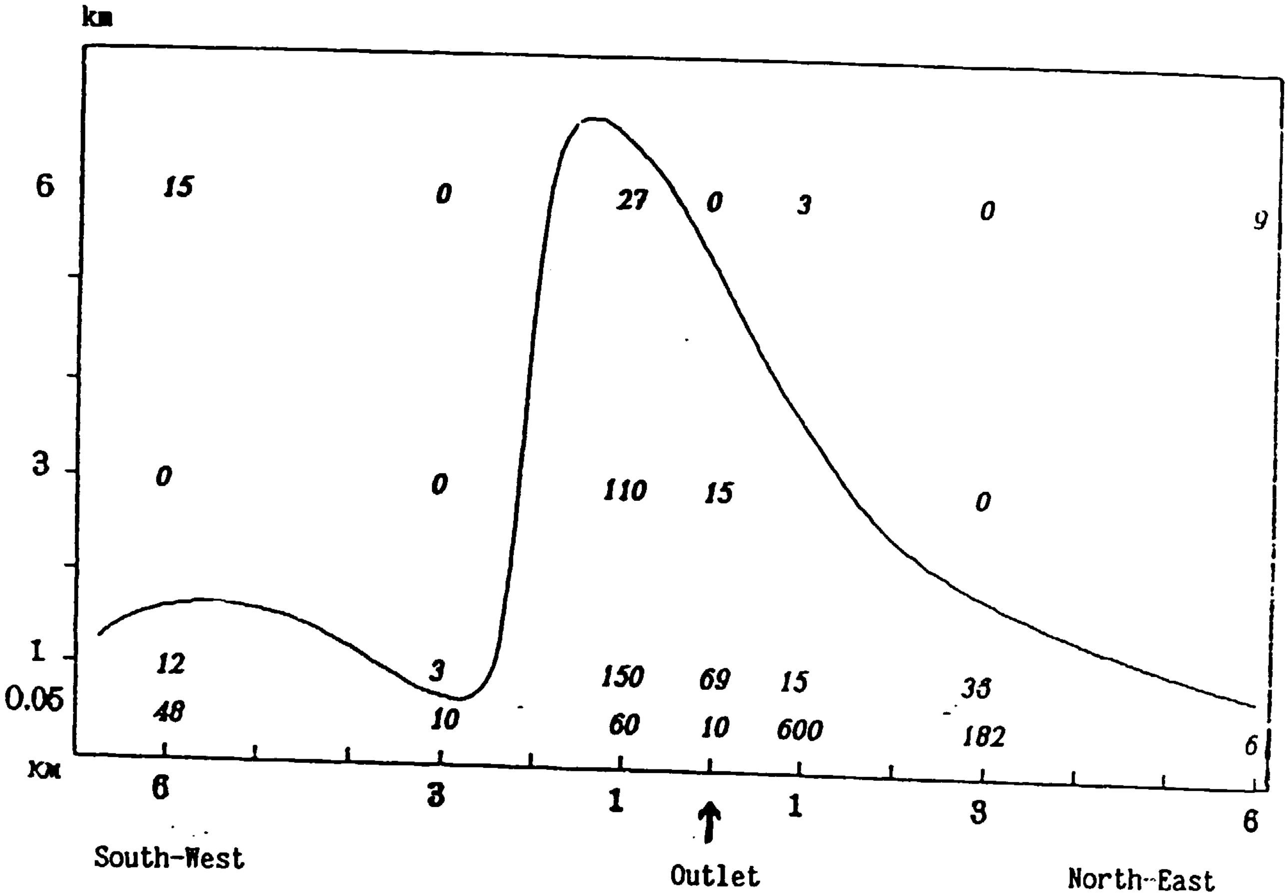

Fig.7. The concentrations of *E.coli* (cells per liter) in the surface waters of Lake Baikal near the outlet of purified waste waters of BPPP, 1992 [42].

bacterioplankton equal to 56 - 86 sq.km.

4.3. Effect upon Phyto- and Zooplankton

The task of evaluation of the effect of waste water of BPPP on natural populations of plankton is a very difficult one because these populations are subject to great, especially seasonal variation. For example, lethal effect of waste water upon the dominating pelagic crustacean *Epischura baicalensis* is masked by natural mortalility due to attack of a fungi *Saprolegnia* [41] (p.180).

In any case, direct impact on these populations is small, compared to their total abundances in Baikal. For *Epischura baicalensis* it amounts to 0.002 - 0.6% [41] (p.157-158). The area of impact cannot be accurately determined (see Annex 2, report for 1994, p.5).

4.4. Contamination of Bottom Sediments

The effect of BPPP upon bottom sediments is well studied. Fig.8 shows a scheme of the distribution of sediments contaminated with cellulose and lignin as determined in August of 1978 over an area of 25-30 sq.km [43]. At that time, strong contamination was found in one of the underwater canyons. However, contaminated sediments are gradually displaced down the slope, as revealed by data obtained by the same workers in March of 1979 (Fig.9). Official documents give a size of the polluted area equal to 69 sq. km; the total area studied was 130 sq. km (Annex 2, report for 1994, p.4); pollution manifested itself in an increased content of sulfides suggesting increased microbial sulfate reduction due to the high content of organic matter.

Organic chlorine compounds have been found in bottom sediments near the outlet of waste water of BPPP [44].

Pollution of the bottom results in a change of benthic communities. Mapping of these communities has been done by many workers (for review see ref.[41], page 245 and below).

4.5. Pollution of the Atmosphere

To study pollution of atmosphere by BPPP, a special program was fulfilled in order to investigate transfer of aerosols and gaseous pollu-

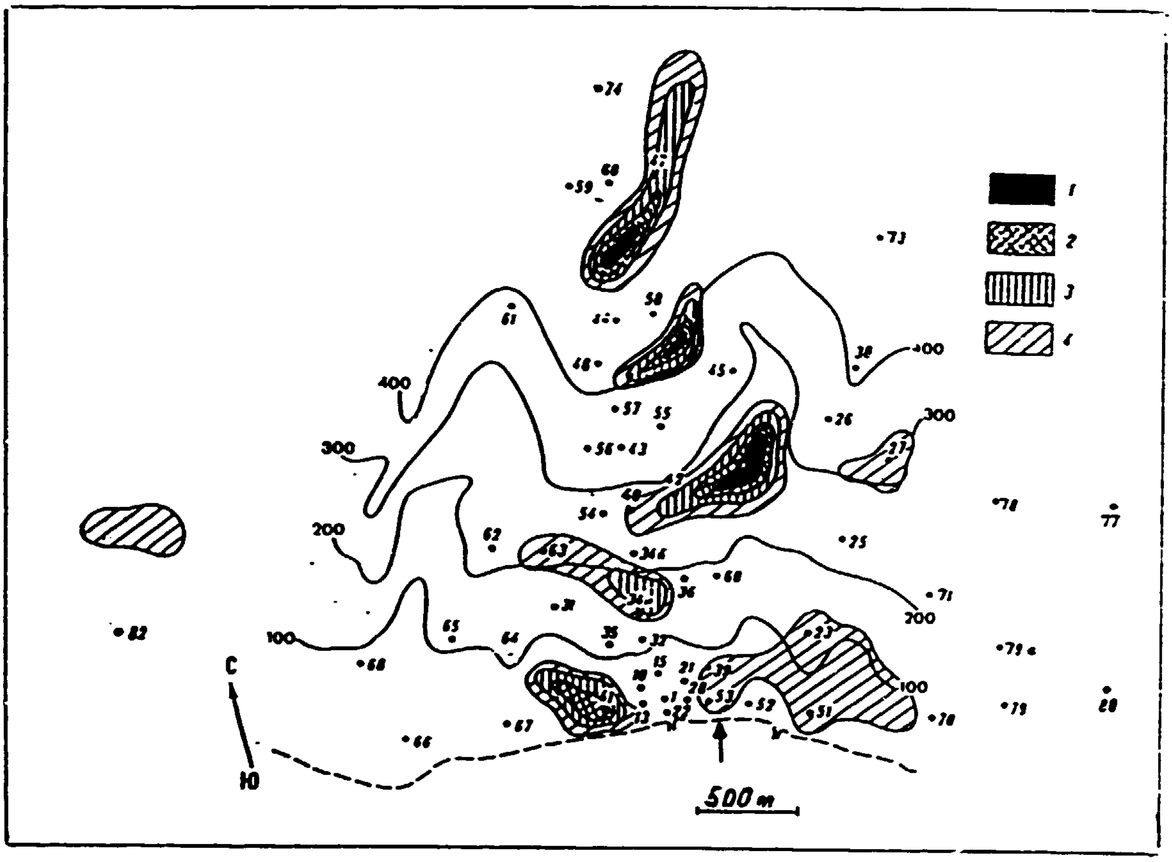

Fig.8. Spots of pollution of bottom sediments of Lake Baikal with cellulose and lignin near the outlet of waste waters of BPPP in August of 1978 [43].

