9th International Conference
on Mercury as a Global Pollutant

ISTC Science Workshop at the International Conference on Mercury as a Global Pollutant

ICMGP 2009

7- 12 June 2009

Guizhou's Great Hall of the People

Guiyang, China

www. Mercury2009.org

The International Science and Technology Center
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The International Science & Technology Center (ISTC)

ISTC is an intergovernmental organization holding diplomatic status, created to prevent nuclear weapons proliferation and to link the demands of international markets with the exceptional pool of scientific talent available in Russian and other Commonwealth of Independent States (CIS) institutes. ISTC was established in 1992 by the European Union, Japan, the Russian Federation, and the United States of America on the basis of a multinational agreement. Norway and the Republic of Korea are signatories to the agreement, and Canada joined as a full Governing Board member in 2004.

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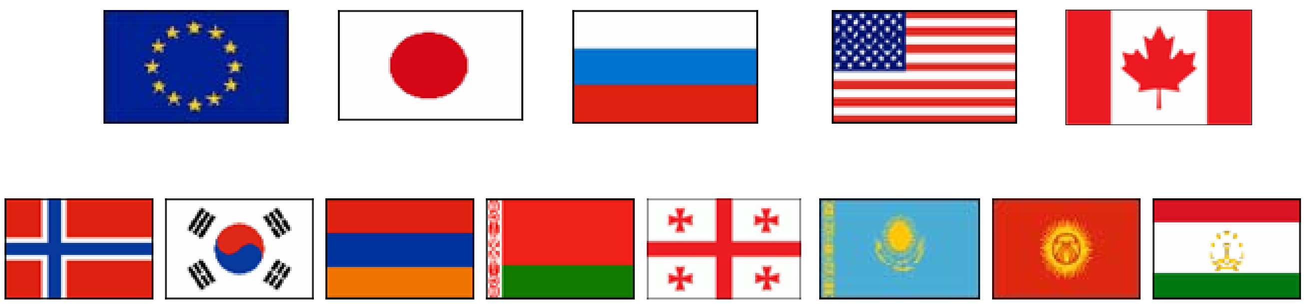

9th International Conference on Mercury as a Global Pollutant
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The International Science and Technology Center (ISTC) is conducting a Science Workshop in the frame of ICMGP 2009 (as Special Sessions SpS 12)

The **ISTC**, headquartered in Moscow, Russia is organizing a scientific workshop in the frame of a special session at the international conference '**ICMGP 2009'**, which will be focused on the following topics:

- **Determination of the extent of remediation needed**
- **Selection of remediation(s) methods**

Mercury contamination of soils and sediments has occurred at numerous industrial sites worldwide. Remediation of mercury-contaminated soils and groundwater can be complicated by changes in mercury speciation, biogeochemical site conditions, and future human use. Decontamination of structures is another problem unique to mercury.

10 scientists from research institutes in Russia and Kazakhstan will present and discuss their project results, related to the abovementioned subject areas. SpS12 will provide an opportunity for senior researchers and directors from such institutes to meet face-to-face and to discuss possible collaborative research and development interests. The main topics of the discussion will be focus on:

- efficiency assessment of engineering solutions and exchange of experience in remediation of areas contaminated with mercury;
- application of different approaches and ways of assessment of mercury effects on health of population;
- development of new approaches and cost-effective technologies to minimize mercury hazard; and
- new scientific and technological studies, and new projects aimed at minimization of mercury hazard.

Environment (ENV) is one of the largest research areas where ISTC has been providing its support to the institutes in the form of project funding. As of May 2009, 428 Projects have been approved for funding. Parties and Partners have allocated $132,8 million for ENV projects. The funds are focused on Monitoring, Risk Assessment, Remediation, Water and Air Pollution and Control, Radwaste issues. More than 330 Institutes and companies from Russia and CIS countries are involved in this activity. ISTC supports innovative research and development in the area of conservation of the quality of environment (air, water, soil) at the level that is safe both for human health and for the ecosystem. Implementation of Projects has resulted in a considerable number of new and improved technologies, analyses and databases on ENV related issues, ready for the next step of development, focused on clean-up and prevention.

Financial and logistic support for this event is provided by the ISTC Science Workshops and Seminars Program. The main goal of the Program is to establish cooperation and sustainable, long-term partnerships between Russian/ CIS experts and their colleagues of the International Science Community.

In 2008, over thirty events were sponsored by ISTC in the framework of SWS Program. More than 4,000 project participants took part in the workshops and international conferences.

The Program facilitates ISTC Beneficiary institutes and former defense experts to contribute to the global S&T community offering cooperative solutions to the most challenging scientific problems and enabling them to establish new international contacts and partnerships.

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A G E N D A
of ISTC Special Session at the conference ICMGP 2009
SpS 12 : Identification, Characterization and Remediation of Mercury Contaminated Sites

10 June 2009
Room 5 Big room

Opening of the ISTC Special Session. Welcome Address by the International Science and Technology Center (ISTC). Rudneva V. Ya (Senior Project Manager, Environment Scientific Coordinator, ISTC).

1. **L.V. Yakovleva** (Almaty Institute of Power Engineering and Telecommunication, Kazahkstan) "Problems of demercurization of industrial objects within the former USSR"
2. **S.A. Abdrashitova** (Institute of Microbiology and Virology, Kazakhstan) **"**Possibilities of bacteria use for remediation of mercury contaminated groundwater"
3. **F. Ingel** (A.N.Sysin Research Institute for Human Ecology & Environmental Hygiene of Russian Academy of Medical Sciences) "Is it necessary to expect new health effects of low dozes of mercury?"
4. **I.M. Kamberov** (Institute for High Technologies, NAC «Kazatomprom») "Project "Nura River Clean Up" Concept, Conditions and Problems of Implementation in Kazakhstan"
5. **M.A. Ilyushchenko** (Almaty Institute of Power Engineering and Telecommunication, Kazahkstan) " Evaluation of demercurization efficiency of chlor-alkali production in Pavlodar City, Kazakhstan"
6. **V.Yu. Panichkin (**Institute of Hydrogeology and Hydrophysics, Kazakhstan*)* "Mathematical modeling of groundwater mercury pollution (case of Northern industrial area of Pavlodar City, Kazakhstan)"
7. **O.A. Konorev** "Prognosis of groundwater mercury contamination spread within an industrial area of "Usol'ekhimprom" Ltd. (Irkutsk oblast, Russia)"
8. **A.V.Ubas'kin** (Pavlodar State University, Kazakhstan) "Mercury Contamination of a Wastewater Storage Pond of Chlor-Alkali Production in Pavlodar and Problems of its Remediation"
9. **O.L. Miroshnichenko** (Institute of Hydrogeology and Geoecology, Kazakhstan) "Mercury pollution within an industrial area of Kiev City, Ukraine and progress of JSC "Radical" territory cleanup"
10. **G.A. Leonova (** Institute of geology and mineralogy SB RAS, Novosibirsk, Russia) "Biofacies role of plankton as natural remediation mechanism of high-mineralization water contaminated with mercury (by the example of the Bolshoe Yarovoe lake, Altay Territory, Russia)"
11. **V.I. Grebenshchikova** (Institute of Geochemistry SB RAS, Irkutsk, Russia) **"**Mercury in biochemical cycle of the Bratsk reservoir and Program of demercurization of chlor-alkali production in Baikal region, Russia"

PROBLEMS OF DEMERCURIZATION OF INDUSTRIAL OBJECTS WITHIN THE FORMER USSR

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In the first half of XX century principle consumption of mercury in Russia/USSR was confined to gold mining (in total about 4000 tons till 1945 and 2000 tons more after 1945 /1/). In the second half of XX century within USSR as well as all over the world mercury use increased abruptly in technological processes especially in chemical industry, including chlor-alkali production with mercury cathode (in total about 13000 tons and more than 100 tons per a year nowadays – Table 1), acetaldehyde production (in total about 2500 tons) /2/, pesticides production (up to 200 tons per year in the 60s-70s) /1/ and other chemicals production (more than 15 tons per year to present day) /1/, vinyl chloride monomer production (more than 7 tons per year to present day) /1/. Total inventory of mercury consumers by independent experts has not been completed yet. At present besides chemical industry mercury is still used in production of thermometers and other measuring devices, light sources, chemical sources of electricity and other electrotechnical equipment. As a result despite tightening mercury normative documents and safety guidelines in the 1970s and introduction of restrictions on mercury use in industry during the later 1980s considerable amount of mercury entered the environment. In the middle of 1990s industrial recession was expected to stop this process however when closing down industrial enterprises in conditions of economic and political crisis scale contaminations of the environment with mercury were committed while uncontrolled dismantling and utilization of equipment and wastes burial.

Scale of mercury loses entered the environment in the former USSR was in the order of a few thousand tons for each of such large-capacity productions as chlor-alkali production or acetaldehyde one and several tens/hundreds tons for smaller chlor-alkali productions within wood-pulp factories, chemical reagents, polymers and pesticide plants, amalgam productions, as well as productions of electrical equipment and measurement instrumentation etc. (in total about 30000 tons has entered the environment without taking into account mercury mobilization while combusting mineral fuel and processing metallurgical feedstock.

At present storages of liquid and solid mercury wastes, mercury contaminated production facilities and buildings (especially their floor slabs and concrete foundations), grounds and underground waters underneath, contaminated soils within industrial areas and treatment facilities as well as along roads, bottom sediments of water bodies and waterways where mercury-bearing wastewater and surface water entered are a source of secondary pollution of the environment and pose a threat to human health. In fact at the present time there occurs a spread of mercury pollution first of all with surface and underground waters at any industrial center as well as through the atmosphere due to volatilization of metallic mercury from contaminated soils and wastes storages (scale of mercury emission to the atmosphere from some territories contaminated with mercury can be comparable with mercury emission from plants for fossil fuels processing/combustion).

Table 1. Chlor-alkali production with mercury cathode within the former USSR (as of 2008)

Enterprises (in parentheses - names of soviet period)	Annual capacity of caustic (thousand tons)	Wastewater treatment method	Mercury consumption rate, g/t of caustic (losses assessment, t)
OPERATING ENTERPRISES			
1. **JSC "Kaustic" Volgograd city,** Russia. The year of mercury electrolysis production start-up - 1968	120	precipitation as sulfide	600-700 (1700)
2. **JSC " Kaustic " Sterlitamal city**, Bashkortostan, Russia. The year of mercury electrolysis production start-up with use of "Krebs" bathes - 1964, the year of shutdown - 1987. Facilities and buildings have been demercurized, wastes rich in mercury were sent to Nikitovskiy mercury factory, wastes poor in mercury were landfilled. The year of mercury electrolysis production of doubled capacity start-up with used of "De Nora" bathes in new production premises - 1982.	150	combined: ion-exchange + purge	400-450 (1300)
3. Surface-active substances factory, Sumgait city (PO "Khimprom"), Azerbaijan. The year of the first mercury electrolysis production start-up – 1956, the year of shutdown - 1981, facilities and electrolysis shop have been demounted, mechanically cleaned from mercury and utilized; wastes rich in mercury were sent to Nikitovskiy mercury factory, wastes poor in mercury as well as debris of floor slab and soil down to 2 m deep from under the shop were landfilled. The year of the second production of the same capacity (new electrolysis building was constructed next to the old one and all infrastructure has been kept) start-up - 1982	70	ion-exchange	600-700 (1300)

4. **JSC Kirovo-Chepetskiy Chemical factory. Kirovo-Chepetsk,** Kirovskaya oblast, Russia. The year of mercury electrolysis production start-up - 1955	200	combined: precipitation as sulfide + ion-exchange	300 (1600)
STOPPED ENTERPRISES			
5. **Factory of chemical concentrates, Novosibirsk city**, Russia. The year of mercury electrolysis production shutdown - 2006. Facilities and buildings have been demercurized, new chlor-alkali production of smaller capacity based on a membrane method is being set up in the same production premises.	200	ion-exchange	300 (1000)
6. **JSC "Sayanskkhimplast", Sayansk city (Ziminskiy Chemical Plant)**, Irkutskaya oblast, Russia. The year of mercury electrolysis production start-up - 1979, the year of shutdown - 2006. Facilities and buildings have been demercurized, new chlor-alkali production of smaller capacity based on a membrane method operates in the same production premises.	150	Combined: ion-exchange + evaporation	600-700 (1400)
7. **JSC "Usolyekhimprom", Usolye Sibirskoe city**, Irkutskaya oblast, Russia. The year of mercury electrolysis production start-up - 1970, the year of shutdown – 1998. The production is being closed down. Design of demercurization of buildings and the territory has been prepared.	110	precipitation as sulfide	600-700 (1100)
8. **JSC "Radikal", Kiev city (Chemicals Plant)**, Ukraine. The year of mercury electrolysis production start-up - 1954, the year of shutdown - 1996. The production has been closed down. Facilities have been demounted. Feasibility study of a design of demercurization of buildings and the territory has been prepared.	60	ion-exchange	600-700 (900)

9. **JSC "Kaustik", Pavlodar city (PO Khimprom)**, Kazakhstan. The year of mercury electrolysis production start-up - 1975, the year of shutdown - 1993. Facilities, buildings (have been demounted) as well as territory (partially) has been demercurized; new chlor-alkali production of smaller capacity based on a membrane method is being set up in other production premises.	120	ion-exchange	1500 (1600)

Besides mercury plants of small capacity operated at: **PO "Kaprolaktam", Dzerzhinsk town**, Nizhegorodskaya oblast (start-up – 1948, shutdown – 1982) – 10 000 tons/year, and also **Arkhangelskiy, Novodvinsk town**, Arkhangelskaya oblast (start-up – 1962, shutdown – 1996) – 16400 tons/year, **Svetogorskiy, Svetogorsk town**, Leningradskaya oblast (start-up – 1951, shutdown – 1993) – 1300 tons/year, **Kotlasskiy, Koryazhma town**, Arkhangelskaya oblast (start-up – 1964, shutdown – 1998) – 19600 tons/year, and **Amurskiy, Komsomolsk-na-Amure city**, Khabarovskiy kray (start-up – 1970, shutdown – 1997) – 7400 tons/year **pulp and paper milks.** Wastewater treatment method used there is precipitation as sulfide. Kotlasskiy plant was demounted and utilized, buildings were demercurized, mercury wastes and heavily contaminated facilities were landfilled; at present chlor-alkali production of the same capacity operates based on a membrane method. Information on demercurization at the other productions is not available.

In total mercury losses during production of chlorine and alkali can be estimated to be 11900 tons + 900 tons = 12800 tons that is twice more than during gold mining in Russia/USSR for all historical period (about 6000 tons) /1/.

At present owing to a number of reasons the principle of which is opportunity of authorities not to account for mistakes of the soviet period in countries arisen at the post soviet space, concealment of industrial pollution of the environment with mercury (apart from a few special cases) has not been a matter of public policy any more. However regional authorities and in particular managers of ongoing enterprises using mercury try to conceal a scale of existent emissions in order to preserve profitability of a production or not to harm to plans of its modernization and development. As a result as a rule local authorities controlling state of the environment do nothing and scientists specialized in the area of environmental protection are not able to get any financing to carry out independent researches. It worth mentioning extremely limited number of new chemical-analytical laboratories having state-of-the-art equipment and highly qualified personnel capable of implementation of such kind of researches as well as degradation of laboratories survived since the soviet time.