100, 200, 300, 400 - depths. 1 - very strong pollution (30 - 39%); 2 - strong pollution (25 - 29%); 3 - weak pollution (19 - 24%). Two-digit figures - numbers of stations.

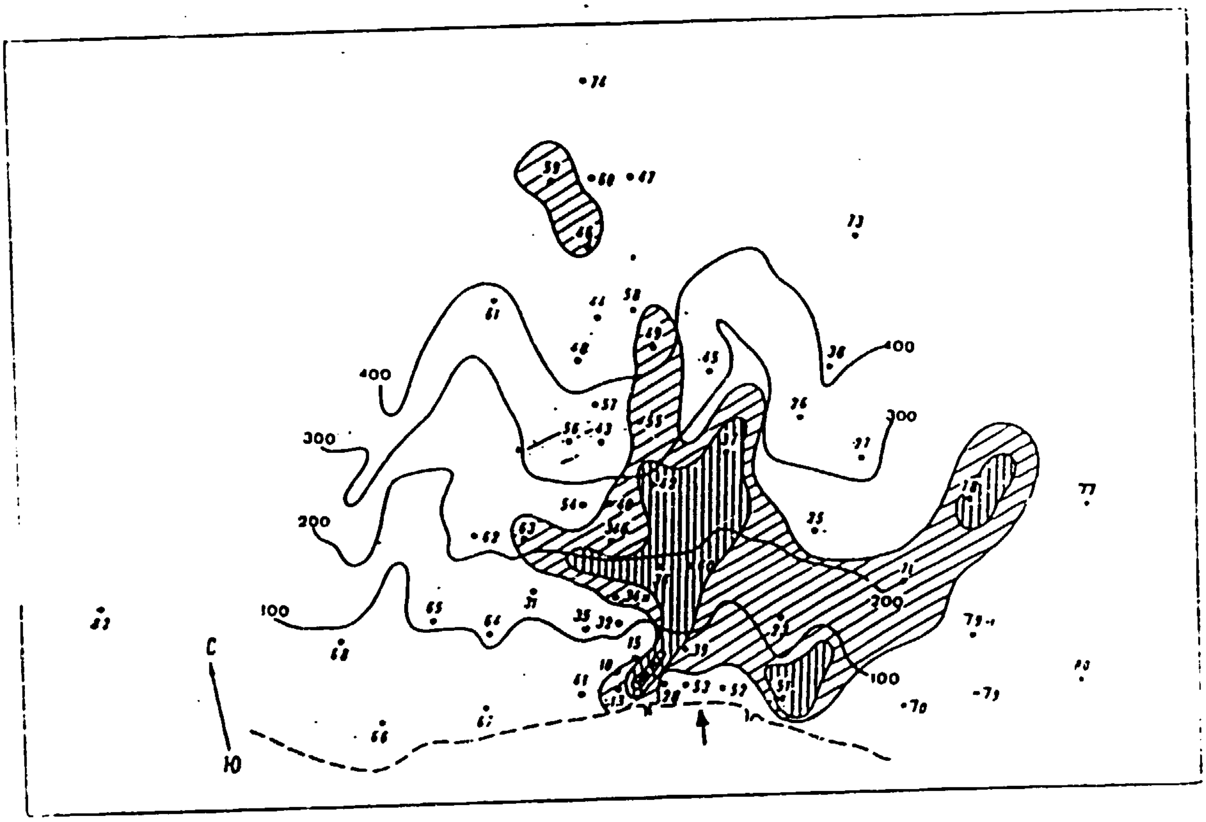

Fig.9. The same as Fig.8, but for March of 1979 [43].

tants. Measurement of the concentrations of pollutants in snow, collected in March during a few years in 1980-1990 resulted in mapping of the zone of influence of BPPP having an area of 300-400 sq. km [23, 45]. Fallout of sulfate (Fig.6) and of insoluble solid particles was increased in this zone, compared to background. BPPP has considerably decreased the discharge of dust in 1990 due to installation of new concentrators of black liquor and electrostatic filters. Presumably, for this reason the area of the zone of pollution with sulfate was reduced to 6 sq. km, and with dust to 36 sq. km (Annex 2, report of 1994, p.4).

Efficient removal of dust may be the reason of the small content of polyaromatic hydrocarbons in snow around BPPP compared to the zone of the influence of the nearby Sludyanka settlement (Table 5; [46]).

Studies of the content of chloroorganic compounds in snow have revealed pesticides, but failed to detect PCBs near BPPP [47]. It was not yet attempted to find polychloro dibenzodioxines and dibenzofuranes in snow near BPPP.

Most uncomfortable for humans are the high concentrations of malodorous compounds of divalent sulfur - hydrogen sulfide, dimethyl sulfide, methyl mercaptan, and dimethyl disulfide - which are present around BPPP. Bad smell is felt at a distance of 10 km around the plant, corresponding to an area of the polluted zone equal to some 400 sq. km. This fact is not surprizung, since the limit of olfactory detection of mercaptans is some 10^{-5} mg per cubic meter of air. BPPP discharges into the atmosphere 1 ton of malodorous compounds per day (300 tons per year, Table 3).

Fig.10 shows results of modeling of the pollution of atmosphere with mercaptans around BPPP [48]. The source was assumed to produce 5.7 grams of mercaptans per second (ca. 200 tons per year). The coefficient of decay in the atmosphere was assumed to be equal to 3×10^{-5} sec^{-1}. It is seen that the data of modeling are in a good accord with organoleptic observations: both in winter and in summer, the probability of concentrations higher than 20 maximum permissible concentrations (at that time MPC was equal to 9×10^{-6} mg per cubic meter of air) was greater than 0.4 over an area of 20 x 20 km. Official data obtained for the town of Baikalsk revealed that concentrations of methyl mercaptan were 30 times greater than MPC (Annex 2, report for 1994, p.6). This undoubtely impacts the development of tourism and recreation.

Table 5. The concentrations of polynuclear aromatic compounds in the air and in snow water collected near settlements Sludyanka, Tankhoy and Baikalsk on the southern coast of Lake Baikal [46].

PAH	SLYUDYANKA		BAIKALSK		TANKHOY	
	air, $ng \cdot m^{-3}$	snow water, ng/l	air, $ng \cdot m^{-3}$	snow water, ng/l	air, $ng \cdot m^{-3}$	snow water, ng/l
1.	<0.1	<5	<0.1	<5.3	<0.1	<5.3
2.	<0.2	<8	<0.2	<7.8	<0.2 - 0.9	<7.8
3.	<0.3	<15	<0.3	<15.0	<0.3	<15.0
4.	<0.04	<2- 200	<0.04	<1.7	<0.04	< 1.7
5.	0.1- 2.4	700-2700	<0.01	32.9- 97	<0.01-0.2	68.9-525
6.	0.1- 0.9	5- 300	<0.01	<0.5	<0.01	<0.5
7.	2.5-22.5	900-5900	<0.05-2.8	<2.3-136	<0.05-2.2	<2.3-670
8.	0.1- 14.8	2- 700	<0.05-0.1	<2.2	<0.05-1.1	<2.2
9.	0.8- 6.2	2- 20	0.2 -0.4	<1.6-101	0.5 -0.6	<1.6
10.	0.4- 2.5	50-1000	<0.02-0.2	30.4-100	0.3 -0.7	<0.7-286
11.	0.3- 10.4	30- 800	<0.03-0.2	<1.3- 92	0.2 -0.6	29.4-170
12.	<0.03	1- 10	<0.03	<1.2	<0.03-0.3	<1.2- 26
13.	0.3- 21.8	20- 800	<0.03	<1.4- 44	<0.03-0.5	<1.4- 93
14.	<0.2	9-1000	<0.2	<8.6- 95	<0.2	<8.6
15.	0.1-13.9	4-1000	<0.1	<4.5- 15	<0.1	<4.5
16.	0.3- 2.7	<1	<0.03	<1.3	<0.03-0.6	<1.3

1- naphthalene; 2- acenaphthylene; 3- acenaphthene; 4- fluorene; 5- phenanthrene; 6- anthracene; 7- fluoranthene; 8- pyrene; 9- benzo[a]anthracene; 10- chrysene; 11- benzo[b]fluoranthene; 12- benzo[k]fluoranthene; 13- benzo[a]pyrene; 14- dibenzo[a,h]anthracene; 15- benzo[g,h,i]perylene; 16-indeno[1,2,3-cd]pyrene.