Nevertheless gradually productions using mercury are being closed down by some reasons or gone into new non-mercury technologies (Table 1). The situation becomes common when development of a design of demercurization starts after a production shutdown and funds for field research aimed at revealing scale and specifics of a particular case of industrial pollution are not found. Absence of objective and correct evidences on the environmental impact assessment, mercury pollution effect on public health usually result in not only serious reduction of a list of remediation measures which should be done but is an obstacles for realization of the necessity in remediation at all (especially for small productions). Moreover no incentives arise to develop and apply new non-traditional cost effective remediation technologies.

As long as mercury had some market value closing of productions using mercury in their operation process was followed by metallic mercury collection including spilt one and utilization of wastes rich in mercury (PO ‘Khimprom”, Sumgait city in the early 1980s, PO “Kaustik”, Sterlitamak town in the late 1980s) which were sent to mercury factories for processing. At present wastes rich in mercury such as heavily contaminated equipment, building structures, sludge and soil are commonly buried without mercury extraction (PO “Khimprom”, Pavlodar city, PO “Karbid”, Temirtay city). Treatment and even removal of soils and bottom sediments less contaminated with mercury has been yet a matter of discussion at the stage of feasibility study working out and not gone beyond. Within the former USSR there has not been any example of bringing a similar problem to its practical implementation because it seems unfeasible to achieve MPCs for mercury (not only the former USSR standard – 2.1 mg/kg, but even European one – 10 mg/kg) in present-day economic conditions.

Kazakhstan has become to some extent an exception when during political and economic crisis in the 1990s mercury pollution risk assessment was done for two large-scale industrial enterprises such as still operating that time acetaldehyde production in Temirtau and closed chlor-alkali production in Pavlodar /3, 4/ for quite small grants allocated by European Union Programs of science and technical cooperation as well as by World Bank and US EPA on a competitive basis. That allowed revising the Design of demercurization of chlor-alkali production developed in USSA by including non traditional approach, new technologies and post-demercurization monitoring and attracting funds of World Bank and Kazakhstan Government for remediation of the acetaldehyde production as well as areas in the vicinity including the Nura River. Results of the research including risk assessment for public health /5/, study of mechanism of mercury transport with suspended solids downstream the river /6/, of many years monitoring of groundwater and computer modeling of mercury spread with groundwater /7/, comparison of balance and actual mercury discharge with wastewater can help to assess both risks posed by similar closed and still operating enterprises in Russia, Ukraine and Azerbaijan and effectiveness of measures on elimination of consequences of their production activity.

ACKNOWLEDGEMENT

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The authors thank Leonid E. Postolov for providing data for the Table 1.

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POSSIBILITIES OF BACTERIA USE FOR REMEDIATION OF MERCURY CONTAMINATED GROUNDWATER

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Although main risks of mercury contamination at the territory of a former PO “Khimprom”, Pavlodar are currently contained within anti-filtration bentonite clay barriers so called “cut-off walls” and capped from the top considerable environmental and public health risks remain in northern outskirt of Pavlodar city due to the following reasons:

- presence of a plume of groundwater mercury contamination which has already spread 2.5 km far from the primary source of the contamination (electrolysis factory) and reached open water bodies.
- possible upward movement of mercury-polluted groundwater which night cause contamination of pastures located in a depression in the vicinity of a wastewater storage pond - Lake Balkyldak
- possible change in the flow of groundwater westward which might cause mercury to enter the Irtysh River and reach water supply wells of Pavlodarskoe village.

Transformation of mercury in the environment is mainly microbiologically mediated; this includs: (i) formation of methyl mercury (MeHg) which can be biologically accumulated by aquatic biota posing an increased threat to the health of people eating fish, (ii) volatilization which can move mercury from a site to the atmosphere from where mercury may be deposited around the globe; and (iii) transformation into less toxic species such as insoluble mercury sulfides /1, 2/.

Mercury presents a number of difficulties to *in situ* remediation, and there are few if any biological technologies available to mitigate environmental mercury contamination.

The common mechanism of bacterial mercury resistance is the transport of ionic or organic mercury into the cell where it becomes reduced to elemental mercury. Elemental mercury can become trapped as globules inside the cell and in bacterial exopolysaccharides. This forms the basis of an end of the pipe bioreactor to treat mercury-contaminated, industrial effluent developed by Irene Wagner-Dobler /3/. However an end of the pipe system is not a viable approach for treating contaminated groundwater since so called “pump and treat” and excavation approaches are often cost prohibitive due to energy and manpower requirements and, as in the case of contaminated ground water, represent long-term propositions.

The most promising bacterial community for groundwazter bioremediation is sulfate-reducing bacteria. Sulfate-reducing bacteria (SRB) release hydrogen sulfide during growth. Sulfide can effectively immobilize mercury forming insoluble mercuric sulfides, but some SRB can also methylate mercury that poses a threat to living organisns because of mercusy accumulation through food chain in water bodies.

The studies conducted under the ISTC K-756p project resulted in:

- getting evidences of aerobic, facultative-anaerobic and sulfate-reducing bacteria (SRB) resistance to mercury and gathering a collection of bacterial communities resistant to mercury;
- finding optimal temperature conditions for growth of aerobic, facultative-anaerobic and sulfate-reducing bacteria resistant to mercury;

***Figure 1**. Soil sampling at the territory of the chemical plant*

***Figure 2**. Drops of mercury visible on soil surface before demercurization works*

- choosing efficient support materials for aerobic and anaerobic sulfate-reducing bacteria colonization;
- revealing conditions for methyl mercury formation by facultative-anaerobic and sulfate-reducing bacteria;

- designing and assembling in laboratory conditions a simulating filtering system with colonized aerobic and anaerobic sulfate-reducing bacteria and evaluating its efficiency.

Several cultures of sulfate-reducing bacteria were isolated from soil surrounding the chemical plant as well as from bottom sediments of a wastewater storage pond – Lake Balkyldak which generated negligible amount of methyl mercury at certain conditions.

The research showed that some properties of these bacteria make them promising candidates for developing *in situ* technologies to mitigate mercury-contaminated groundwater.

Laboratory experiment which simulates a treatment of mercury contaminated water using sulfate-reducing bacteria suggests capability of these bacteria for efficient mercury sequestration with negligible formation of methyl mercury. At that decrease of mercury level in groundwater occurs down to maximum permissible concentrations (MPC for Hg total in drinking water is 0.5 µg/L, in soil – 2.1 µg/kg; MPC for MeHg in drinking water is 0.05 µg /L).

Research conducted in the framework of the ISTC K-756p project has shown that $HgCl_2$ (at the same concentrations found at the Pavlodar site) may be removed from groundwater using support material colonized with native isolates of aerobic or anaerobic bacteria.

At present the research "*Application of native bacteria for in situ bioremediation of mercury contaminated groundwater occurring in Northern Kazakhstan as a result of operation of the former PO "Khimprom" chemical plant in Pavlodar*" is being conducted within the frameworks of ISTC K-1477p prpject. The objectives of the research are: 1) to scale up the bench scale bioreactors to pilot scale reactors in order to optimize the conditions for removal of mercury with limited formation of dissolved or methylated mercury, and 2) to conduct small scale field trials at the contaminated site using the bacterial cultures.

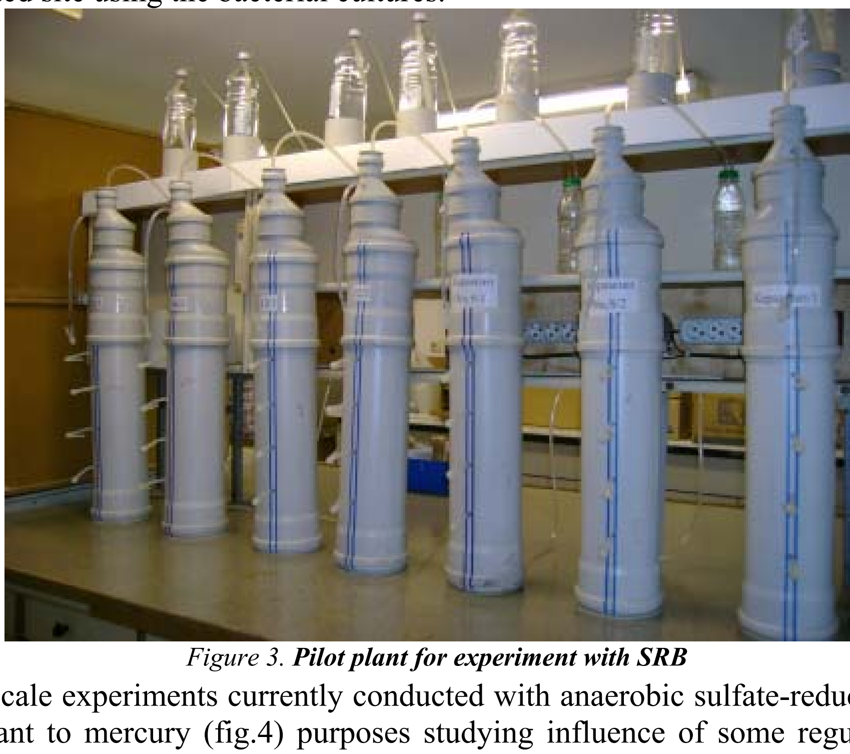

Figure 3. ***Pilot plant for experiment with SRB***

The pilot scale experiments currently conducted with anaerobic sulfate-reducing and aerobic bacteria resistant to mercury (fig.4) purposes studying influence of some regulable factors on effectiveness of groundwater clean-up from mercury.

As a result of the research initial data are expected to be obtained for conducting full-scale *in situ* bioremediation of mercury contaminated groundwater at Northern outskirt of Pavlodar city. The bioremediation will be based on the isolates of native bacteria adapted to environmental conditions at the contaminated site. This approach can result in development of a cost-effective way of mercury contaminated groundwater treatment avoiding expensive technologies. Controllable experiments carried out in pilot scale reactors which are soil columns used for the process optimization will allow understanding factors responsible for mercury mobility and methylation. Field tests will contribute to development of a method of bioremediation of mercury contaminated groundwater and demonstrate in general potential of bacteria use for mercury contaminated groundwater treatment.

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IS IT NECESSARY TO EXPECT NEW HEALTH EFFECTS OF LOW DOZES OF MERCURY?

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"**Toxicity of mercury** and **poisoning** — reality with which it is necessary to collide to each American. Both EPA and National Academy of sciences declare, that 8 - 10 % of American women have level of Hg, leading to occurrence of neurologic frustration for any child born by them. According to the Center to the control of diseases (CDC), each sixth child in the USA has infringements in development of neurologic character".

Boyd Haly, Kentucky University.

All people now are exhibited by mercury and its compounds as a result of natural and anthropogenous emissions. The natural level of influence of mercury is about 2000; it is probable, that all of alive organisms on the Earth are adapted for this influence - otherwise the life on our planet would stop. Almost double excess of this level is connected with anthropogenous activity - up to 3900 t/year (http://www.econ-hg.ru/doc-html/rtut.htm), that, basically, can reach borders of natural tolerance to mercury of different biological species.

Recent studies show that mercury exposure may occur in the environment, and increasingly in occupational and domestic settings. Several sources of toxic Hg exposure in human have been reported in biomedical literature: (1) methylmercury, the most widespread source of Hg exposure, is most commonly the result of consumption of contaminated foods, primarily fish; (2) ethylmercury, which has been the subject of recent scientific inquiry in relation to the controversial pediatric vaccine preservative thimerosal; (3) elemental Hg vapor exposure through accidents and occupational and ritualistic practices; (4) inorganic Hg through the use of topical Hg-based skin creams and in infant teething powders; (5) metallic Hg in dental amalgams, which release Hg vapors, and Hg2+ in tissues [1].

Regulatory Standards and Advisories for Hg^0 :

The occupational exposure limit set by the U.S. Occupational Safety Health Administration is 100 µg/m^3 as a time-weighted average (TWA) for 8 hr/day, 5 days/week (NIOSH 1997 [2]). The American Conference of Governmental and Industrial Hygienists (ACGIH) recommends a maximum Hg^0 concentration of 25 µg/m^3 as a TWA for the same exposure duration (ACGIH 1994 [3]). Because children are more sensitive than adults to mercury, occupational standards do not apply to them. For Hg^0, the recommended limit for continual habitation by children is 0.2 µg/m^3, according to the ASTDR (1999) [4]. However, this concentration is very hard to achieve after an Hg^0 cleanup. For the natural gas regulator spills, the ATSDR and U.S. EPA worked with IDPH to develop suggested action levels for mercury vapors, 1 µg/m^3 for clearance and a home evacuation level of 10 µg/m^3 in living areas (ASTDR 2002, 2004 [5,6]).

Maximal concentrations of Hg in air, detected in Central Europe, were: from 2.5 ng/м3 - open air; till 5 -15 ng/м3 – in industrial zones; for Northern-East Atlantic - 1.6 ng/м3 (www.helcom.ru/doc/vv6.pdf). Are they dangerous?

In accordance with FDA, WHO, ATSDR and EPA, the safety level of Hg's daily intake decreased during last 30 years more than in 1000 times (Fig.1). Scientists report that now level of Hg, associated with harmful effects, achieve the lowermost - EPA - regulatory standard

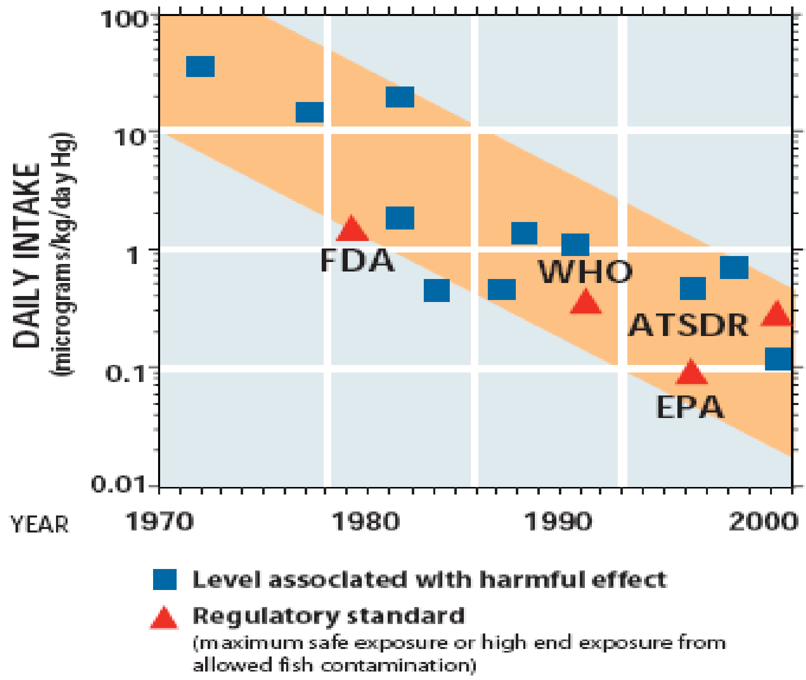

Fig.1 **"What mercury levels are safe for me?" – by the data of University of Minnesota** (http://www.noharm.org).

In an organism mercury is distributed, practically, in all tissues and subcellular structures, but most of all was find out in blood, liver, kidneys and brain. In cells non-random distribution of mercury is observed: 54 % collect in soluble fraction, 30 % - in nuclear, 11 % - in mitochondrial, 6 % - in microsomal [7].

These data allow suppose that Hg may induce mutations, influence to generation and distribution of power in cell and effects to systems of detoxification.

Blood mercury levels of <10 µg/dL and 300 µg/dL corresponded to mild effects and death, respectively [8]. Teratogenic effects due to organic or inorganic Hg do not well documented for humans or animals, although some evidence exists for mercury-induced menstrual cycle disturbances and spontaneous abortions, congenital abnormalities and reduced fertility is limited [7, 9, 10]. *Ionic Mercury* induces C-mitosis with inactivation of mitotic spindle resulting in aneuploidy and polyploidy, chromosomal aberrations and micronuclei in peripheral lymphocytes and increase frequency of sister chromatid exchanges. Effects of *Methylmercury* connect with abnormal mitosis, single-strand breaks in cellular deoxyribonucleic acid and spindle disturbances. For example, 0-25 x 10^{-6} M methyl-Hg and 0-434 x 10^{-6} M dimethyl-Hg induced dose-depending increase of frequency of chromosomal aberrations in culture of human blood lymphocytes as well as induction of C-mitosis with inactivation of mitotic spindle resulting in aneuploidy and polyploidy [11]. All of the effects, enumerated above, may be connected with development of tumor diseases and cancer, so they are first group of illnesses, new for mercury.

Next, mercury may influence to resistance of an organism to other exposures. So, [12] Brown Norway rats display a relative resistance to experimental Chlamydia-induced arthritis. Mercuric chloride modulated this innate resistance to arthritis: mercury-exposed rats had a marked exacerbation of the histopathological severity of the arthritis, and the infiltration was predominantly neutrophilic. Mercury exposure was also associated with marked enhancement in IgE levels and an alteration in IgG2a/IgG1 ratio, reflecting a Th2 shift. The local cytokine profile in the joint was markedly altered after mercury exposure, with a suppression of tumor necrosis factor-alpha and interferon-gamma but an enhancement of vascular endothelial growth factor. This was associated with decreased host clearance capacity reflected in enhanced bacterial load in both the spleen and the joint and was accompanied by enhanced detection of microbial antigens in the synovial tissues by immunohistological staining. I.e, genetically defined cytokine production in the joint defines the severity of reactive arthritis by dictating the local clearance of the pathogen. This interplay can be altered dramatically by mercury exposure, which results in suppression of protective cytokines in the microenvironment of the joint and may cause the other type of Hg-dependent diseases - immunologic.

Experiments on rats (Tabl 1) demonstrated, that Hg0 vapor exposure increased the expression of genes encoding inflammatory responses, such as chemokines, tumor necrosis factor-alpha (TNFalpha), TNF-receptor-1, interleukin-2 (IL-2), IL-7, prostaglandin E2 receptor, and heat-shock proteins. As adaptive responses, glutathione S-transferases (GST-pi, mGST1), metallothionein, and thioredoxin peroxidase were all increased in response to Hg exposure. Some transporters, such as multidrug resistance-associated protein (MRP), P-glycoprotein, and zinc transporter ZnT1, were also increased in an attempt to reduce pulmonary Hg load. The expression of transcription factor c-jun/AP-1 and PI3-kinases was suppressed, while the expression of protein kinase-C was increased. Expression of epidermal fatty acid-binding protein was also enhanced. Real-time RT-PCR and Western blot analyses confirmed the microarray results. In summary, genomic analysis revealed an array of gene alterations in response to Hg0 vapor exposure, which could be important for the development of pulmonary adaptation to Hg during Hg0 vapor inhalation [13]

Effect of mercury vapor exposure on rat's **gene expression** (by **Jie Liu et al, 2003)**

Inflammation-related genes	***Effect (folds)***	***Transporter and related genes***	***Effect (folds)***
CXC chemokine LIX	14.47	Multidrug resistance protein (MRP2)	1,63
TNF- alpha	2.52	P-glycoprotein-1	2,95
TNF-R1	2,06	Zinc transporter ZnT-1	1,72
Macrophage inflammatory protein-1	2,88	Organic cation transporter OCT1	2,25
Interleukin-2	2,12	***Signal transduction-related genes***	
Interleukin-7	1,71	c-jun/AP-1	0,48
Prostaglandin E2 receptor	2,73	Phosphatidylinositol-3-kinase p85	0,53
Glutathione system and antioxidants		Nur77 early response protein	0,28
Glutathione S-transferase GST-pi	2,74	Protein kinase C alpha	2,71
Microsomal GST1	1,53	Protein kinase C gamma	2,08
Glutathione reductase	1,70	Other genes of interest	
Heat shock protein-60	1,50	Epidermal fatty acid-binding protein	2,34
Thioredoxin peroxidase	2,26		
Cu,Zn-superoxide dismutase	1,24		

So, next group of mercury induced diseases are pulmonary ones, and, probably, tumors of lung.

From the other hands, demonstrated data shown that mercury expresses groups of genes, responsible for both - common and special reactions.

As mercury is natural toxic factor, for preservation of life on the Earth evolution should arise the inherited mechanism for protection of alive organisms. For this reason protection should be determined genetically and to search for iti is necessary in the certain combination of polymorphic variants of the genes responsible for transformation of mercury and detoxification. Now it is known already more than 200 of " genes of an environment ". For many of them are revealed genetic polymorphism, influencing on functional activity of alleles. It is essential, that in each group of the enzymes participating in detoxification, are found out mutant isoforms which function can be broken in comparison with normal alleles. And these functionally defective alleles meet among persons with various diseases much more often, in etiology which important role play adverse exogenous factors. The genes having such alleles, also it is possible to consider as "genes of predisposition" to those or other diseases.

Whether all people are equally sensitive to mercury and its compounds? Differently, whether it is possible to suppose, what unconditional observance of specifications will keep health to mankind?

Because detoxification of the most of dangerous organic compounds of Hg in human body requires reduced glutathione, all people with mutations in one of big glutathione S-transferases gene family (GSTs) are the most of sensitive to very low level of Hg and its compounds. By different data, frequency of mutations in GST genes varies from 35 to 50% among Euro-Asian human population - all of them are candidate in risk group. For example, relatively new disease, linking with Hg - autism - connects with GSTs polymorphism, too. Some light to the connection between GST polymorphism and metallothionein expression in context of body levels mercury throw study among students in Austria [14]. Authors has shown that hair mercury concentrations are significantly increased in persons with the double deleted genotype (GSTT1-/- and GSTM1-/-) as compared to persons with the intact genotype, and b) MT1X expression is higher in persons with the intact genotype (GSTT1+/+ and GSTM1+/+). They concluded that the epistatic effect of the GSTT1 and the GSTM1 deletion polymorphism is a risk factor for increased susceptibility to mercury exposure. The relationship between MT gene expression and GST gene polymorphisms needs further investigation. If MT expression depends on GST polymorphisms it would have important implications on the overall metal detoxification capability of the human organism.

Level of mercury in human biosubstrata, usually, is not high [15, 16]. However influence of these dozes on health very difficultly to determine because for more than 100 years of research of these compounds well studied are only effects of very high (toxic) dozes. Therefore the main task of modern researches is studying health effects of small dozes of mercury and itscompounds.

The special attention should be turned on that fact, that the structure of a complex of a protective combination of genes (a protective genotype) should include not only certain alleles of the genes connected with detoxification directly, but also the genes determining character of general reactions, for example, connected with development of stress - nonspecific response of all organism to any influence.

Thus, here the main is the question - which genotype is protective, and what combination of other alleles the same genes strengthens toxic effect of mercury and its compounds, or is connected with increase of individual sensitivity of an organism. Besides this it is represented rather important to estimate capacity (efficiency) of protective genotype, because the situation when the protective genotype is sufficient for long (during all life of an organism) oppositions of a natural exposition is rather probable, but it is ineffective at a greater level of influence.

The analysis of prevalence of the protective genotype in human populations also is one of priorities of the present stage of researches on a problem " Mercury and health of the person ", including as it is directly connected with features of influence of mercury and its compounds on health of autochthonous populations of Northern countries.

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Concept, conditions and problems of realization of "Nura River Clean-up" Project in Kazakhstan

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In the report it is informed that the information regarding realization of the mercury clean-up Project for Nura River and industrial site of the former factory for acetaldehyde production in Central Kazakhstan, initiated by the Government of the Republic of Kazakhstan together with the World Bank and planned for 4 years. Project realization started in 2007 by the Committee for Water Resources of the Ministry of Agriculture of the Republic of Kazakhstan, Contractors from the Chinese People's Republic – "KitayStroy" Ltd and "CGC Overseas Construction Co., LTD Kazakhsan Branch", also by Supervision Engineer - the Austrian company Posch&Partners Consulting Engineers.

Introduction

The source of rise of large mercury biogeochemical anomalies in 1950-1993 near Temirtau in Central Kazakhstan was the production of acetaldehyde. Technological scheme of acetaldehyde production presumed some mercury losses in the form of atomic-dispersed mercury in products; metallic compact, atomic-dispersed, ionic inorganic mercury and mercury organic compounds in wastewater and gas form mercury in ventilation discharges. Mercury discharges into the environment occurred during emergencies, also due to the imperfection of the technology during thermal mercury regeneration from sludge, discharge of mercury containing wastewater into the Nura river (average annual water flow in the river in the section line of Temirtau is about 10 m/s), accumulations of mercury wastes on factory area and beyond its bounds. As a result of it the soil on factory site and around it, river-bed, river banks, and flood-plain got contaminated for 30 km downstream. Area of the former factory for acetaldehyde production due to buildings emergency condition, lack of proper control and means for preventive measures became a potential pesthole of secondary contamination of the environment, rise of emergency situation for people of Temirtau, Karaganda and adjacent regions.

Before to evaluate scope of mercury contamination there were performed the following investigations:

1. During 1997 - 98 within the international project INCO Copernicus the areas of factory site, river banks, flood-plain, and river-bed of the Nura were investigated.
2. In 2001-2002 in order to prepare the draft of Feasibility study for the clean-up of the river basin and factory area the BCEOM company had performed investigations to evaluate localization and thickness of mercury containing ash layers.
3. In 2002- 2003 the Ramboll company carried out investigations of the former sludge trap for mercury containing wastes – the Zhaur swamp.
5. In 2004 to determine a possibility to use historical data during working up of the Feasibility study and evaluation of excavation quantities of the contaminated soil the Posch & Partners company carried out field and laboratory investigations of the river banks, flood-plain, river-bed, and the Zhaur swamp, also the results of previous investigations were analyzed.


Figure 1. General view of the former acetaldehyde production factory.

Tasks and aims of the Project

To improve the ecological situation in Temirtau the Government of the Republic of Kazakhstan together with the World Bank planned and implement the following nature conservation measures designed for 4 years ("Nura River Clean-up" Project):

- construction and operation of the landfill for hazard wastes,
- removal and transportation to the landfill of the mercury contaminated materials, sludge, and soil from the sites related to the industrial site of acetaldehyde production and waste treatment plants,
- clean-up of the river-bed, river banks, and flood-plain: excavation of the contaminated soil and its transportation to the landfill.

The main aims of the Nura River Clean-up Project are:

1. Improvement of living conditions of the people living within the river basin;
2. Removal of the mercury contamination source and provision of safe and inexpensive water supply source which corresponds with the growing needs of water consumers.

Information regarding Project realization process

In 2007 the Contractors from the Chinese People's Republic - "KitayStroy" Ltd and "CGC Overseas Construction Co., LTD Kazakhsan Branch", also Supervision Engineer – the Austrian company Posch&Partners Consulting Engineers, started the Project realization.

During the first two years there was completed a set of works specified in the project.

1. GIS database for the clean-up area was developed. There were carried out works on development of basic cartographic base of GIS-project based on topographic maps, forming of the structure of attribute data bank, insertion of the results of field and analytical works into the attribute data bank, connection of attribute data bank to the GIS-

project and data visualization, geographical binding of historical data, actualization of GIS-project based on new information insertion, modeling of soil mercury contamination spread by layers and calculation of quantities of soil mercury contaminated.

2. The first stage of the monitoring near Tegiz-Zhol village is done. Soil samples were taken from the depth to 3 m from flood-plains and river-banks with various investigation grids.
3. Buildings and structures on the area of acetaldehyde production were dismantled. All the mercury contaminated buildings technologically related to the production process are dismantled to its base.

Figure 2. Drops of metal mercury on the industrial factory site.

4. Excavation and disposal of the contaminated soil from the industrial factory site was done on the landfill. Soil was excavated to 2 m deep based on the data of the previous investigations. Soil disposal was implemented in landfill cells considering hazard class.

Figure 3. Excavation of soil from the base of factory buildings.

5. 1st stage of the landfill construction is done including administrative and auxiliary buildings, laboratory building, cells for disposal of mercury contaminated wastes of the hazard class 1-4, vehicles registration unit, etc.


Figure 4. Landfill panorama.

Figure 5. Containment of the landfill cell base.

6. Sedimentation-ponds of the treatment plants are isolated. Depending on mercury content in sediments there were carried out works on its excavation and containment with further area recultivation.
7. Temporary drain was built; the main drain of Temirtau is cleaned from mercury contaminated sludge and put into operation. Bottom sediments with mercury content higher than then-up criteria were disposed on landfill. Banks of the drain are isolated with clean soil.
8. Pre-excavation investigations by the control grid of the Nura river banks and flood-plain are implemented. Investigations were carried out by regular grid with sampling to 3 m deep and 20 cm interval. Contamination maps with marked detailed investigations are built.
9. Mercury reduction plant is constructed. However, the plant was not put into operation due to a number of technical imperfections.
10. The contaminated sections of the ash-dump are investigated, removed, and isolated. Ash-dump sections with mercury content more than 1500mg/kg were removed and disposed on landfill. Less contaminated sections were covered with clean soil layer.
11. The first transfer station for re-loading of mercury contaminated soil was built, it is located near the road close to the Zhaur swamp and it is provided with a unit for vehicles registration, weighbridge, areas for temporary stockpiling of contaminated soil prior its delivery to the landfill.
12. Excavation and disposal of contaminated soil from the Zhaur swamp are started. After the determination of sections with mercury content more than 10 mg/kg and 1500 mg/kg the contaminated soils were removed and delivered to the landfill cells for the hazard class 1 and 2-4.
13. Monitoring of environment objects is being carried out. Mercury vapors content is measured on factory site, in inhabited localities, landfill, on transfer stations, and on work sites taking into account “wind rose”, meteorological parameters of the environment.

For 2009 the following work types are planned:

1. Maintenance and updating of GIS database;

2. Second stage of monitoring near Tegiz-Zhol village;
3. Evaluation of clean-up success of Zhaur swamp, factory site and area recultivation;
4. Detailed pre-excavation investigations of river-banks, flood-plain, and river-bed;
5. Completion of works for containment of sedimentation ponds of treatment plants and/or excavation of sediments;
6. Setting-up, test and put into operation of mercury reduction plant;
7. Completion of landfill construction;
8. Excavation and disposal of the contaminated soil and sediments of the river banks and river-bed;
9. Continuation of monitoring of environment objects.

Complicating factors of Project realization

Main complicating factors during works are the difficult climate conditions and lack of qualified specialists at Contractors. The project area is located in Central Kazakhstan and is characterized with sharp continental and dry climate. Spring starts in the end of March, winter starts in November. The region is characterized with constant windy weather. Soil freezing depth depends on air temperature and thickness of snow cover and varies within 1.3-1.5 m. The deepest of soil freezing reaches 3.5 m. Because of it during autumn-winter period works are complicated with climate conditions.

Works carried out by the project include not only construction-assembling works but also ecological investigations (pre-excavation investigations, evaluation of clean-up success, analytical measurements, monitoring over environment condition, etc.). Contractors' staff is basically represented by specialists of construction, topographical-geodetic and earthworks. Lack of sufficient number of specialists of environment engineering at Contractor's staff complicates works implementation at a proper level.