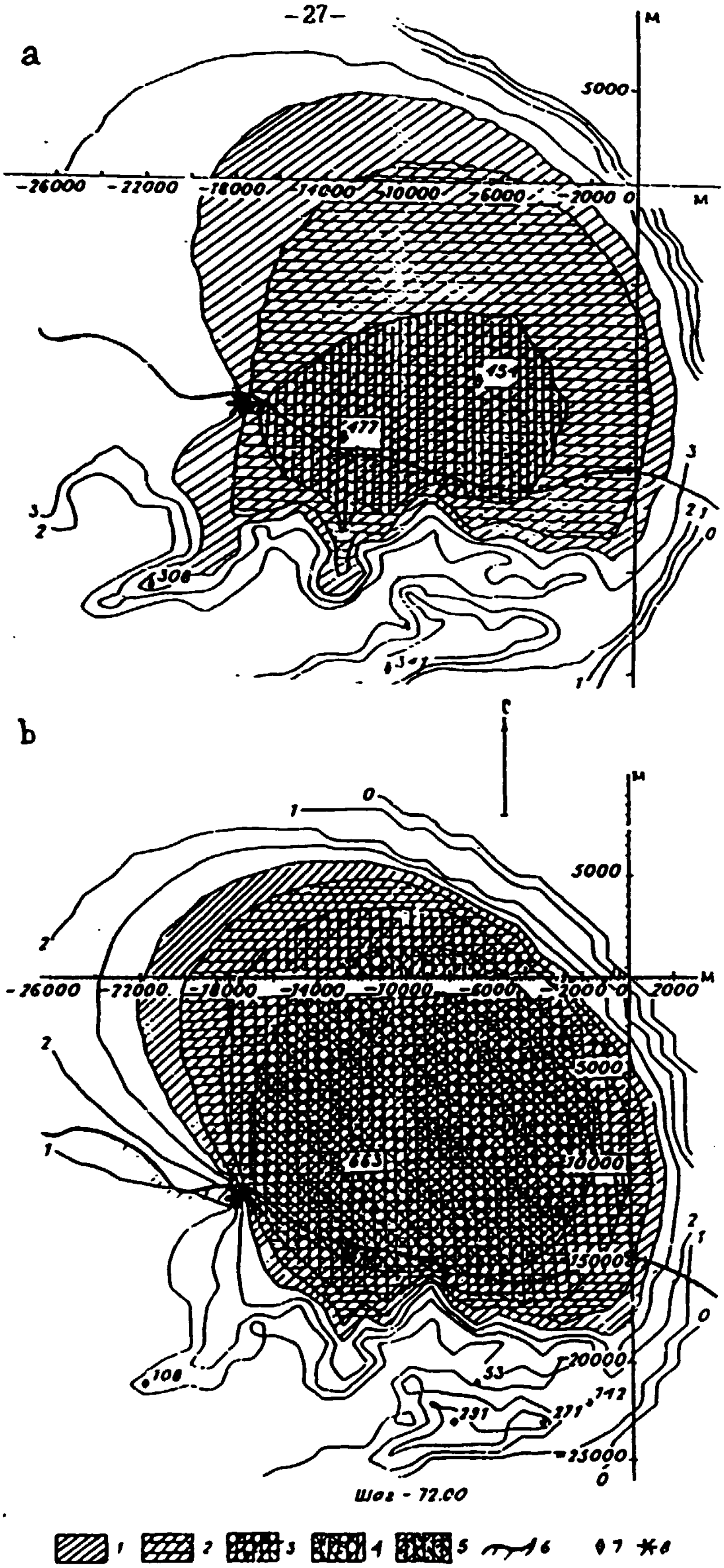

Fig. 10. The probabilities of occurrence of high concentrations of methyl mercaptan near BPPP (results of modeling) [48]. a - in July; b - in December. The probabilities per month were calculated for concentrations equal to 20 maximum permissible concentrations. Probabilities: 1 - more than 0.4; 2 - more than 0.5; 3 - more than 0.6; 4 - more than 0.7; 5 - more than 0.8. Thick line - the shoreline of Lake Baikal. - local extrema. 8 - source of pollution (BPPP).

4.6. Impact of BPPP upon Terrestial Environment

The impact of BPPP upon terrestial environment has been studied in detail. Survey of 1983 [49] revealed that some 13 sq. km of forest dried out, and some 350 sq.km was irreversibly weakened around BPPP. However, studies which were done later disagree with the conclusion that the forests dry out exclusively due to the impact of BPPP [50, 51]. Changing climate and recreation activity may have contributed to this process.

A sensitive indicator of environmental pollution are lichen. Detailled studies of lichen around BPPP were done in 1979-82. Reliable data on the area of the zone of pollution have been obtained (Fig.11); there is no doubt that this zone is due to the impact of BPPP [52].

4.7. Impact upon Landscapes

BPPP occupies a plot of land on the southern coast of Lake Baikal having a length of 12 km, from Babkha River to Solzan railroad station. Natural landscapes on this plot are totally deteriorated: there are buildings of the plant, stacks having a height of 100-120 m, ponds with waste lignin slime and suspension of fly ash having a volume of 5 million and 3 million cubic meters, respectively, pipelines and roads, big reservoirs, open storages of wood and chips, ponds of the waste water purification facilities, etc.

Having a width of 2 km, land of BPPP occupies some 6% of the territory of the southern coast of Lake Baikal. This area has a considerable recreation potential since it is connected to industrial centers by the Trans-Siberian Railroad, and by a highway; however, BPPP does not allow to use this potential.

BPPP is clearly visible from the opposite shore of Lake Baikal, e.g., from Listvyanka village which is 60 km apart. Smokes of BPPP are seen from the mountains at a distance of 40-50 km. Hence, deterioration of landscapes by BPPP is of a large scale. Industrial, rather than natural landscapes now dominate approximately half of the territory of Southern Baikal.

However, BPPP causes a by far greater moral damage to Lake Baikal, and to Russia in general. The authors of the present paper oftenly meet journalists, plain people and scientists from Russia and from abroad. A great majority of these people, especially if they have not seen Baikal themselves, sincerely believe that BPPP has already totally ruined the

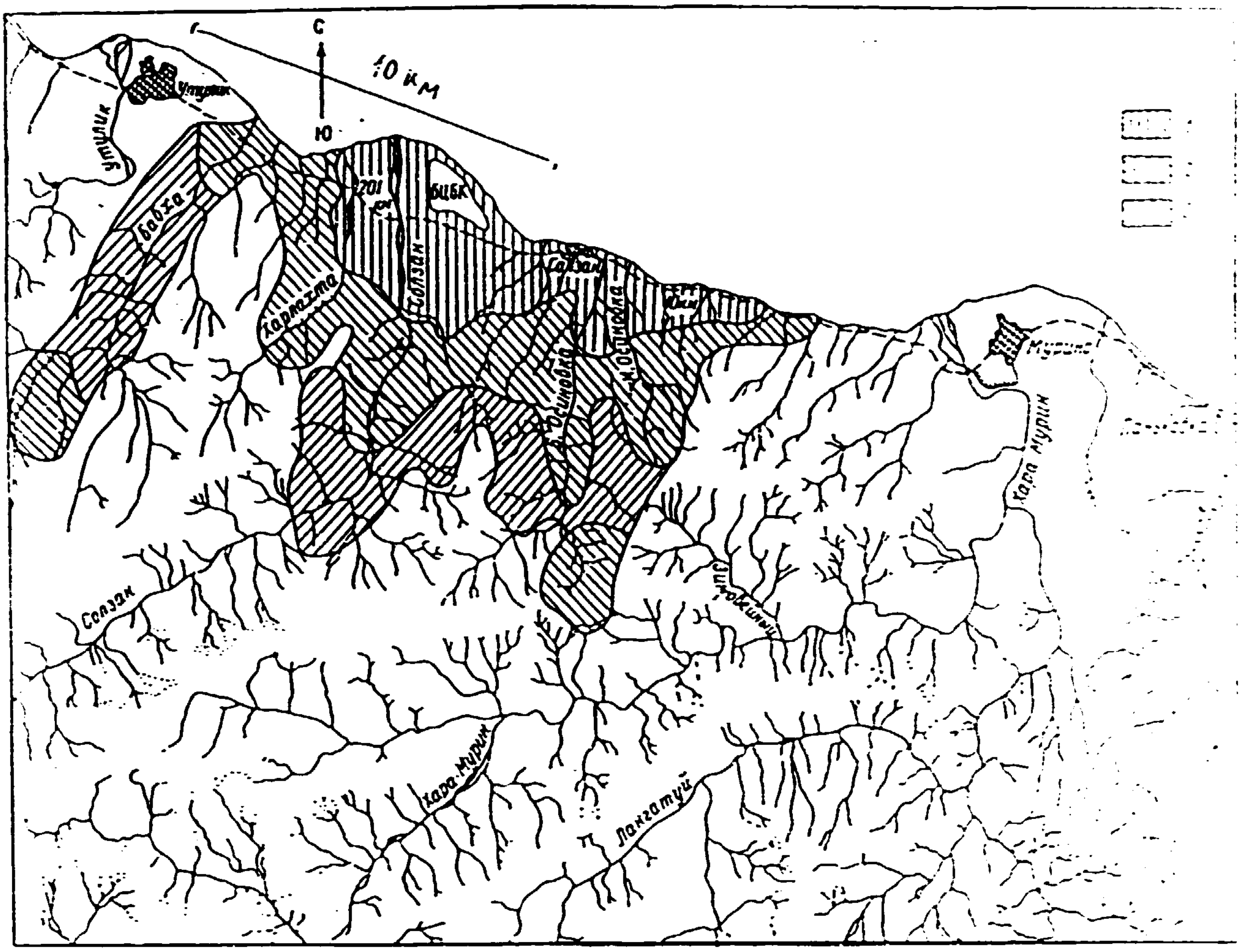

Fig.11. Zones of pollution around BPPP as revealed by studies of lichen [52].