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EVALUATION OF DEMERCURIZATION EFFICIENCY OF CHLOR-ALKALI PRODUCTION IN PAVLODAR CITY, KAZAKHSTAN

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The case of mercury contamination in Pavlodar typical for the former USSR has resulted from chemical plant PO ‘Khimprom” activity in 1975-1993 containing chlor-alkali production based on electrolysis with mercury cathode at the production capacity of 100000 tans of chlorine per year /1/. Due to the economic crisis in mid 1990s the chemical plant was in fact decommissioned and most of valuable facilities were utilized. Total load of metallic mercury got to the environment for less than 20 years and mainly deposited in soils was estimated to be 1310 tons. A plume of groundwater about 400 m wide polluted with $HgCl_2$ up to a concentration level of 0.1 mg/L has spread over basalt clay stratum at the depth of 5-20 m 2 km far from an electrolysis shop to the north-west (fig.1).

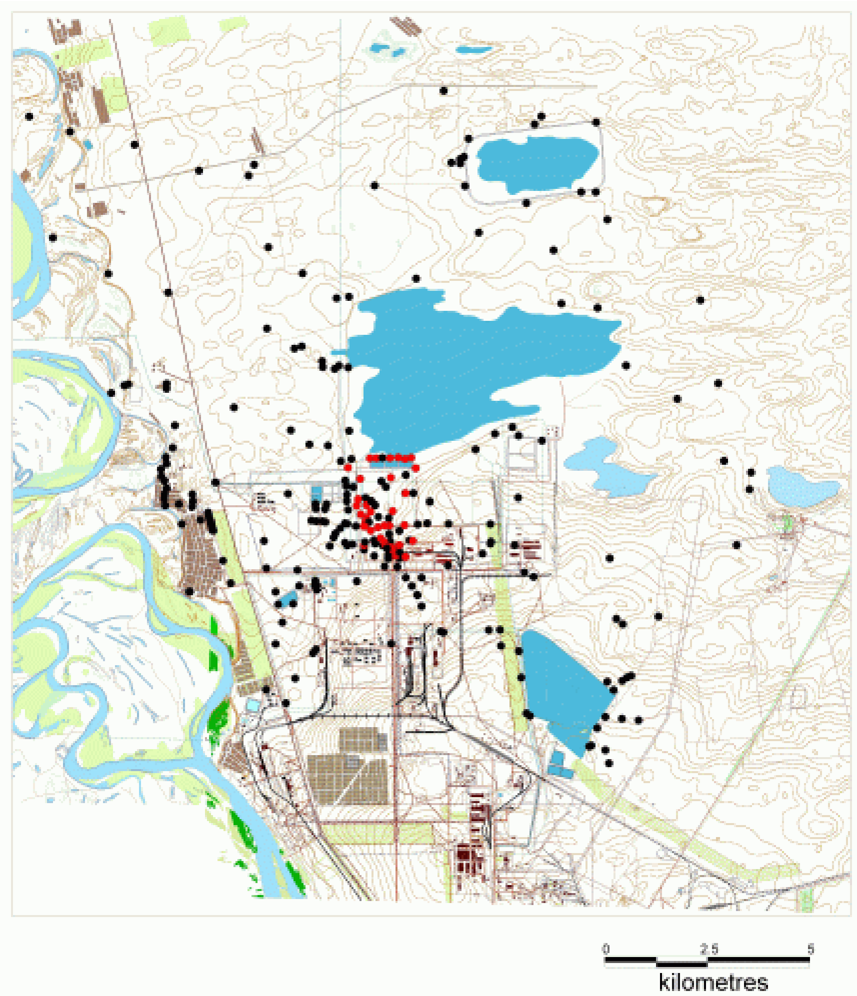

Figure 1. *The area of field works on the project ICA2-CN-2000-10209 “Toxicmanagement” in 2001-2001(dots on the map are groundwater sampling points; black ones – when mercury concentration in water is lower than 500 ng/L, red ones – higher than 500 ng/L)*

The plume was recharged with soluble mercury compounds from two sources: the major one – accumulation of metallic mercury, alkaline and chloride brines under the electrolysis factory (fig.2) and the additional one – accumulation of metallic mercury and sewage under the building of a wastewater pumping station located 900 m far from the electrolysis factory downstream the groundwater flow.

Figure 2. *Electrolysis factory after closing down chlor-alkali production in 1993*

Main risks to the environment were posed by mercury emissions to the atmosphere from mercury contaminated semi-destroyed industrial buildings and topsoil as well as by dissolving buried mercury in groundwater followed by spread of this contaminated groundwater towards the Irtysh River floodplain located at a distance of 5 km to the west from the chemical plant. Mercury vapors and mercury containing fish caught by fishermen from a wastewater storage pond (the technical water body with capacity of about 60 million m^3 located 2 km far to the north from the plant) posed a risk to health of still working personnel and population living in the vicinity. Groundwater mercury contamination also could reach water-supply wells of large village situated 4 km far from the chemical plant between the plant and the Irtysh River.

The first phase of demercurization was completed at the beginning of 2005. It involved demounting and utilization of all processing equipment of chlor-alkali production, manual collection of metallic mercury, dismantling of mercury contaminated production buildings, partial removal of heavily contaminated topsoil, and isolation of main underground hotspots of elemental mercury and mercury wastes from the atmosphere and groundwater, construction of a landfill for mercury containing building structures and the facility components. Some cleanup works had to be conducted in extreme conditions. So in spring of 1999 at the beginning of the works intensive evaporation of spilt metallic mercury occurred on dismantling the electrolysis building roof. All the territory the chemical plant owned was declared to be an emergency zone. The state of emergency lasted for two months until complete dismantling of the electrolysis hall and manual collection of most mercury spilt (17 tons).

According to original plan of demercurization (developed by JV “Evrohim”, Kien in 1995) it was prescribed to recover most metallic mercury occurring under the electrolysis factory (about

900 tons) by means of gravitational separation of pulp prepared of mercury contaminated soils as well as of thermal treatment of concrete debris of the factory floor slabs in a special furnace.

However monitoring research conducted in 2001-2002 on INCO Program of European Union found wider boundaries of contaminated area extent and hotspots unknown before that necessitated expanding substantially scope of remediation activity. That is why the proposal was accepted: to replace the strategy of mercury recovery by more cost-effective one of containment of main sources of mercury pollution. The containment strategy proceeded from understanding of impossibility of to achieve sanitary standards for mercury in all polluted media as well as absence of demand for commercial mercury at the legal market.

Figure 3. *Construction of anti-filtration barrier "cat-off wall" around electrolysis factory*

Four mercury heavily contaminated underground hotspots (under the electrolysis factory, a plant for mercury containing wastewater treatment and a wastewater pumping station as well as a repository of mercury wastes and sludge) were isolated along their perimeter from groundwater by constructing anti-filtration barrier so called "cut-off wall" at the depth down to 20 m 0.5 m deepening inside the basalt clay stratum. The cut-off wall 0.6 m thick was made of clays similar to bentonite and having filtration coefficient not more than 10^{-7} cm per second. The cut-off wall was constructed using two unique excavators equipped with a clamshell scoop fixed on a vertical pole (fig.3). Total length of the cut-of wall was 3588 m. Concrete floor slabs remaining of chlor-alkali facilities were isolated fro the atmosphere with compacted clay cap and at the repository for mercury wastes and sludge – with multilayer cover (ash, gravel, fertile soil and turf). The landfill for mercury containing building structures and components of chlor-alkali facilities was located 50 m far from the electrolysis factory and represented a pit down to 3 m deep with compacted clay layer 0.5 m thick and filled up with different materials containing not more than 1% of mercury and soil-concrete solution. Having formed monolith it was covered with asphalt to prevent from dusting. The area of the asphalt shield has amounted to 15810 m^2 (fig.4).

Figure 4. *Landfill for mercury wastes at the territory of chlor-alkali production*

Post-demercurization monitoring was conducted in 2004-2007 within the framework of ISTC K-1240p project and involved observation over mercury concentrations in near-earth atmosphere, groundwater, and topsoil within the polluted area around the industrial site of chlor-alkali production as well as in bottom sediments, water and fish in the wastewater storage pond.

Measurement of mercury vapor concentration over insulating protective screens at the repository of mercury wastes and sludge as well as over the landfill for mercury bearing building structures gave values lower than 100 ng/m^3 that proved their reliable insulation from the atmosphere. However the clay screens covering concrete foundation of demolished buildings of chlor-alkali production turned out to be washed away by rainfall and flood flows in many places. In summer time concentration of mercury vapors was steadily above 10000 ng/m^3 over track of dried streamlets which were studded with visible drops of metallic mercury.

Measurements of total mercury content in water samples taken from observation boreholes network showed that despite insulation of underground mercury hotspots, general configuration of the groundwater contamination plume and level of dissolved mercury concentration on the whole were the same during three years of the monitoring. Significant local decrease in mercury concentration in the groundwater was found only at the territory of the chemical plant outside of the site of chlor-alkali production to the west of the former electrolysis factory; the reason of this could be slight deviation of the plum of contamination under flank action of new sources of water loss from underground sewage system of the plant rather than cessation of the groundwater recharge with soluble mercury compounds from the main underground hotspot. It was shown that topsoil contamination with metallic mercury at the most of industrial area of the former chlor-alkali production was still abnormally high (up to 0.1% mass) and was a source of emission of high mercury concentration vapors to the atmosphere (above the level of 300 ng/m^3 in near-earth air layer 0.5 thick at 27^{o}C). The same topsoil could become the main source of groundwater recharge with soluble mercury compounds due to infiltration of atmospheric precipitation and water from melted snow through it that in general kept high level of mercury concentrations in the groundwater within the industrial site of chlor-alkali production. The plume of contamination also kept a tendency to transition of dissolved mercury of high concentrations in the direction of groundwater movement resulted in finding mercury in earlier uncontaminated observation boreholes of the monitoring network which monitored west direction of the mercury spread.

Soil sampling outside of the industrial area of the chemical plant allowed finding one more mercury hotspot at the area of a pasture inhabitants of nearby village used for their livestock. A level of the topsoil contamination was 100 mg/kg; the area of contaminated site was not less than 0.05 km^2; the place of contamination coincided with the area of the plum of groundwater mercury contamination spread at the depth of 6-8 m. Possible groundwater rise up to the ground surface as well as the topsoil mercury contamination resulted from the water evaporation was earlier predicted by simulation of the groundwater behavior using computer modeling software GMS 6.0.

Post-demercurization monitoring suggested a necessity to conduct the second phase of remediation works. Topsoil within the industrial site of the former chlor-alkali production contaminated with metallic mercury has still been the source of main risk so undoubtedly it must be treated using cost-effective technology. Also more reliable cap covering concrete foundation of the demolished buildings of chlor-alkali production must be constructed. Only then the correct investigation can be conducted to reveal the efficiency of the anti-filtration barrier – “cut-off wall” around underground mercury hotspots.

Because of the high potential dander posed by mercury contaminated groundwater a long-term seasonal monitoring of movement of the plum of mercury contamination including monitoring of mercury accumulation in topsoil in places of polluted groundwater rise up to ground surface must be arranged. In case of a real danger of the contamination occurrence in the vicinity of sources of population water supply either a technology of the polluted groundwater interception with help of drain wells or cost-effective technology of mercury immobilization within the plum of the contamination must be applied.

In /2/ literature containing additional information on this problem is given.

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MATHEMATICAL MODELING OF GROUNDWATER MERCURY POLLUTION (CASE OF NORTHERN INDUSTRIAL AREA OF PAVLODAR CITY, KAZAKHSTAN)

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In northern Kazakhstan, there is a serious case of mercury pollution near the city of Pavlodar from an old mercury cell chlor-alkali plant. The soil, sediment, and water is severely contaminated with mercury and mercury compounds as a result of the industrial activity of this chemical plant. Several international organizations such as the EPA and the EU countries have provided technical and financial support to the Kazakhstan government to remedy this mercury problem. Many mercury study efforts have been done. The aim of this particular project has been groundwater mercury pollution distribution aureole forecasting This paper/poster provides methods and results of mathematical simulations of hydrogeological conditions in the northern industrial zone of the Pavlodar City chemical plant.

INTRODUCTION

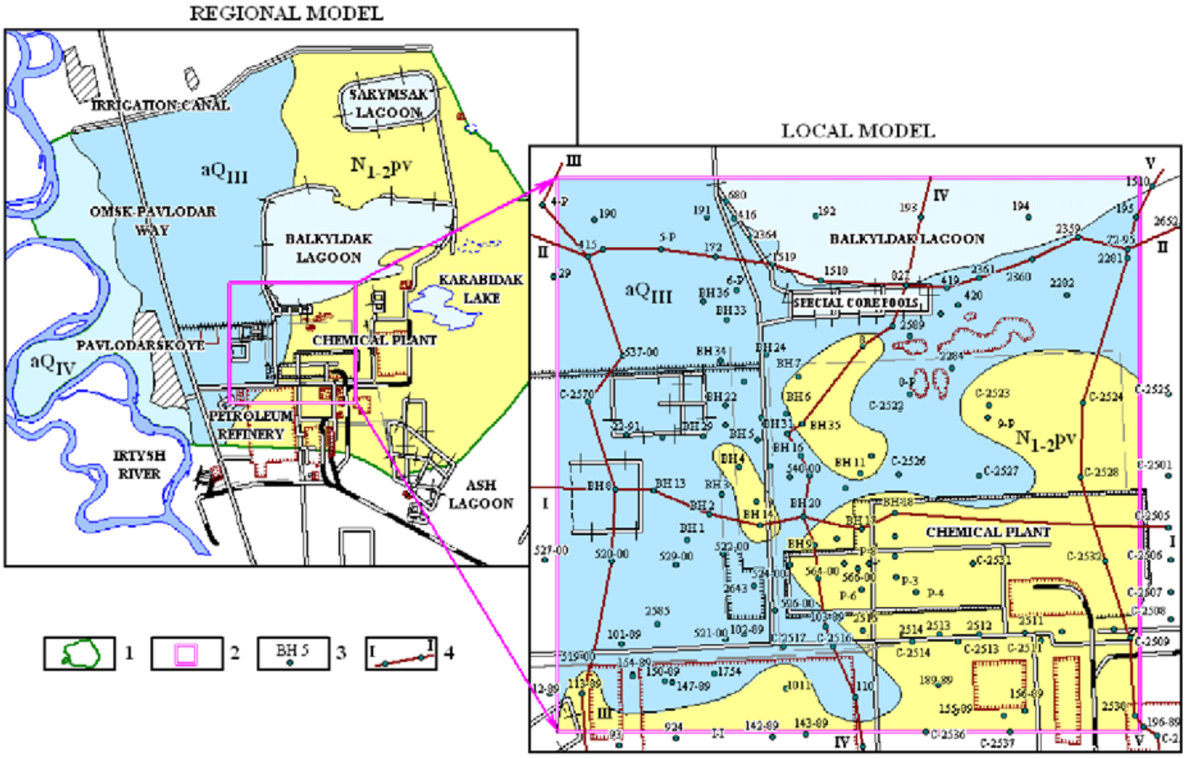
Mathematical modeling is the most effective method of investigation of groundwater mercury pollution processes. There was created in Kazakhstan the system of hetero-scaled interconnected mathematical models of hydrogeological conditions for the northern part of Pavlodar industrial region. In the result of modeling it managed to forecast mercury pollution aureole transport direction, to estimate groundwaters pollution dangers for the environment and to develop measures for risk lowering.

Administratively, the territory investigated is situated at the boundaries of Pavlodar region, Pavlodar district (Republic of Kazakhstan). Immediately on the working site chemical, oil-processing carton-ruberoid plants, power-and-electric stations are functioning. On the western part of the region described is situated the village Pavlodarskoe, the inhabitants of which use groundwaters for drinking.

The region in question is situated on the right shore of the River Irtysh. On the territory investigated the aquifer in modern alluvial depositions of the Irtysh river flood plain (aQ_{IV}), aquifer of Upper-Quaternary depositions of the first supra flood plain terrace (aQ_{III}) and the aquiferous complex in Upper-Miocene Lower-Middle-Pliocene depositions of Pavlodar suite ($N_{1-2}pv$) are distributed (Fig. 1). As the first from land surface regional aquiclude are clays of Kalkaman suit of Neogene. Water-holding rocks are presented by sands with interlayers of non-persistent in strike clays, sandy loams, loams. Groundwaters of modern Upper-Quaternary depositions and depositions of Pavlodar suite have a good hydraulic linkage among themselves (Fig. 2).

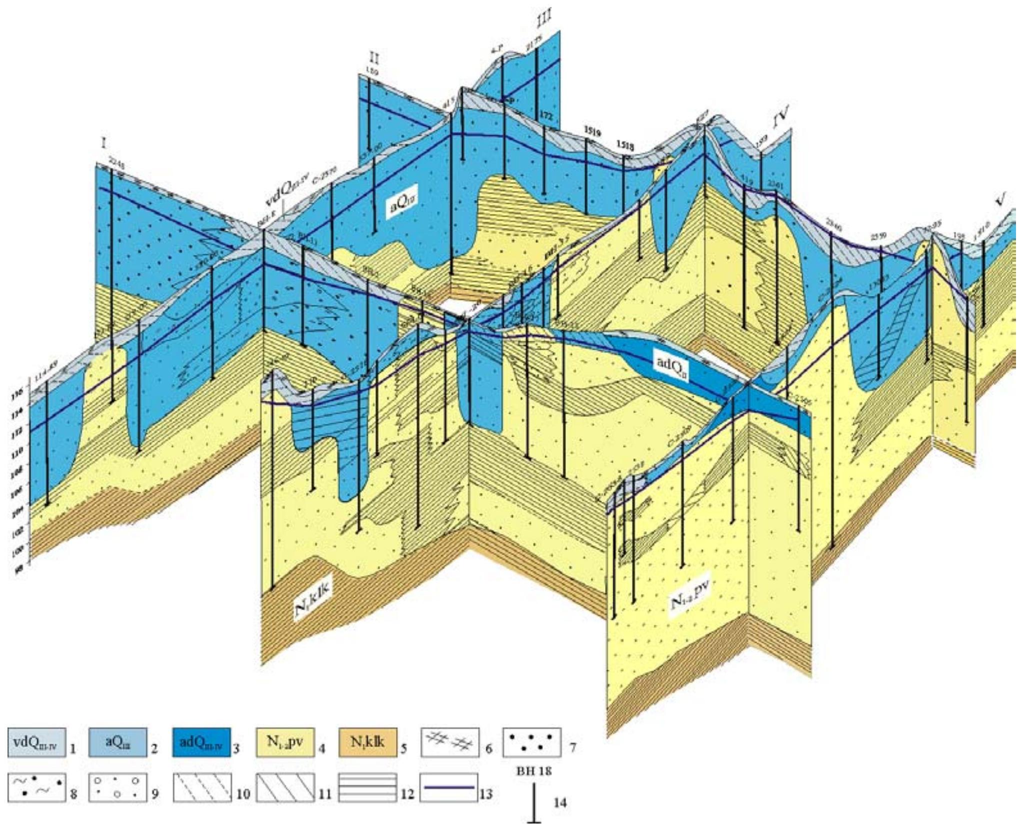
Regional groundwater formation in natural conditions has been made presumably at the expense of atmospheric precipitation infiltration and inflow from outer boundaries. Groundwaters flow, forming at the depositions of Pavlodar suite, was partly discharging into Upper-Quaternary depositions, and then into flood plain which was draining by the Irtysh river. Also groundwaters discharge has taken place into lake basins, by the way of evaporation and outflow through outer boundaries (4, 7).

A considerable influence onto hydrogeological conditions of the region investigated have made technogenic factors – construction of the plants (chemical, oil-processing, et al.), waste waters accumulators – Bylkyldak, Sarymsak, special experimental-industrial storage ponds-evaporators, ash damps from heat and electric power stations, magistral irrigation channel, and irrigation massives et al.



1 – regional model boundary, 2 – local model boundary, 3 – hydrogeological well and its number, 4 – line of hydrogeological section and its number

FIGURE 1. Site of the region investigated



1 - water-permeable practically nonaqueous Upper-Quaternary and Modern depositions; 2 – aquifer in Upper-Quaternary Alluvial depositions; 3 – sporadically flooded Middle-Quaternary Alluvial- Deluvial depositions; 4 – Aquiferous complex in Lower-Middle-Pliocenic, Upper-Miocenic depositions of Pavlodar suite; 5 – Water-resistant rocks in Lower-Middle- Miocenic depositions of Kalkaman suite; Lithological composition of rocks: 6 – soil; 7 – sand; 8 - clayish sand; 9 – gravelly sand; 10 – sandy loam; 11 – loam; 12 – clay; 13 – head surface of groundwaters; 14 – hydrogeological well and its number.

FIGURE 2. Three-dimensional diagram of lithological structure of the region modeled

Pavlodar chemical plant, situated at the distance of 5 km from Irtysh river bed, is the source of groundwaters mercury pollution. It has been at exploitation from 1975 till 1993. Groundwater pollution has been taken place mostly in the result of mercury losses at the caustic soda production department (department No 31), and also because of leakage from communication at the region of pump station, doing the pumping of mercury-containing industrial waters. Groundwaters flow, forming at the ash dump region, goes under the caustic soda production department, is polluted by mercury and transport it in northern-western direction.

In accordance with the data of preliminary observations, losses of mercury at the period of 1975 – 1990 were more than 1000 tons, and this case the greater part (about 1000 tons) proved to be situated under department No 31 (2, 3, 5, 6). Mercury concentration at groundwaters near the department No 31, has reached the value of 12.5-103 mg/cubic decimeter. Maximal admissible concentration of mercury at groundwaters is 0.0005 mg/cubic decimeter. The pollution was distributed to the depth of 20 meters.

MATERIALS AND METHODS

The system of hetero-scaled interconnected mathematical models has been developed with the aim of groundwaters mercury pollution aureole distribution forecast for the estimation of mercury occurrence danger into Irtysh river and wells and pits of the village Pavlodarskoe, and also for the development of measures for risk lowering. The system includes regional and local models (Fig. 1, 3).

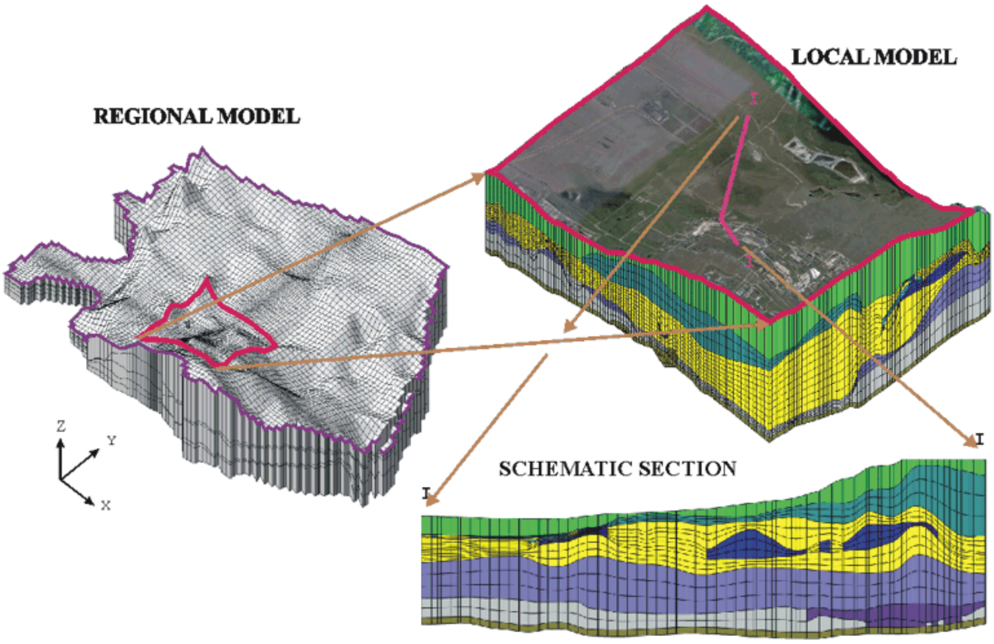


FIGURE 3. Hydrogeological conditions models system structure for the northern part of Pavlodar industrial region.

Regional model. The regional model is intended for groundwaters head level surface position change forecasting, and also for the approximate estimate of change of direction and sizes of mercury pollution aureole. As boundaries of the regional model in plane on west is the Irtysh river, on north – magistral irrigation channel. On east the boundary goes through the chain of lakes. The region modeled in section was represented in the form of five layers with taking into consideration of the peculiarities of its lithological structure. The model takes in consideration the basic regional factors, producing a considerable influence onto the process modeled – imitates groundwaters charging at the expense of infiltration of atmospheric precipitation, waste waters at the regione of ash dump, reproduces charging of the accumulators

Bylkyldak and Sarymsak, water losses from communications. Regional model was developed in the years of 2003 – 2005 with the help of the system GMS 3.1 (1).

It is worth noting that the regional model didn't take into consideration mercury sorption processes by water-containing rocks. Besides this, too rough schematization of the region modeled in section has not allowed with enough degree of precision to reproduce groundwaters mercury pollution transport in vertical direction. Therefore it has been decided to develop the local model on the base of the programming complex GMS 6.0 (2, 3).

Local model. The territory modeled includes the region polluted by mercury and more precise reflects the change of hydrogeological conditions in space and time (Panichkin et al., 2007). Hydrogeological conditions in section are schematized in the form of 19 layers. The local model imitates mercury sorption processes by water-containing rocks. It has been used the supposition that equilibrium among soluble and sorbed phases of mercury establishes momentarily and sorption is irreversible. Therefore for its description we have used the linear isotherm of Henry:

$$\overline{C} = K_d C ,$$

where $\overline{C}$ [MM^{-1}] – sorbed concentration, C [M/L^3] – dissolved concentration, K_d [L^3M^{-1}] – distribution coefficient.

Sorption constant values for sandy and clayish rocks were given from the results of laboratory determinations. Distribution coefficient changes in the boundaries from 0.01 to 0.04 decimetre^3/mg for clayish rocks, and from 0.00001 decimetre^3/mg for inequigranular sands to 0.0015 decimetre^3/mg for clayish and dusty ones. Porosity for clayish rocks was 0.3, for sandy rocks – 0.22. Mercury concentration in the sources was changing from 0.3 to 0.04 [mg/decimetre^3].

Now on the territory of Pavlodar industrial region are already constructed filtration screen around the basic sources of groundwater pollution. They are imitated on the local model as aquifer absence regions.

Interrelation of local and regional models has been made by the way of assigning of the heads as of the boundary of local model. They are calculated by interpolation of hydrodynamic task solution results on the regional model into limiting blocks of the local model.

Calibration of the local model is executed after its formation. Its quality has been estimated as of the degree of its conformity with the existing natural conditions, with taking into consideration of the results, produced on the regional model. The calibration has included into itself the solution of the series of inverse tasks: stationary and transient hydrodynamic tasks, the task of mercury transport by the groundwater flow.

During solution of the inverse stationary hydrodynamic task, position of groundwater heads was reproduced onto conditionally undisturbed period (1970). Surface head level change from 1970 till 2007 was imitated by the solution on the model of the inverse transient hydrodynamic task. Specific yield coefficient was assigned as equal to 0.22. Specific storage of the water-containing rocks was equal to 0.001 [1/m]. Maximal value of groundwaters recharge at the expense of the losses from engineering communications reached 0.002 [m/d]. Inverse task of transport (1975 – 2007) has been solving for the mercury transport process modeling by the groundwater flow in plane and in section. Advective component of substance flow was calculated coming from hydrodynamic task solution.

Coincidence, with reasonable degree of precision, of calculated values of heads and concentrations with values, received at the result of execution of the field and laboratory investigations allows to speak about adequacy of improved local model with the existing natural conditions (Fig. 4 and 5).