1 - *Usnea* and *Bryoria* sp. absent;

2 - *Usnea* and *Bryoria* sp. damaged;

3 - *Usnea* and *Bryoria* sp. non-damaged, but their layers are thinner than normal, and occurrence rarified.

lake. Of course, this is an exaggeration, but it is evident that moral damage also leads to substantial economic losses.

5. RISK OF ECOLOGICAL DISASTERS ASSOCIATED WITH BPPP

5.1. Earthquakes

Guidelines issued by the State Committee for Construction of USSR (Gosstroi SSSR)[53] claim that the area occupied by BPPP belongs to a zone of high seismic activity where earthquakes may have a magnitude of 9-11 balls (on a 12-balls Richter scale). Buildings of BPPP stand on a lacustrine terrace consisting of gravel and boulders. Underground water stands 1.5-2 meters below surface. Rocks of this type become mobile during strong earthquakes. Hence, there is a risk that some buildings and installations of BPPP may be destroyed, although they are designed to withstand earthquakes. Reagents and wastes from destroyed reservoirs may reach Baikal. The probability of earthquakes stronger than 10 balls on Southern Baikal is more than 1 in 200 years (V.V.Ruzhich, personal communication; see Annex 12).

When considering risks, one has to take into account leakage of tanks with liquid chlorine, alkali, oil, sulfuric acid, and disruption of dams of the ponds where waste lignin slime is stored. Such disasters may be caused by earthquakes and other reasons.

5.2. Leakage of Liquid Chlorine

Reservoirs with liquid chlorine - 6 tanks, 60 cubic meters each - are situated at a distance of 300 m from the shore, 3 m above the level of Baikal. The storage is equipped with sprinklers for neutralization of chlorine in case of emergency.

The consequences of disasters which really happened due to destruction of tanks with chlorine are described by Marshall [54]. Spilling of a few dozen tons of liquid chlorine caused death of people within a radius of 400, rarely - 800 meters; the number of victims varied between 1 and 100. Hence, leakage of chlorine in case of BPPP may be dangerous to workers of the plant, but will not seriously damage inhabitants of the town of Baikalsk.

Under certain conditions, the cloud of chlorine may reach the surface of Baikal, and chlorine will dissolve in water. Assuming that the concentration of chlorine which kills all aquatic organisms is 1 mg per liter, we may conclude that mass mortality of these organisms will take place. However, crude estimates suggest that the area affected in this way will not exceed a few hundred square kilometers, i.e., a small part of the area of Southern Baikal.

Interaction of chlorine with organic matter present in the water of Lake Baikal will result in formation of chloroorganic compounds. The yield of these compounds due to leakage of even one tank will exceed the amount of TOCl discharged by BPPP during a year of its normal work. Evidently, BPPP will have to pay penalties for this kind of disasters. The sizes of these penalties may exceed the price of annual product of BPPP, if environment protection laws will not be violated (see below).

One tank of liquid chlorine (30 tons) is delivered to BPPP every day. There is a probability of accidents resulting in overturn of such tank-cars. Accidents resulting in overturn of railroad trains may be as frequent as one per year. Intensity of the traffic is 100 trains per day. Hence, probability of overturn of a tank-car intended for BPPP is ca. once per 100 years.

5.3. Leakage of Oil

Accidents of this kind may happen with heavy oil during its transportation, and storage. Up to 12 000 tons of heavy oil may be stored at BPPP. The storage tanks are 400 m off the shoreline, 4.2 m above Baikal level. Leakage of this amount may be dangerous for Lake Baikal, especially because oil tends to spread as a thin film over the water surface. It would lead to pollution of some 20 cubic kilometers of water (maximum permissible concentration 0,5 mg/l).According to historic data on oil spills at other locations, beaches and shallow waters suffer first. Spillage of oil may be caused by an earthquake. The risk of spillage of oil is much greater at the railroad, since it serves to transport much greater quantities of fuel compared to those consumed by BPPP. However, the risk is reduced due to adsorption of oil by soil. Real disasters of this kind did not yet affect Baikal.

5.4. Leakage of Sulfuric Acid and Alkali

BPPP consumes 24 tons of concentrated sulfuric acid per day. Neutralization of this quantity would take 0.0005 cubic kilometers of Baikal water, a small quantity compared to the total volume of Southern Baikal. Such an accident would only have local consequences - benthic organisms would die on an area of less than 1 sq. km.

Capacity of the tank with 60% alkali at BPPP is some 1200 cubic meters. There are also a few tanks with diluted alkali. Simple calculations show that leakage of these amounts of alkali will only have local consequences due to neutralization with carbon dioxide present in the waters of Lake Baikal.

5.5. Destruction of Dams of Waste Lignin Slime Ponds

The present state of these reservoirs, the fact that they are filled to the very top make the risk of the disaster of this type probable even without an earthquake. Destruction of dams may be caused by a strong rain. The most dangerous is destruction of the uppermost dam (see scheme in Annex 4) which may lead to breakthrough of all the ponds which store 5 million cubic meters of semi-liquid (5%) lignin slime.Disaster of this type will result in instant delivery into Baikal of 250 000 tons of organic matter, i.e., of a quantity equal to that discharged by BPPP during 700 years. Lignin slime has a high content of organic chlorine. Consequences of breakthrough of dams may be heavy. A large zone poisoned with hydrogen sulfide will appear on the bottom, and mass mortality of hydrobionts may be the case. Urgent actions are necessary in order to bury lignin slime which has accumulated earlier. At present, this waste is no longer accumulated, because it is dried and burnt.

5.6. General Evaluation of the Risk

No big disasters or earthquakes have happened with BPPP up to this date. However, the fact that the equipment of the plant is weared out is a matter of special concern. Official data [55] claim that the extent of wear-out of different installations of BPPP is 74-94%. This extent has not been separately evaluated for the installations which determine the gravity of ecological disasters. It is evident that their renovation will need great capital investments. It does not seem to us probable that any insurance company would agree to insure BPPP against ecological disasters. If such an insurance will be obtained, it will be very expensive. In our opinion, the first large-scale disaster will result in bancrupcy and in closure of BPPP.

6. ECONOMIC CONSEQUENCES OF THE APPLICATION OF ENVIRONMENTAL LEGISLATION TO BPPP

6.1. The Law of Russian Federation "On the Protection of Natural Environment"

The main law which regulates environment protection on the territory of Russia is that accepted by the Russian parliament on December 19, 1991, named "On the Protection of Natural Environment". Section 4 of this Law regulates the quality of environment and stipulates that maximum permissible impact values should guarantee ecological safety and conservation of the genetic fund, rational use and reproduction of natural resources, sustainable economic development. The same section (Article 26) defines that maximum permissible concentrations (MPCs) of dangerous compounds and microorganisms have to be used as the major characteristics of the state of natural water bodies and atmospheric air from the viewpoint of safety for humans, animals and plants [56].

Article 27 of the Law demands to approve norms of maximum permissible discharge (MPDs) of pollutants for every plant in order to ensure that maximum permissible concentrations of dangerous compounds are not exceeded beyond the sanitary zone.

6.2. Guidelines on the Permissible Impacts upon the Ecological System of Lake Baikal for 1987-1995

Article 33 of the Law stipulates the possibility to establish norms of maximum permissible impact onto the environment according to potential viability of different territories, taking into account the necessity to prevent destruction of natural ecological systems and irreversible changes.

For the catchment basin of Lake Baikal, "Guidelines on the Permissible Impacts upon the Ecological System of Lake Baikal for 1987-1995" [57], approved by governmental bodies of USSR in 1987 (Annex 5), may be regarded as such special norms. These Guidelines contain the following sections which may be important for BPPP:

(i) Classification of pollutants according to their danger for the ecological system of Lake Baikal:

- Ecologically extremely dangerous - highly toxic alien compounds; toxic alien compounds accumulating along food webs in tissues of aquatic organisms; slowly-decomposed alien compounds. Compounds are regarded as "alien" if they did not exist before they were synthesized by man.

- Ecologically highly dangerous - compounds which are present at natural background concentrations in waters of Baikal and of its tributaries, but may be dangerous at higher concentrations;

- Ecologically dangerous - alien compounds of moderate toxicity, rapidly decomposed, or volatile;

- Ecologically moderately dangerous - compounds present in the waters of Baikal and its tributaries and non-toxic towards aquatic organisms at relatively high concentrations.

The "Guidelines..." put the following demands:

- Discharge of ecologically extremely dangerous compounds into Lake Baikal and its tributaries is forbidden;

- Ecologically highly dangerous compounds may be discharged into Lake Baikal and its tributaries, but only in quantities the same as those taken with fresh water; special studies are done on every site to determine the background concentrations;

- Ecologically dangerous compounds may be discharged into Lake Baikal and its tributaries in concentrations and quantities established by special expertise, on the basis of individual permits;

- Ecologically moderately dangerous compounds may be discharged into Lake Baikal in concentrations, corresponding to maximum permissible ones for the purpose of fish protection, if other demands do not put more stringent requirements.

"Guidelines..." contain lists of compounds of different categories. Chlorophenols and chlorolignin belong to ecologically extremely dangerous compounds; mercury and heavy metals - to ecologically highly dangerous compounds; methanol, mercaptans, terpentine - to ecologically dangerous compounds; sulfate and chloride - to ecologically moderately dangerous compounds.

Similar requirements are put to compounds discharged into the atmosphere.

The "Guidelines ..." demand reduction of the discharge of pollutants into Lake Baikal by means of planned introduction of the best available technologies.

6.3. Environment Protection Demands to BPPP

The "Guidelines ..." have forbidden discharge of chloroorganic compounds into Lake Baikal, and for this reason it would be necessary to close BPPP already in 1987, if they did not contain a paragraph, according to which special environment protection demands should act with respect to BPPP until its re-profiling which was planned for 1993. These special demands were introduced in 1985 on the basis of the average characteristics of waste waters of BPPP which were achieved up to that date (Table 2). At present, these special demands are not valid.

Article 45 of the Law of Russian Federation "On the Protection of Natural Environment" stipulates that "...for transition to maximum permissible discharges (MPDs) of pollutants, temporary approved norms of discharge (TADs), or limits, may be introduced simultaneously with plans of reduction of discharge of pollutants down to MPDs". Such norms (TADs) for BPPP for 1995 have been approved by a permit for discharge(Annex 6). For an unknown reason, maximum permissible discharge values for BPPP have been established in such a way that maximum permissible concentrations of pollutants in waste water are equal to their concentrations in pure Baikal water. Such MPDs are absolutely non-realistic, and it is not surprizing that BPPP has never presented a plan of their achievement. Hence, issue of the permit (Annex 6) was a violation of the Law.

6.4. Payments of BPPP for Environment Pollution

Unfortunately, neither the Law of Russian Federation "On the Protection of Natural Environment", nor any other laws stipulate any particular sums to be payed for environment pollution. These sums, according to Article 18 of the Law, are determined by agreements on the use of natural resources which are concluded by the users and the executive bodies (local governments) of districts, regions, cities on the basis of "...licenses for the use of natural resources given to users by specially entitled governmental bodies of the Russian Federation in the field of environment protection".

The procedure of issuing these licenses is not defined in the Law. This gives a possibility of arbitrary decisions. For example, the term "specially entitled governmental body of the Russian Federation in the field of environment protection", evidently, is the Ministry of Natural Environment Protection and Natural Resources of the Russian Federation. In practice, however, licenses are given by district environment protection agencies (committees), which are not "governmental bodies of Russian Federation", but only regional divisions of such bodies. It is not clear which local government should conclude agreements with users - in case of BPPP, administration of Irkutsk District, or of Sludyanka Region, or of the town of Baikalsk?

The order of payments is determined by a decree of the Ministry of Natural Environment Protection (Annex 7). Table 6 presents a calculation for BPPP. The payments consist of three components: (1) "normal" payments for discharges within the maximum permissible discharge (MDP) values; (2) "limit" payments for discharges within the limits of temporary approved norms of discharge (TADs); (3) "above-limit" payments for discharge in excess of TADs.

"Normal" payment is included into the cost of production. According to the above mentioned decree of the Ministry of Natural Environment Protection, the prices for discharge depend on the relative toxicity of substances, i.e., on their inverse maximum permissible concentrations (MPCs): the smaller is MPC, the greater becomes the payment. Prices of "toxicity units"have been defined in 1992 (Annex 7); their values are multiplied by 1.7 due to the special value of environment near Baikal. A coefficient equal to 17 is established for 1995 - the sums are multiplied by it to take into account inflation. "Normal" payments of BPPP for 1995 will be

Table 6. The planned payments of BPPP for the discharge of pollutants into Lake Baikal with waste waters for 1995.

Component	MPD, tons	Price, thousand rubles per ton	Payment, thousand rubles per year	TAD, tons per year	Price, thousand rubles per ton year	Payment, thousand rubles per year	Total payment, mln. rubles per year
1	2	3	4	5	6	7	8
Suspended solids	53.2	2.95	157	266	14.7	3140	3.3
BOD_{compl}	88.5	0.73	64	798	3.7	2560	2.7
COD	326	-	-	3326	-	-	-
Lignins	133	1,1	147	598	5.5	2580	2.7
Furfurol	0.7	222	147	13	1109	14015	14.2
Petroleum	2.1	44.3	88	5	222	738	0.8
Phenols	0	2218	0	0.66	11088	7376	7.4
Chloroform	0.33	444	88	10	2218	21391	21.5
Sulfate soap	6.65	22.2	147	199	111	21391	21.5
Mercury	0.0045	221750	988	0.032	$1.1x10^6$	31452	31.5
Dimethyl sulfide	0.00066	221750	147	2.1	$1.1x10^6$	$2.2x10^6$	2212
Dimethyl disulfide	0.00066	221750	147	2.7	$1.1x10^6$	$3x10^6$	2950
Ammonia (N)	2.66	5.65	14.8	56	23	1475	1.5
Nitrate	133	56	7.5	133	278	0	0.01
Chloride	1996	0.007	14	7983	0.035	209	0.02
Sulfate	665	0.02	13.3	13771	0.1	1310	1.31
Methanol	6.65	22.2	147.5	6.65	111	0	0.15
Terpentine	8.25	11.1	91.5	8.25	55.5	0	0.09
Aluminium	2.7	55.4	147.5	5.32	277	737	0.89

Table 6 (continued)

1	2	3	4	5	6	7	8
Sulfide anion	0.00066	221750	147.5	0.00066	$1.1X10^5$	0	0.15
Phosphate	2.7	3.63	9.6	6.7	18.2	72.6	0.08
Synthetic detergents	0.00066	4.44	0	6.7	22.2	147	0.15
Formalde-hyde	6.65	5.5	36	6.7	27.5	0	0.04
TOCl	0.00066	221750	147.5	75.2	$1.1x10^6$	$83x10^6$	83350
Nitrite	0.066	33.6	2.2	0.066	168	0	0.002

	TOTAL	2963	88620
Multiplied by 1.7 (coeeficient for Baikal Region)		5000	150000
Multiplied by 17 (coefficient of inflation for 1995)		$85.6 \cdot 10^6$	$2.6 \cdot 10^{12}$

Total calculated payment for 1995: 2.6×10^{12} rubles; equivalent of $ 500 000 000, according to market price of dollar.

equal to a symbolic sum of 85.6 million rubles, or $ 17 200 - a small fraction of the market price of the bleached cellulose which will be produced (ca. $ 160 000 000). This sum is small for a simple reason: due to the "very strict" MPCs - if these permissible concentrations were greater, the payment would be proportionally greater. For example, if MPCs were equal to those which were accepted in 1985 based on technological possibilities, the payment would be equal to 108 billion rubles ($ 21 000 000, or ca. 13% of the market price of the product; Table 7).

"Limit" payments are collected in another way. According to the letter of the Ministry of Natural Environment Protection of December 2, 1992 No. 01-15/65-6117 (Annex 7), the price of a unit of toxicity within TAD limits is 5 times greater than that within the limits of MPDs. This payment, as well as "above-limit" payment is not included into the cost of production - it is exempt from the profit of the plant (after taxes). The outcome of this legally approved approach is shown in Table 6: payments of BPPP for environment pollution would be equal to $ 500 000 000, or three times more than the market price of its annual product. Majority of the large chemical plants of Russia would be closed, if Law was not violated.