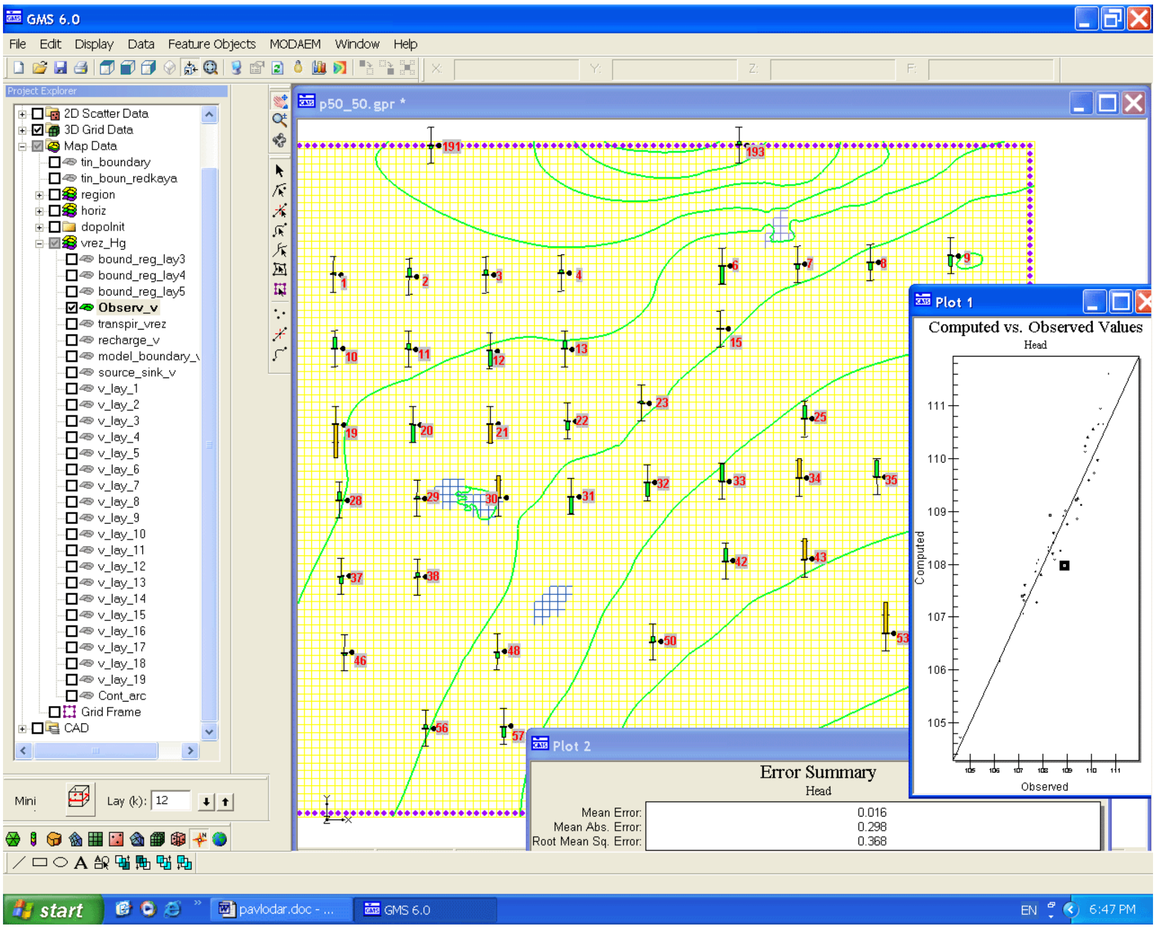


FIGURE 4. Inverse stationary task solution result

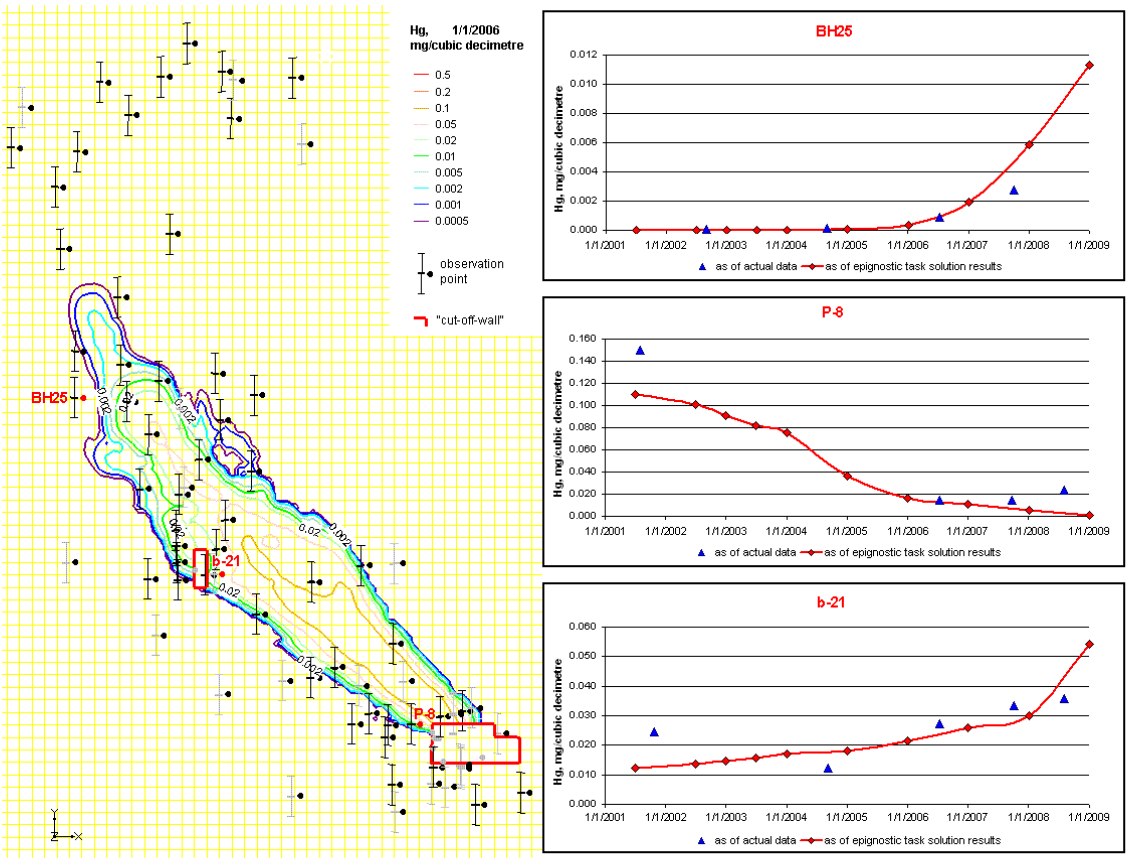


FIGURE 5. Result of the solution of the inverse task of transport

RESULTS AND DISCUSSION

The regional model has taken into consideration the basic factors, producing considerable influence onto the process modeled. It has been used for the rough forecasting of groundwaters mercury pollution aureole distribution direction. It has been made on it four variants of prognosis for the period of 30 years. The first variant presupposed conservation of the existing sources of pollution (under department and at the region of pump station, realized earlier the transport of mercury-containing industrial wastes into accumulator Bylkyldak). The second one – localization of sources under the department, as it has been presupposed by the program as of demercurization of the chemical plant territory. At the boundaries of the third variant has been imitation the elimination of water losses at the region of sewage purification equipment, at the result of which was groundwater flow direction change and, as a consequence – pollution aureole transport direction. Localization of the two basic sources of pollution, situated under the department and in the region of pump station, with the help of the filtration curtain of the type "cut-off-wall", has been reproduced during execution of the fourth variant of prognosis.

Solution of the forecasting tasks of the regional model allows to speak about mercury occurrence danger absence during the nearest decades into Irtysh river and into wells and pits of the village Pavlodarskoe under conservation of the existing hydrogeological conditions. In accordance of the results of the forecasting, isolation of the basic mercury sources will stop further local pollution of groundwaters.

The results of the solution of the forecasting tasks on the regional model has been taken into consideration during planning of demercurization measures. Solution has been adopted about construction of the filtrational curtains of the type "cut-off-wall" around the department No 31 and pump station, produced earlier the transport of mercury-containing wastes. These measures were made during the years of 2003 – 2004.

For the estimation of the effectivity of the measures adopted, the local model has been developed which more precisely takes into consideration lithological structure of the hydrogeological object and the processes of mercury sorption by water-containing rocks. Transport of soluted in groundwaters mercury not only in horizontal but also in the vertical direction has been reproduced on the more precise local model. Task of prognosis of mercury transport by the flow of the groundwaters has been soluting for the period of 30 years (2007 – 2037). It was possible, as of the results of the solution, to conclude that to the end of prognosticated period groundwaters mercury pollution aureole will be preserved, though the great quantity of mercury will be sorbed by clayish rocks (Fig. 6). In the result of groundwaters evaporation from the head level surface, the mercury pollution aureole will rise upstairs through "windows" in clayish layers and mercury consideration in water near groundwaters table will increase. This will give a definite danger of mercury occurrence from groundwaters into soil and accumulation of it in vegetation.

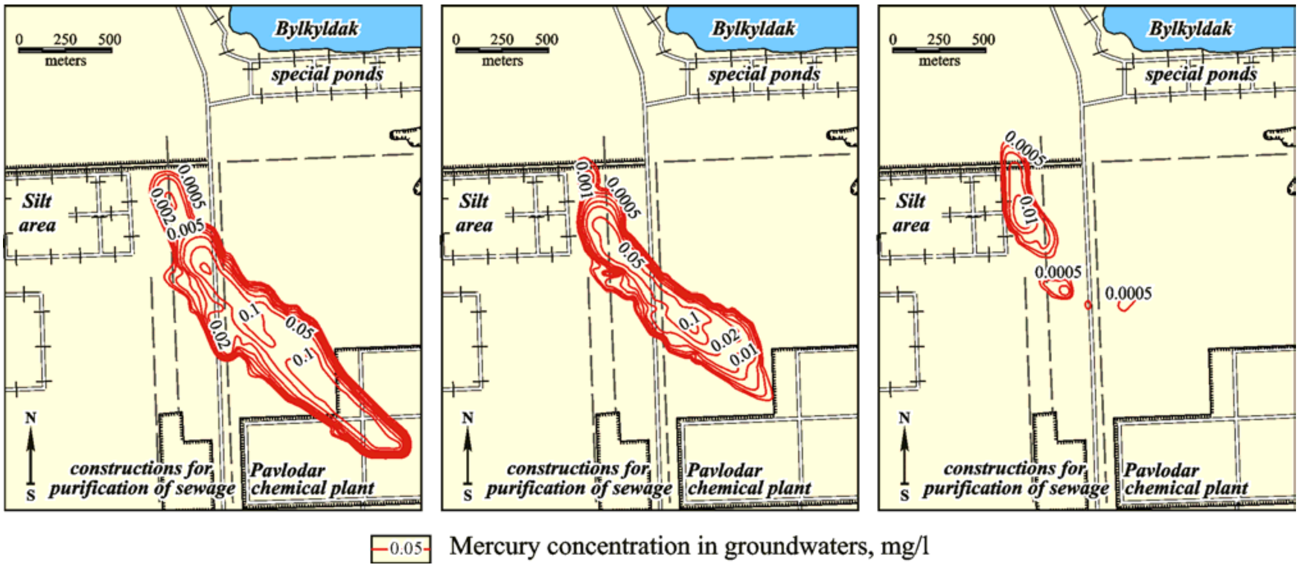


FIGURE 6. Result of the solution of the task of prognosis.

CONCLUSIONS

Utilization of the system of hetero-scaled interconnected mathematical models is a very effective technique during investigation of the territories, subjected to the technogenic pollution of groundwaters. The regional model is used for the producing of preliminary forecasts, the local one – for its more precise determination. This allows more safely to estimate risks and to give more precise recommendations for its minimization.

Now on the territory investigated anthropogenic impact in considerable degree determines hydrogeological conditions. Therefore organization of monitoring and establishment of constantly acting systems of models is a perspective direction of the further investigations. It will allow more operatively to trace the changes of hydrogeological conditions, to forecast further distribution of groundwaters mercury pollution aureole, to estimate effective measures conducted for demercurization.

ACKNOWLEDGMENTS

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PROGNOSIS OF GROUNDWATER MERCURY CONTAMINATION SPREAD WITHIN AN INDUSTRIAL AREA OF "USOL'EKHIMPROM" LTD. (IRKUTSK OBLAST, RUSSIA)

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There is groundwater mercury contamination at the territory of "Usol'ekhimprom" Ltd., Russia. Spread of the groundwater contamination aureole is predicted and risk of mercury ingress to Bratskoe reservoir is assessed using methods of mathematical modeling.

INTRODUCTION

The territory of "Usol'ekhimprom" Ltd. is located between the Belaya River and Bratskoe reservoir constructed on the Angara River at the northern part of an industrial area of Usol'e Sibirskoe town, Russia. Since 1973 after a workshop of caustic soda and chlorine production putting into operation groundwater pollution with mercury has occurred due to a number of reasons (accidents, losses of the process solution containing mercury and so on). According to researches /1, 2/ about 510 tons of metallic mercury was found to be accumulated in clay rocks 10 m deep under an electrolysis factory.

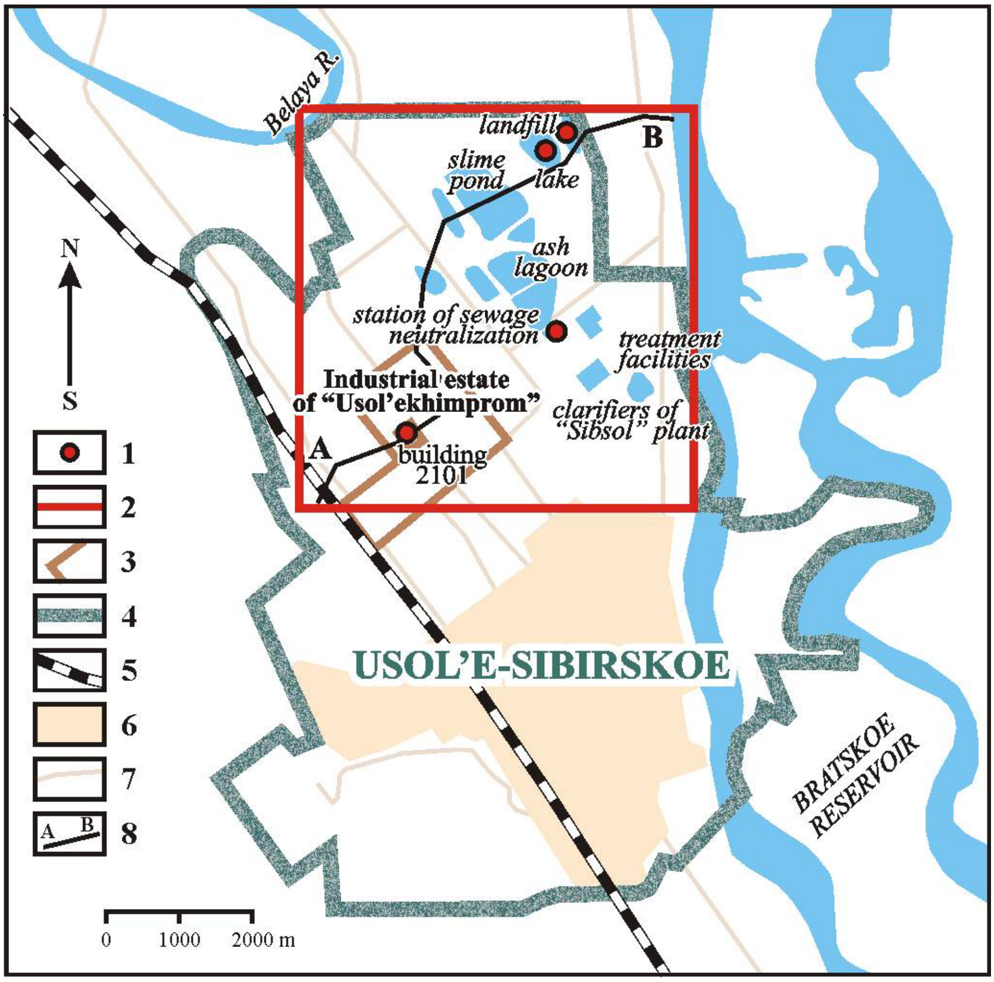
Computer simulation was conducted with a view to predict groundwater mercury contamination aureole spread for justification of designing monitoring network at the industrial area of Usol'e Sibirskoe town, Russia.

MATERIALS AND METHODS

The building #2101, a wastewater neutralization station, a landfill for industrial wastes as well as a lake located at a distance of 100-150 m to south-west from it where sewerage from a sludge lagoon goes to are supposed to be main sources of the groundwater mercury contamination. They are situated 1.7-4 km far from the Angara River left bank (fig.1). Mercury concentration in the groundwater ranges from a few ng/L to 100 ng/L, the highest concentration was found in the vicinity of the landfill for industrial wastes /3/.

There are following main aquifers and aquiferous complexes at the territory surveyed: an aquifer of Middle-Upper Quaternary alluvial depositions (aQ_{II-III}); an aquifer of Neogene-Quaternary lacustrine-alluvial depositions (alN_2-Q_I); an aquiferous complex of Lower-Jurassic depositions (J_1cr); and an aquiferous complex of Lower-Cambrian depositions of Angarskaya suite ($Є_1an$). The groundwater recharge comes predominantly from infiltration of atmospheric precipitation as well as from losses of technical water from engineering works – ash lagoon of a heat power plant, the sludge lagoon, sewage system etc., as well as from its inflow on outer boundaries of the area simulated (mainly from the south-west). Groundwater discharge occurs to Angara and Belaya rivers by a way of evaporation from the groundwater surface as well as of its outflow on the outer boundaries of the area simulated (mainly to the north).

The east boundary of the area surveyed goes along the Angara River, the north-west one – along the Belaya River. At the model they are schematized as boundary conditions of III type. The other outer boundaries are schematized as boundary conditions of I type. The area simulated in horizontal projection is approximated with irregular orthogonal grid, size of which ranges from 50 m in places where the main sources of groundwater mercury contamination are located to 100 m in peripheral parts of the area. At the model hydro-geological conditions in section were schematized as eight layers. The fig.2 illustrates the schematization principle.