In order to save such "problematic" plants, the Ministry of Natural Environment Protection recommended that only a certain part of their profit should be taken as payment for pollution. The size of this fraction has to be determined by "consensus commissions" consisting of representatives of the plants, of the district governments, and of the district environment protection agencies. As for BPPP, its agreement with the Irkutsk District Environment Protection Committee of March 31, 1994 (Annex 8) established, according to the decision of the "consensus commission", that the "limit payments" for environment pollution in 1994 were equal to 10% of the profit, and "above-limit payments" were equal to 20% of the profit. In fact, these payments were equal to 1 950 mln rubles ($ 400 COO), or 1.5% of the market price of bleached cellulose produced by BPPP. Hence, all the "toxic unit prices" and calculations presented above do not have any practical importance - real payments are decided by voluntary decisions of district administrations. This practice does not create any economic motivation to reduce discharges.

6.5. Prognoses

THe "strict" environmental law of Russia is far from perfect. Sooner

Table 7. The calculated payments of BPPP for the discharge of pollutants into Lake Baikal according to the permitted discharges of 1985 (non-valid).

Components	MPD tons per year	Price, rubles per ton *)	Total payment, rubles
BOD_{compl}	1005	730	733 000
COD	4360	-	-
Suspended solids	402	2950	1.12×10^6
Salts	40870	-	-
Sulfur organic compounds	17	221×10^6	3730×10^6
Phenols	1	2.2×10^6	2.2×10^6
Sulfate	20100	20	402 000
Chloride	6700	7	47 000
		TOTAL:	3735×10^6

Multiplied by 1.7 (coefficient for Baikal Region) and by 17 (coefficient for inflation of 1995) — 1.1×10^{11} rubles, equivalent to $ 22 000 000

*) Prices according to the instruction of the Ministry of Natural Envirinment Protection of 1992.

or later, this law will be changed, and principles of environmental law accepted in countries with developed market economy will be introduced. These principles are based on real possibilities of the society, and on planned implementation of the best available technologies. It is impossible to evaluate the impact of this non-existing law on the economy of BPPP. However, one may expect that it will demand from BPPP great capital investments into environment protection, and great running expenses because of the special value of its adjacent environment. This will put BPPP into a difficult position in competition with other plants.

One more possibility is direct prohibition of the cooking of cellulose on the shore of Lake Baikal. The Law of Russian Federation "On the Protection of Lake Baikal" accepted in the first reading by the Parliament of Russia (Annex 9) contains a clause according to which "work and siting of cellulose-producing, petrochemical, metallurgic, and organic synthesis plants in the Central Zone (i.e., on the shore of Lake Baikal) is prohibited".

7. PROGNOSIS OF SUSTAINABILITY

7.1. Formulation of the Problem

At present, BPPP occupies a leading position in the economy of the Sludyanka Region. Other enterprizes, like the marble-mining company "Pereval", Sludyanka Station of the Trans-Siberian Railroad, the gravel-mining company "Angasolka", the Kultuk meat factory, the Southern Baikal fish canning plant, small units of food industry, motels, etc. - give only a small fraction (ca. 10%) of the total income. The situation on the market of bleached cellulose is very favourable, the price of one ton of this product has increased during a short time interval from $ 600 to $ 1000. Due to the high quality, and because of the economic crisis in Russia almost all the cellulose produced by BPPP in 1994 was exported, and gave a big profit not only to the plant and to the state, but also to Sludyanka Region, and to Irkutsk District in general.

Baikalsk is a typical "company town", and welfare of its 16 000 inhabitants completely depends on the welfare of BPPP. The plant supports hospitals and ambulances, sportive units (among them a swimming pool with warmed Baikal water, a mountain skiing elevator, etc.), pays taxes making it possible to maintain all the infrasructure of the town, gives heat, electricity, cold and hot water, purifies municipal waste waters.

Considering alternative ways of sustainable development on the southern coast of Lake Baikal, we have to take care that this goal is achieved without a decrease in the level of life of people of Baikalsk, of Sludyanka Region, and of Irkutsk District in general. On the other hand, we have to insure that economic development would not result in rapid (compared to natural) changes in the ecological system of Lake Baikal. One has to take care also that prosperity of Baikalsk would not prohibit sustainable development of other settlements on the southern coast, and of the Baikal Region in general.

We have to consider the following: (1) the present state of BPPP compared to state-of-the-art in the world, and competitiveness of the plant compared to other plants; (2) compatability of the "cellulose" way of the development of Baikalsk with the goals of sustainable development; (3) "non-cellulose" alternatives.

7.2. The Present State and Competitiveness of BPPP

The project of BPPP created in the beginning of 1960-ies involved the best available technologies of that time. Moreover, unique waste water purification facilities unprecedented in the world industry were designed and put into operation. During the last decade, much attention was payed to removal of dust (new electrostatic filters), of organic sulfur compounds and hydrogen sulfide (new brown liquor concentrators and catalytic purification of condensates), of sulfur dioxide (Lifak Plant) from the exhaust gases, as well as to reduction of the volume of solid wastes (the system of concentration, drying and burning of lignin slime). According to the Decree of the Central Committee of CPSU and of the Government of USSR of April 13, 1987, the plant producing fodder yeast was dismounted in order to improve the quality of waste water. On the other hand, basic equipment used for cooking, washing, bleaching, soda regeneration, wood preparation, etc., was not changed and remained at the level of 1960-ies. For this reason, many economic and environmental characteristics of BPPP are at present behind those of the best similar plants.

For example, specific water consumption of BPPP (270 cubic meters per ton of cellulose) is three times higher than that of the Ust-Ilimsk Pulp and Paper Plant producing similar bleached pulp. Some plants abroad had a water consumption of 44 cubic meters per ton of cellulose already in

1991 [59].

Discharge of priority toxicants, chloroorganic compounds at BPPP was 0.52 kg per ton of cellulose in 1994. Until recently, this was a very good figure. However, Environment Protection Agency of USA is going to introduce in 1995-98 a demand to have this value equal to 0.156 kg of TOCl per ton of pulp ([58]; TAPPI 1994, No.6, p.16); it is possible because the leading plants have already achieved this level. Considerable progress in reduction of TOCl is due to the use of chlorine oxide instead of elementary chlorine for bleaching ([58]; TAPPI 1994, No.8, p.163-168), and of bleaching with ozone and hydrogen peroxide (a mini-review - see ref. [60]). In both cases, TOCl discharge falls to zero.

Much effort is spent by leading companies to improve the processes of washing of pulp. These improvements lead to a decrease of the consumption of water and reagents. Introduction of sofisticated filters [61] by BPPP could help to reduce discharge of sulfate and chloride anions which may be important pollutants for Baikal.

A considerable decrease of the discharge of malodorous sulfur compounds into the atmosphere may be achieved by a long-known method - by burning of exhaust gases either in special furnaces, or in rotating furnaces producing calcium oxide. This needs construction of gas holders to collect exhaust gases produced at the stages of cooking and unloading (after condensation of terpentine). Smell of mercaptans around plants with such incineration systems is noticed only within a radius of 1 km, compared to 10 km around BPPP.

A great environmental effect may be achieved by means of more rational use of energy according to technologies already apllied at the leading plants. For example, a two-fold decrease of the discharge of sulfur dioxide may be achieved without any additional purification of exhaust gases, only due to the introduction of energy-saving technologies.

This list of possible improvements may be continued. However, every improvement needs big capital investments. Return of this money takes a long time - 10 or more years. The problem is aggravated by the fact, that the equipment of BPPP is not only old-fashioned - it is physically weared out. Official estimate of the residual value of BPPP which was done according to a decision of the administration of the Irkutsk District of December 12, 1992 No.842p is the following: bleaching plant - 26% ; caustization plant - 6% ; drying plant - 16% ; cooking plant - 11% of the initial value [55]. Hence, renovation of BPPP needs investments which are of the same order of magnitude as those necessary to build a new plant.

The capacity of BPPP is small compared to that of the leading plants in Russia and abroad. For example, a majority of the plants of Sweden has a capacity of 300 000 tons of cellulose per year and more (Fig.12; [59]). It is known that doubling of the capacity of a chemical plant usually needs only 1.6 times greater capital investments. The cost of manpower remains almost the same, since expenses for maintainance practically do not depend on the scale of production.

Hence, if renovation of BPPP will not result in an increase of its capacity, the plant may loose competitivenes at the internal and the external markets. However, increase of the capacity results in an increase of the gravity of disasters [54].

Productivity of BPPP is small compared to that typical of the leading plants. Leading plants of an optimal capacity of 300 000 tons of cellulose per year usually have a staff of 150-200 people, wherease the number of employees of BPPP is more than 3 000.

Hence, BPPP is behind the leading plants of this sector of economy in many respects. Its position is unfavourable compared with that of other plants, e.g. of the Bratsk Woodworking Complex, and of the Ust-Ilimsk Pulp and Paper Plant situated in Irkutsk District. These plants have a greater capacity, and may get cheaper wood due to the smaller cost of its tranportation from the cutting areas. BPPP cannot get wood near its location, since industrial wood cutting on the shore of Lake Baikal is prohibited.

7.3. The "Cellulose" Way of Development of the Economy of the Southern Coast of Lake Baikal and the Goals of Sustainable Development.

The ways of renovation of BPPP which do not lead to a no-effluent plant have little chances to be accepted. For this reason engineers and politicians who are interested to continue the production of cellulose in Baikalsk look for technologies involving complete closure of the water consumption cycle. This search was stimulated by successful closure of the water consumption cycle which was for the first time in the world introduced at the Selenginsk Pulp and Cardboard Plant (SPCP) - a plant located in Selenginsk, in Buryat Republic, on Selenga River, the major tributary of Lake Baikal, 70 km from its shore [62-64].

This plant discharges no waste water since 1990. The pre-requisite of the success was its sophisticated and expensive waste water purification facilities similar to those of BPPP. Full closure of the water consumption cycle at SPCP took 15 years.

Unlike BPPP, SPCP produces unbleached cellulose of relatively low quality from low-quality wood and chips collected at the sites of forest felling. The market price of unbleached cellulose is approximately two times smaller than that of bleached "rayon-brand" cellulose produced by BPPP. One of the variants of re-profiling of BPPP (the so-called "Variant 6") proposes to stop the production of bleached cellulose, to perform full cycling of water consumption in the same way as at SPCP, and to produce unbleached kraft pulp. We do not believe that this variant is viable. Firstly, "renovated" BPPP will produce pulp of the same quality as that of SPCP, and for this reason there will be a severe competition on the limited regional market. Secondly, the smaller price of unbleached pulp will result in an increase of the specific cost of transportation, and it will be more difficult to sell the product on remote markets, compared to bleached pulp. Thirdly, the proposed production of ready cardboard boxes will not help much, since such boxes are already produced in Selenginsk and Bratsk; the demand for cardboard boxes in East Siberia is not great because this region does not produce much consumer goods.

Exactly as with bleached cellulose, it will be necessary to increase the capacity of the plant 1.5-2 times in order to make it competitive. Introduction of modern technologies will result in a smaller demand for manpower, i.e., in unemployment in Baikalsk.

SPCP has large reservoirs for temporary storage of waste water in case of emergency situations. There is no room at BPPP for such reservoirs having a volume of 6 mln cubic meters. Without emergency reservoirs, reliability of the no-effluent technology becomes questionable, and there arises a risk of pollution of Baikal.

With Variant 6, there will remain a necessity to produce energy on the shore of Lake Baikal by means of combustion of fuels on a large scale. Remarkably, the town of Baikalsk consumes 10 times less energy than BPPP. The neighbouring Sludyanka .will soon be heated by electricity - all its coal-burning energy plants will be closed for the sake of protection of Baikal (V.K.Yakovenko, personal communication).

A more promising option is believed to be the so-called "Variant 6a" - a way of re-profiling which was elaborated by BPPP with the support of some leading pulp-and-paper companies. According to this variant, it is proposed to produce bleached cellulose using no-chlorine technologies, and to have no effluent. In principle, it is possible to have such a plant, although processes of this kind have only been introduced on an industrial scale for the production of thermomechanical pulp, and secondary pulp, rather than kraft pulp. As for bleached kraft pulp, technologies have been tested only on a pilot scale [60, 65]. Therefore, one may ask the question: is it a reasonable suggestion to make this experiment for the first time on the shore of Lake Baikal ? Will governmental ecological expertise allow this experiment ?

As for the other problems in connection with Variant 6a, they are the same as those with Variant 6. These are the necessity to increase capacity, uneployment due to modernization, continued local production of energy, continued deterioration of landscapes, hard availability of crude wood, absence of room for emergency reservoirs.

However, the main questions are the following. Is it reasonable to develop production of cellulose on the shore of Lake Baikal ? Is it reasonable to make great capital investments in Baikalsk into the production of cellulose, rather than into other sectors of economy ?

Let us look into the figures. The value of BPPP on January 1, 1993 was 254 mln rubles (prices of 1991) [55]. With the same prices, the cost of "re-profiling" of BPPP according to Variant 6 was 383 mln rubles - one more argument in favour of the conclusion that re-profiling means in fact construction of a new plant. Approximate estimates suggest, that the cost of Variant 6a will be 1.5 times greater compared with that of Variant 6, some $ 100 000 000 in prices of 1993. It may well happen that this cost will soon increase to 150 -200 million dollars due to increase of the price of cellulose on the world market and to inflation*. These investments will pay back no sooner than in 10-15 years, as it usually happens in pulp-and-paper industry. We believe that investments of this size may be used in a more reasonable way.

7.4. "Castling"

We propose to consider the idea of "castling" - to close BPPP, and to renovate the Selenginsk Pulp and Cardboard Plant into a modern plant pro-

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*UNIDO experts believe that the investments necessary for the reconstruction of BPPP are equal to $140,000,000 (R.Assumpcao, personal communication) ducing 300 000 - 400 000 tons of bleached and unbleached cellulose per year on the following conditions: (1) no-chlorine technology; (2) no effluent; (3) at least ten-fold decrease of the discharge of malodorous compounds and other pollutants into the atmosphere; (4) complete utilization of solid wastes as composts and raw materials for construction. Data presented in "Variant 6a" suggest that renovation of SPCP of this kind is possible. It is important that our proposal to have two lines of production at SPCP - one yielding bleached, and the other yielding unbleached pulp - will make it easier to have no effluent. It is known that the most difficult problem in the solution of this task with no-chlorine bleached cellulose is the accumulation of bivalent metal ions at the stages of bleaching and washing. They cannot be returned into the water cycle because a precipitate falls out and clogs pipelines and other items of equipment. However, parallel production of unbleached pulp gives a possibility to "export" divalent cations with this ready product.

Undoubtedly, the idea of renovation of SPCP and of the increase of its capacity will encounter resistance of the green movements and of some politicians. However, this resistance will be much stronger with "Variant 6a" apllied to BPPP. The distance from Selenginsk to the shore of Lake Baikal is 70 km, this town is located outside the central zone of the Baikal Region, in terms of the Law of Russian Federation on Lake Baikal. It is a territory of Republic Buryatia which is much interested in the development of the woodworking sector of its economy, in increasing the value of the end products yielded by this sector (Annex 10).

In our opinion, "castling" has to be initiated by starting alternative economic activities in Baikalsk. We propose to develop here two major sectors of economy. The first one is food industry based on the availability of ultra-pure Baikal water: it is production of bottled drinking Baikal water itself, of beverages, of beer, of juices (from concentrates), of alcoholic drinks (either from imported, or from locally produced ethanol), of spaghetti, etc. In this connection, it is proposed to produce in Baikalsk bottles of imported polyethylene terephtalate (PET) - this production may be of independent economic significance since PET containers are produced in Russia in very limited quantities. The second sector of economy to be developed in Baikalsk is tourism and recreation.

Limnological Institute has started pilot production of bottled Baikal drinking water. The high quality of this product has been internationally approved (Annex 1). Marketing studies have shown that even bottled Baikal drinking water alone may be a viable and a profitable alternative to production of cellulose. Development of tourism and recreation may be less economically efficient, but seems to us important since this sector creates many jobs.

To avoid unemployment, it is also possible to produce furniture and ready-built houses, as it is proposed, for example in "Variant 8" of the re-profiling of BPPP. Houses built of light-weight materials are at present unpopular in Russia, compared to houses of brick and concrete, and there are certain doubts on whether this product will be bought by rich people who can afford construction of private houses. However, a very strong argument is the fact that light-weight constructions are earthquake-resistant, and for this reason will be preferred in the Baikal Region.

"Castling" may facilitate the development of other industries of the Baikal Region outside Baikalsk and Selenginsk, like production of hydrogen peroxide and alkali at the chemical plant in Usolie-Sibirskoye for bleaching pulp in Selenginsk; production of aluminium foil and cans in Shelekhov at its gient akuminium plant for packaging beer and beverages in Baikalsk; production of high-quality PET at its petrochemical plant in Angarsk; production of high-quality cardboard boxes at SPCP for packaging food industry goods produced in Baikalsk; production of glass bottles at an existing plant in Ulan-Ude for packaging drinks and beverages in Baikalsk; production of compests of lignin slime, fly ash and manure in Selenginsk for improvement of the eroded soils of Buryatia (these composts are already tested, and there is a ready project of a special plant). "Castling" will increase the activity of the section of the Trans-Siberian Railroad belonging to the Baikal Region. It will help to implement the long-discussed idea of electric heating of the settlements on the shore of Lale Baikal - the industries proposed for Baikalsk as alternatives to cellulose production consume much less energy, and this energy may be delivered by the existing high-voltage electric power lines.