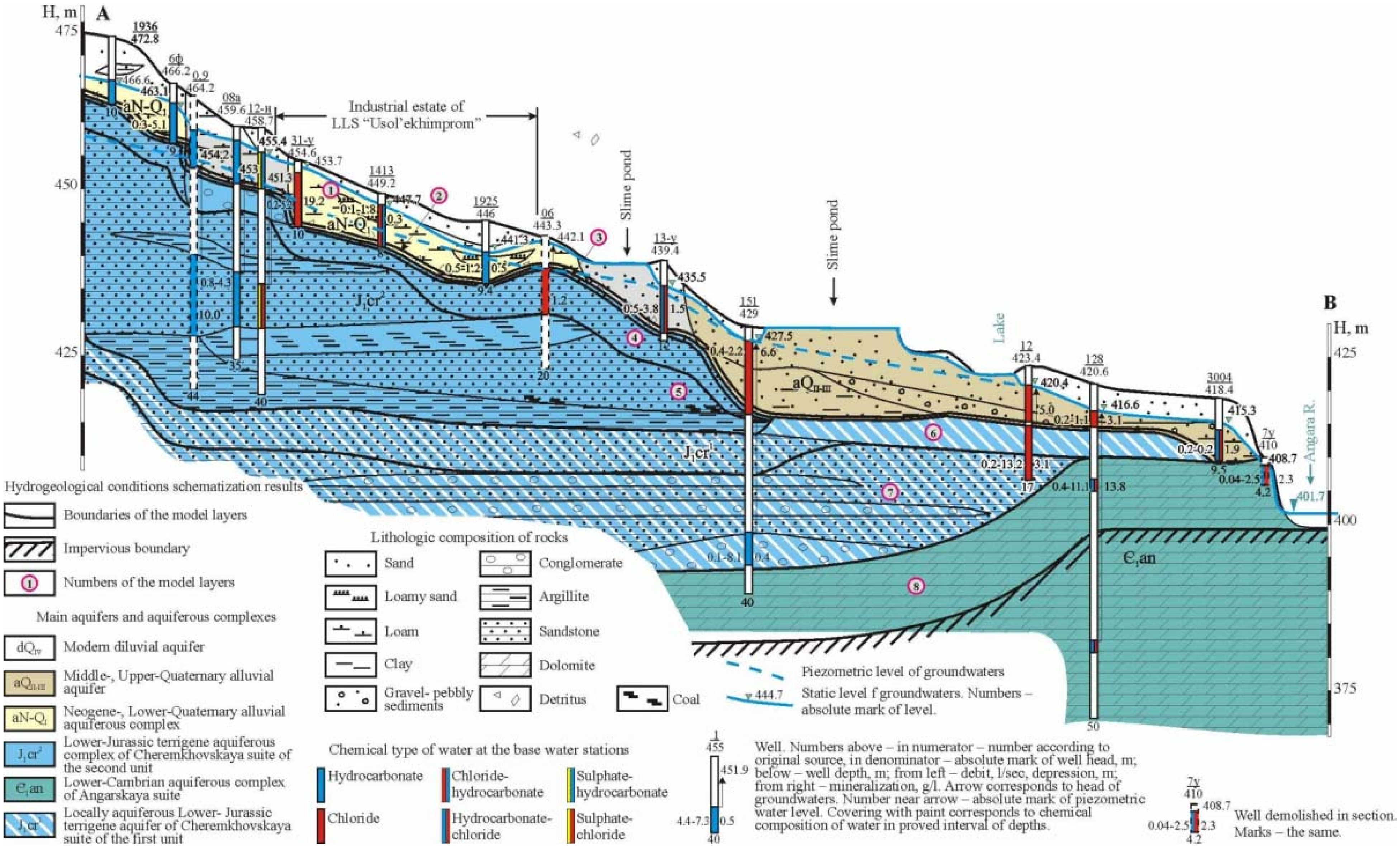
1 – basic sources of groundwater mercury pollution, 2 – boundary of investigating area,
3 – boundary of industrial area of LLS "Usol'ekhimprom", 4 – boundary of the city of Usol'e-Sibirskoe,
5 – railway, 6 – residential area, 7 – automobile roads, 8 – line of hydrogeological section

Figure 1. General map of the area surveyed

At the model aquifer in Cainozoic depositions are schematized as a slightly permeable layer in the upper part of the section (layer #1) and permeable one (layer#2) in its lower part. Upper part of a roof of pre-Cainozoic rocks is represented with alluvial loams and clays 0.5-2 m thick. At the model it is schematized as a slightly permeable layer (layer #3). Water-bearing stratum of Jurassic depositions is schematized as two water-permeable layers (layers #4 and #6) corresponding to aquifers of the second ***(J_1cr^2)*** and the first ***(J_1cr)***geological unit of Cheremhovskaya suite of Lias. The horizons are divided with a thickness of slightly permeable depositions schematized at the model as a layer #5.

At the model aquifer in depositions of lower sub-suite of Angarskaya suite is schematized as water-permeable layer #8 interacting with overlaying aquifer belonged to the first geological unit ***(J_1cr^1)*** of Cheremhovskaya suite via slightly permeable layer #7. The aquifer in depositions of lower sub-suite of Angarskaya suite was considered to be underlain with the regional basalt clay stratum that is why at the model subface of the horizon was schematized as impervious boundary (fig.2).

The mathematical model simulates three-dimensional convective transfer of mercury with groundwater flow without taking into consideration sorption with water-bearing rocks. Using the model two scenarios of the aureole spread were forecasted for 50 years. The first scenario allows for persistence of all main sources of the contamination; the second one – their complete insulation from the environment. The simulation was conducted using software GMS 6.0 /4/.

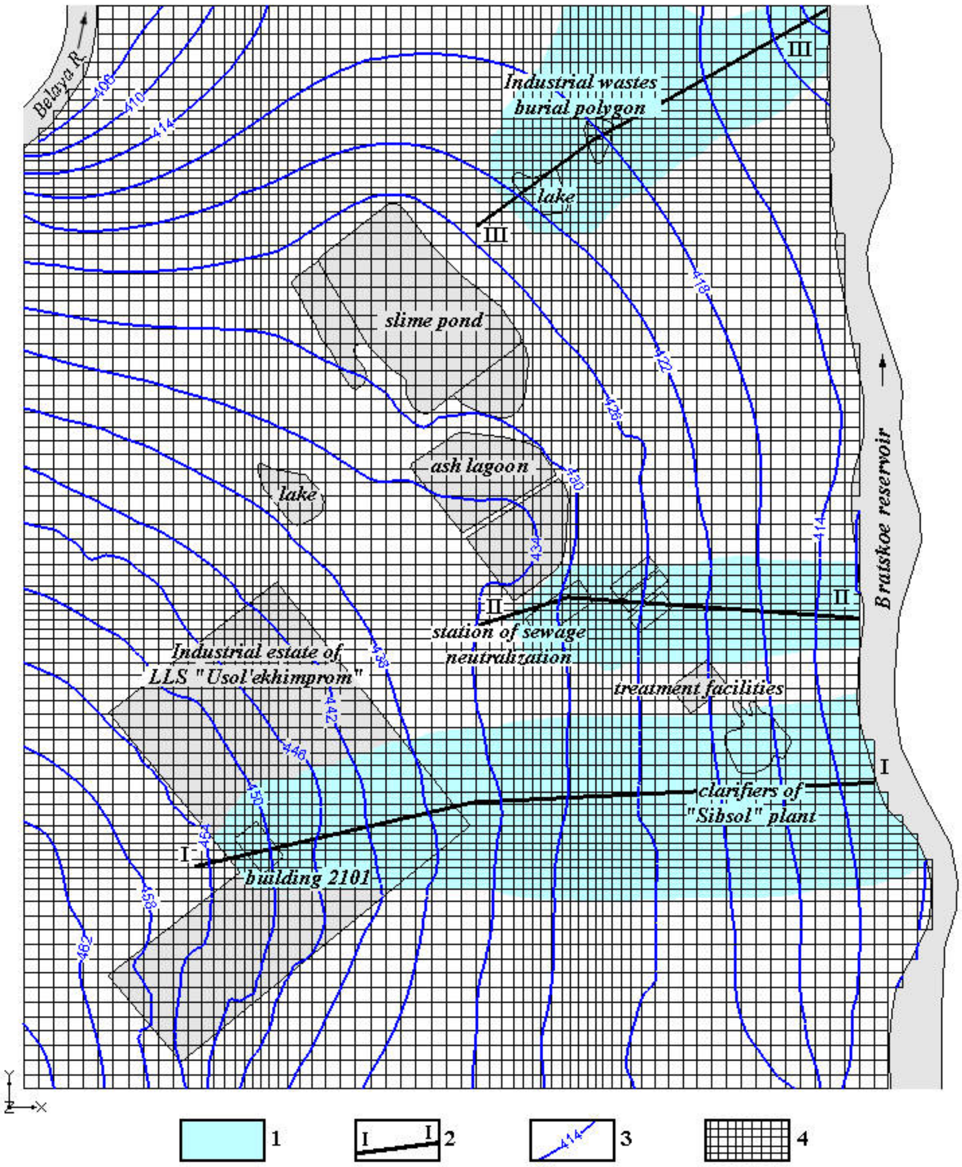


.**Figure 2.** Hydrogeological conditions schematization in section.

CONCLUSIONS

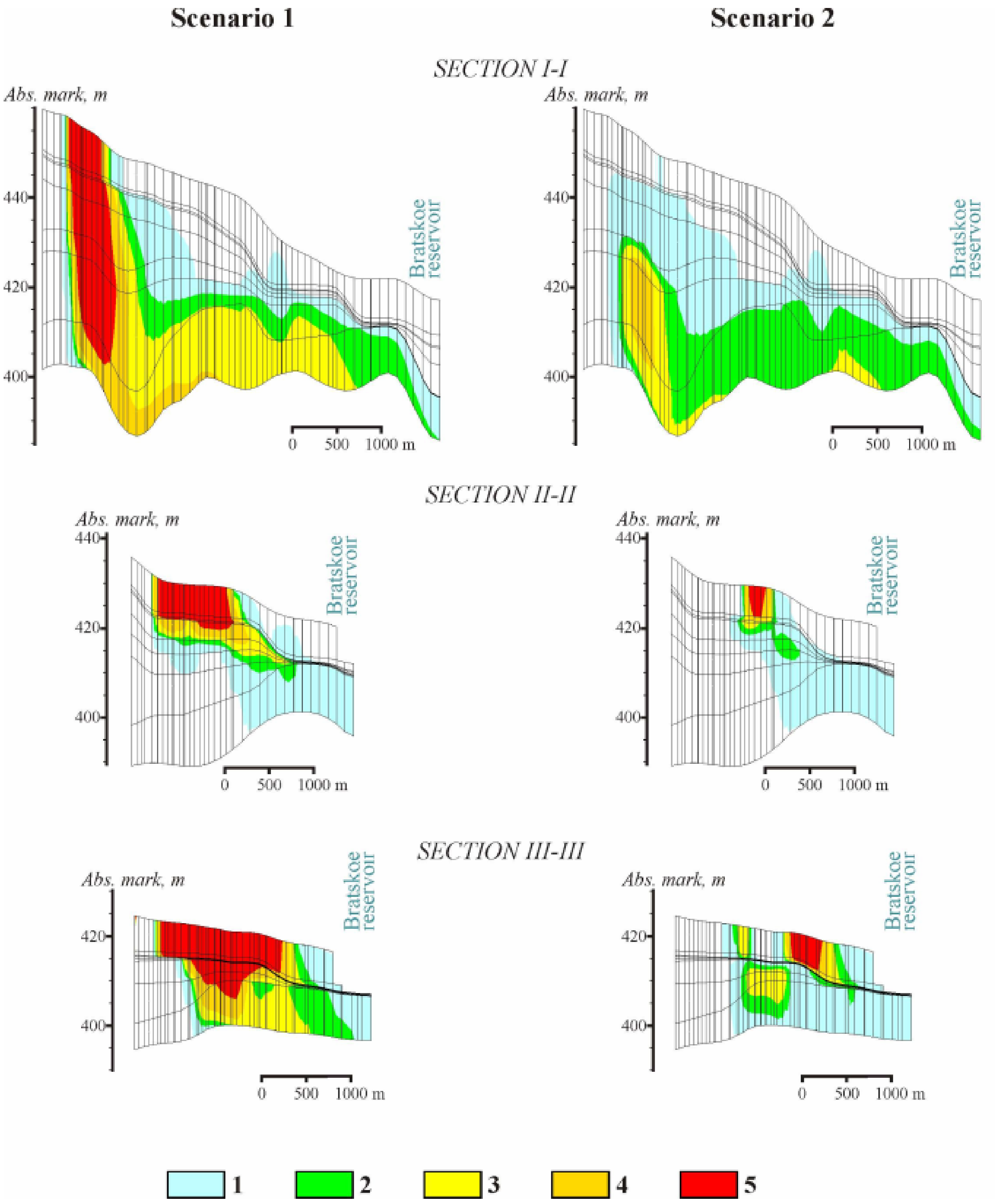
According to the first scenario of the forecast the aureoles of mercury contamination will spread along the direction of the groundwater flow movement to the east-north-east. The aureoles of mercury contamination at the area of the wastewater neutralization station, the landfill for industrial wastes, and the building #2101 are expected to reach the Angara River by the years 2008, 2013 and 2026 respectively. By the end of the forecasted period mercury concentration in the groundwater close to the river will not exceed 0.0005 mg/L. According to the second scenario of the forecast the aureoles will decrease slightly in size in horizontal projection only in the immediate vicinity of the sources of contamination in comparison with the first scenario. Thus insulation of the sources of contamination is supposed not to improve substantially the groundwater quality. Considerable mercury ingress to the Angara River with the groundwater flow is not expected (fig. 3, 4).

It is important to notice that in order to prove (or deny) the results obtained it is necessary to arrange monitoring observation within the expected aureoles of groundwater mercury contamination that requires drilling new observation boreholes near the main sources of groundwater mercury contamination filters of which should be set in Cainozoic, Jurassic, Cambrian aquifers.



1- Projection of aureole of groundwater contamination onto day surface. Mercury concentration on outer boundary of 0.00001 mg/L. 2- the section line; 3- hydroisohypses; 4- grid approximation of the area simulated.

Figure 3. Prognostic map of groundwater mercury contamination as of the state for 01.01.2058 (the first scenario)



Mercury concentration in groundwater at the section, mg/L: 1- from 0.00001 to 0.0005; 2 - from 0.0005 to 0.001; 3 - from 0.001 to 0.002; 4 - from 0.002 to 0.005; 5 - more than 0.005.

Figure 4. Scheme of aureole of groundwater mercury contamination spread in section. Forecast as of 2058.

The work on risk assessment of groundwater contamination with mercury at the territory of "Usol'ekhimprom" Ltd. was funded by "Usol'ekhimprom" Ltd.

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MERCURY RISK ASSESSMENT FROM A WASTEWATER STORAGE POND IN PAVLODAR CITY, NORTHERN KAZAKHSTAN

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A wastewater storage pond located in the Northern Industrial Area of the city of Pavlodar was constructed at the place of the natural saline Lake Balkyldak 5 km far to the east from the Irtysh River floodplain. The storage pond capacity is 74 millions m^3; water-surface area – 18 km^2, and evaporation efficiency – 11.4 millions m^3 per year at a critical level mark of 110.8 m. Maximal depth of the storage pond is 10 m. The storage pond operation has been started since 1971 without construction of any environmental protective objects there. At present the pond has been confined from two sides (west and east ones) with two protective solid earth-fill dams 8425 m long and from three side (west, north and east ones) – with clay impervious barrier so called cut-off wall 10 557 m long, 0.6 m wide and 2.5 – 6.0 m deep reaching the basalt clay layer. According to balance calculation more than 10 tons of mercury have been released to the storage pond together with wastewater of Pavlodar PO “Khimprom” running chlor-alkali production with mercury electrolysis in 1975-1993.