"Castling" will stimulate capital investments into modern environment-friendly technologies, into construction of highly efficient municipal waste water purification plants, since companies depending on the high purity of Baikal water and on the image of Baikal as a clean lake will have a strong motivation for such investments.

At present, "castling" is only a crude idea which has to be thoroughly evaluated by professionals. However, some preliminary estimates are al-

Table 8. Numbers of employees and annual incomes in Baikalsk after "castling".

	Number of employees	Annual product, units	Annual income, $
Woodworking	172	100,000 m^3	25
Ready-built houses	56	800	30
Furniture	417	175,000	52
Baikal water, beverages and juices	250	150 mln. bottles	225
Beer	145	10 mln. liters	20
Plastic bottles and tetrapack band	280	1.3 billion containers	130
Tourism and recreation	220	30,000 nights	15
Total	1540		497

This list does not include auxiliary jobs: transportation by cars, buses, railroad; communication; production of energy; waste water treatment; etc. The number of jobs of this kind at BPPP is at present equal to ca. 900.

Table 9. Characteristics of the waste waters of Baikalsk before, and after "castling"

	Before "castling"	After "castling"
Total volume of purified waste waters, million cubic meters per year	80	5.2
Suspended solids, kg per day	570	1.6
BOD_5, kg per day	360	16
COD, kg per day	7800	260
Organic compounds of sulfur, per day	36	0
Phenols, kg per day	2	0
Terpentine, kg per day	27	0
Sulfate, kg per day	42000	260
Chloride, kg per day	21000	100
TOCl, kg per day	300	0
Microbial pollution, concentration of *E.coli*, cells per liter	300	3

Aerial pollution in Baikalsk before and after "castling" (production of energy due to burning of coal continued)

	Discharge of pollutants, tons per year	
	Before "castling"	After "castling"
Sulfur dioxide	2300	610
NO_x	3600	250
Dust	5500	1100
Dimethylsulfite	130	0
Dimethyldisulfide	15	0
Methyl mercaptan	70	0
H_2S	200	0
CO	670	110
Buthyl acetate	0	75
Other	74	64

ready available (Tables 8-10).

The idea of "castling" - of structural re-organization of the economy of the Baikal Region for the sake of sustainable development - has been for the first time proposed by A.N.Suturin, A.P.Sukhodolov, and by the authors of the present paper in September of 1994, at a NATO-sponsored advanced international workshop on sustainable development of the Baikal Region which took place in Ulan-Ude [66]. This idea interested the participants of the workshop, as well as governmental structures of Republic Buryatia (Annex 11). We regard it as a framnework construction for planning under the new conditions of nascent market economy, as an approach which may couple many independent investment projects. In order to make these projects attractive to Russian and foreign investors, it will be necessary to develop and to implement a series of federal and regional legal acts, first of all the Law of Russian Federation on Lake Baikal.

Of great interest from this viewpoint is the initiative of the European Union which has announced the Baikal Region as the region of action, beginning from 1996, of the TACIS program. It is intended, according to this program, to attract many experts of the European Union to joint work with Russian experts aimed at the preparation of detailed business plans of investments in the Baikal Region. These internationally approved business plans will be presented to Russian and foreign investors, and will have good chances to be accepted.

During the visit of the delegation of the European Union to the Baikal Region in the beginning of 1995 the idea of "castling" has attracted the attention of experts and officials. The countries of Europe have successfully solved problems of this, and even greater scale under the conditions of market economy. Examples are liquidation of the coal-mining industry of Belgium, restructuring of the production of energy in France, etc. Russia also solved tasks of this kind, but during the times of planned and centralized economy. Exchange of experience, given sufficient political willingness, may help to solve the problem of sustainable development of the Baikal Region in general, and the "problem of BPPP".

8. CONCLUSIONS

1. Lake Baikal, in spite of the presence of local sources of its pollution, firstly the Baikalsk Pulp and Paper Plant (BPPP), and of the transfer of pollutants from distant sources, still remains the greatest strategic deposit of pure fresh water due to the efficient work of its biota.

2. BPPP discharges 200 000 cubic meters of waste water into Lake Baikal daily. This volume is the same as that discharged by a city with 500 000 inhabitants - 1/3 of the population of the catchment basin of Lake Baikal. Waste waters discharged by BPPP contain salts, phenols, chloroorganic compounds, organic compounds of sulphur, petroleum hydrocarbons, resin acids and other hazardous compounds. BPPP discharges large quantities of pollutants into the air; these are ubiquitous pollutants typical of production of energy by means of burning organic fuels, and specific pollutants associated with the production of sulphate pulp, particulary, malodorous derivatives of sulphur. Solid waters of BPPP occupy large-volume accumulation ponds which are not reclaimed.

3. Zones of pollution have been formed around BPPP in different media. Estimates of the area of the zone of chemical pollution of the water body of Baikal vary due to the unsufficient sensitivity of analytical methods. The zone of microbiological contamination has an area of a few dozen square kilometers. Bottom sediments are contaminated over an approximately the same area. Forests are damaged around BPPP, but this may be in part due to recreational burden, and in part due to changing climate. Fall-out of pollutants from the atmosphere clearly manifests itself by accumulation of pollutants in snow, and by affecting lichens over an area of some 100 sq.km. The atmosphere is polluted by malodorous compounds over an area of 400 sq.km.BPPP gives a dominating contribution to the destruction of natural landscapes of the southern shore of Lake Baikal.

4. Buildings and installations of BPPP are sited in a zone characterized by a high probability of strong earthquakes. For this reason, and because of the need to deliver hazardous compounds to BPPP by railroad, there is a significant risk of ecological catastrophes. The greatest risk is due to the presence of ponds with liguin slime which was accumulated earlier as product of the waste water purification.

5. Russian environmental law is imperfect, and allows BPPP to pay negligible fees for environmental pollution, in spite of the fact that it is sited on a territory of unique value, and of its continuous violation of the law of Russian Federation on the Protection of Natural Environment. However, this situation may change in the nearest future. The Law of Russian Federation "On Lake Baikal" accepted in the first reading by Russian Parliament directly forbids continuation of cooking of cellulose on the shore of Lake Baikal.

6. The facilities of BPPP and its technologies have become obsolete, in spite of the fact that BPPP possesses a unique, and a very expensive waste water purification system. Its specific discharge of hazardous compounds (e.g. TOCl per ton of cellulose) has become greater than that of the best bleached pulp plants in other countries. The small capacity of BPPP (160 - 200 thousand tons per year), compared to the optimal one (300 - 400 thousand ton per year), the small productivity of manpower, the long distance from the sources of wood will result in the future in a decrease of the competitiveness of BPPP on the world market which is nowadays great due to the small salaries, to negligible payments for environmental pollution, and to increase of the demand for bleached pulp.

7. The cellulose way of development of the economy of Baikalsk does not solve the problem of unemployment, contradicts to the idea of conservation of Lake Baikal as of a unique natural property of Russia, and, at the same time, needs great capital investments which are equivalent to the construction of a new pulp-and-paper plant in place of BPPP. The time of return of these investments is long, more than 10 years. Intro-

duction of a fully closed cycle of water consumption at the re-constructed BPPP will need even greater investments; on the other hand, success of implementation of no-discharge technology is not unquestionable, since it will be the first attempt to operate it on a full, rather than a pilot scale. The "cellulose" way will conflict with the development of alternative branches of economy of the southern shore of Baikal.

8. A solution of the "problem of BPPP" may be found if it is regarded as a component of a plan of structural rearrangement of the economy of the Baikal Region for the sake of a sustainable development. One of the possibilities is "castling" - closure of BPPP, and reconstruction of the Selenginsk Pulp and Cardboard Plant involving increase of its capacity, and installation of a second production line yielding bleached cellulose, on the condition that the already existing fully closed water consumption cycle will be sustained. As for Baikalsk, it is proposed to develop here food industries based on use of pure Baikal water - production of bottled drinking water, beverages, juices, drinks. Investments into food industry pay back much faster than those into pulp-and-paper industry, and, unlike those into the latter one, create a basis for long-term sustainable economic development on the southern shore of Lake Baikal, and for safe protection of the lake. To prevent unemployment, it is proposed to develop also wood-working industry and tourism.

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