Figure 1. *Wastewater storage pond Balkyldak south shore*

After the plant decommissioning in 1995 only about 1 million m^3 of wastewater per year are discharged to the storage pond however its level does not drop lower than 110.0 m mark. The water body is recharged by groundwater fed in turn by an ash lagoon of two heat power plants located 2 km far to the south from the lagoon. Offshore strip of the storage pond is covered with reeds with the area of 2.6 km^2 (fig.1). Several species of non predatory fish (generally silver crucian carp) inhabit the storage pond, which are the objects of intensive sport fishing for humans living in Pavlodar city outskirt despite danger warning and prohibitions.

Figure 2. *Bottom sediment sampling from the depth of 9 m.*
Wastewater storage pond Balkyldak, March 2006

The researches (Fig.2) of 2000-2008 allowed producing a map of the storage pond bottom sediments mercury contamination (maximal mercury concentration is 1 g/kg), calculating amount of mercury there (135.3 tons), determining aquatic organisms mercury contamination level (mercury concentration in fish is up to 2.5 mg/kg), finding dependence of spread of technogenic sediments across the bottom of this not deep water body on waving activity on its surface as well as dependence of mercury content in surface water (maximal total mercury concentration in water is 350 ng/L and maximal dissolved mercury concentration - 10 ng/L) on amount of suspended solids there. Also a map of soil mercury contamination within the territory between the storage pond and the plant has been produced. Within the framework of demercurization of the former chlor-alkali production the containment of mercury sludge lagoons located on the shore of the wastewater storage pond has been conducted.

In case of dredging, capping or at least consolidation of mercury contaminated bottom sediments of the storage pond it can be used as a source of clean fresh technical water (for example for the heat power plant or metallurgical works located in the vicinity). With a view to health risk minimization for communities living in the vicinity of the wastewater storage pond the issue of possibility of destruction of mercury contaminated fish inhabiting the technical water body using some ichthyological poisons is being discussed.

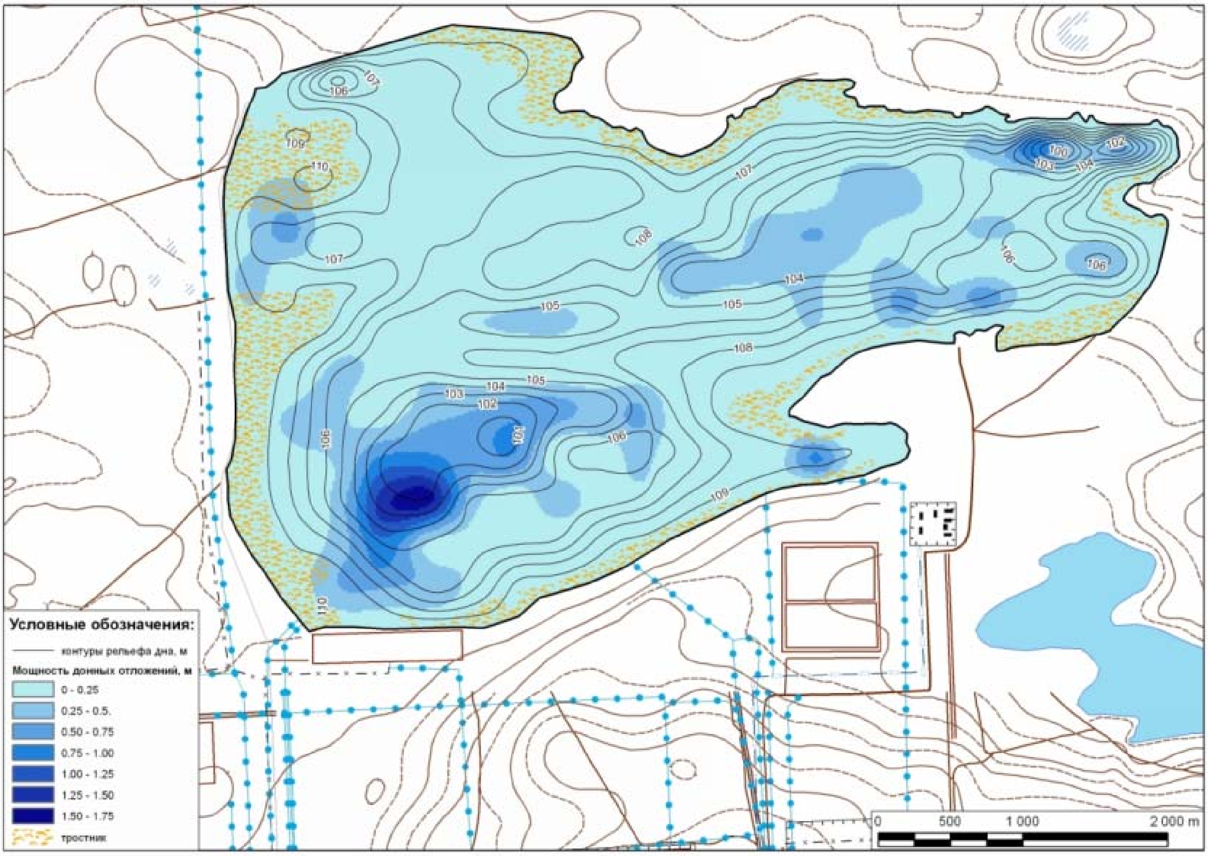

Figure 3. *Wastewater storage pond Balkyldak bathymetric map and bottom sediments thickness*

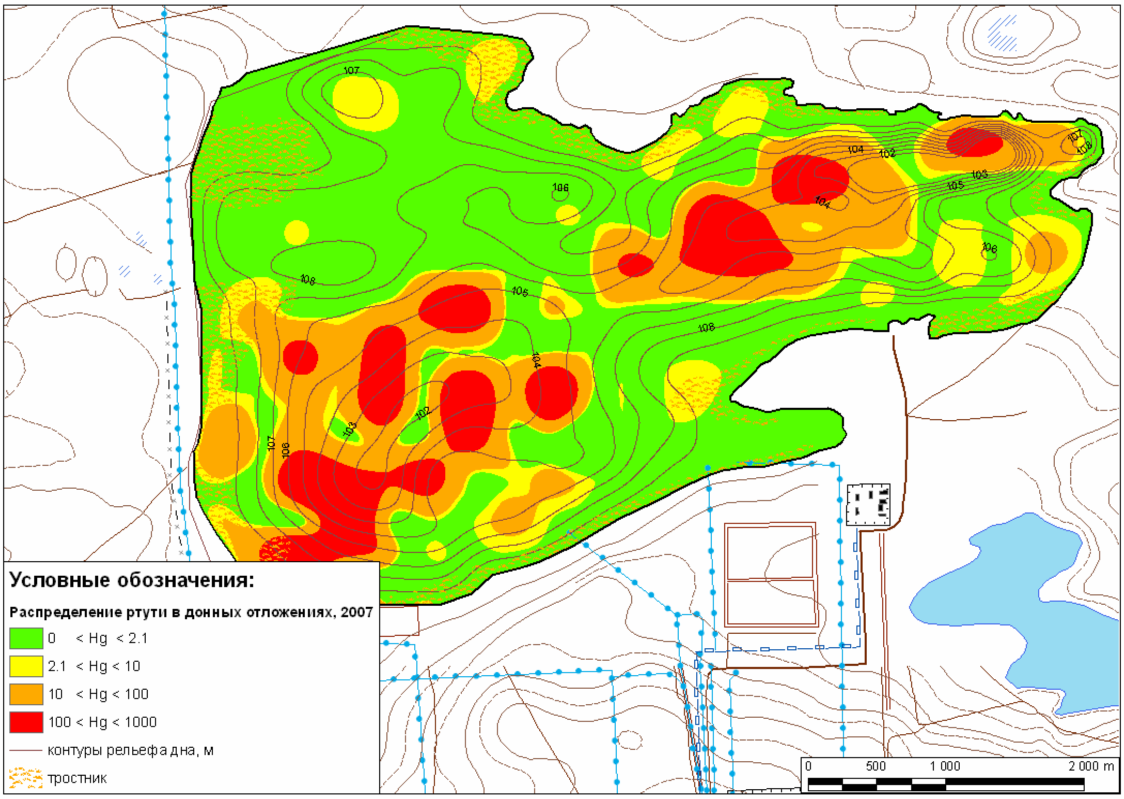

Figure 4. *Wastewater storage pond Balkyldak bottom sediments*

ACKNOWLEDGEMENTS

The work was financially supported by International Science and Technology Center (ISTC project # K-1240p).

MERCURY POLLUTION WITHIN AN INDUSTRIAL AREA OF KIEV CITY, UKRAINE AND PROGRESS OF JSC "RADICAL" TERRITORY CLEANUP

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Groundwater mercury pollution on the territory of the city of Kiev has taken place in the result of the accident on JSC "Radikal". It has been forecasted, by the methods of mathematical forecasting, the distribution of pollution aureole. On the base of results analysis estimation of danger for environment has been given.

INTRODUCTION

JSC "Radikal" in Kiev has been producing chlorine and alkali by the way of electrolysis with mercury cathode from 1954 till 1996. Calculated value of mercury losses has been more than 700 tons. Industrial constructions and soils polluted with mercury, are the source of the secondary pollution of air, underground and surface waters.

The plant is situated on the left shore of the river Dnepr in city territory at the boundaries of the first supraplain terrace. The distance to Dnepr is 4.5 km. From south and east the territory of the plant is bordered by the technological channel (streamlet of Plyakhovy), having water discharge about 0.2 m^3/sec and inflowing further into Dnepr. At the boundaries of the zone of 2 km from source of mercury pollution are exploited at least 8 water intaking wells.

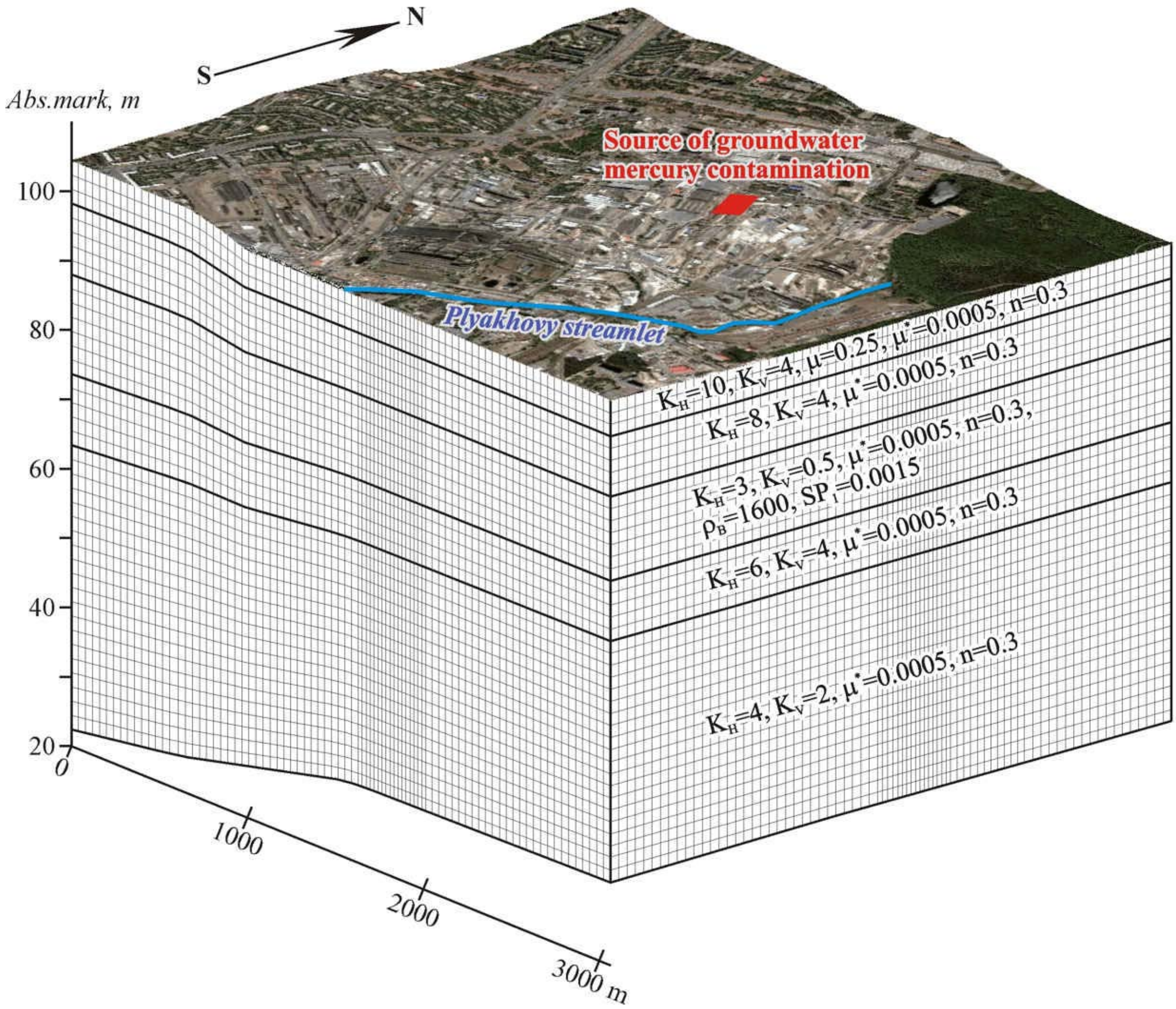
At the region of JSC "Radikal" the first from surface aquifer has capacity of more than 60 m and is underlying by marls and clays with depth of 12-20 m. Its feeding is made at the expense of atmospheric precipitation and leaks from underground communications. Groundwaters discharge is made, basically, into river Dnepr. Groundwaters aureole area, polluted by total mercury, higher than sanitary standards (500 mg/l) is more than 1.5 km^2 (2,3). The aim of modeling has been groundwaters mercury pollution aureole distribution forecasting for projecting of monitoring net. System of modeling of GMS, USA (1) has been used.

MATERIALS AND METHODS

The modeling has been made in several stages: initial data preparation with use of GIS MapInfo, FoxPro database, hydrogeological conditions schematization and putting of task, creation of the model by means of GMS, model calibration, solution of the two prognostic tasks with the period of 50 years, results analysis.

Boundary conditions of the first type with changing in time levels of groundwaters for outer borders of the model has been given. Streamlet Plyakhovy was schematized by boundary conditions of the third type. The area modeled in plan was approximated by rectangular net, the size of which was M*N=85*77 nodes. The step of the net was changing from 20 m near pollution source and to 40 m on periphery of the model. In section the area modeled was schematized in the form of 5 layers with various filtrational and migrational parameters with taking into consideration of the peculiarities of lithologic structure of area modeled. The number of steps in vertical direction was 40 (Fig. 1).

Groundwaters feeding in natural arbitrarily undisturbed conditions (up to 1954) has taken place at the expense of atmospheric precipitation infiltration and inflowing by outer boundaries. Discharge has been made by the way of outflowing through outer boundaries and into streamlet Plyakhovy. Beginning from the year of 1954, after starting of exploitation of the plant "Radikal", in the result of losses from communications, has appeared an additional source of replenishment of groundwaters resources, schematized on the model as an additional area feeding. From 1996 after stopping the plant additional feeding on the model has been executed. It has been supposed that beginning from the year of 1954 in the result of various reasons (accidents, losses of technological solutions containing mercury a.s.o.) groundwaters mercury pollution begins. On the model it has been schematized in the form of area with the given mercury concentration in groundwater. It has been supposed that mercury concentration at the source, beginning from 1954 till 1962, has been 3 mg/l, then during 25 years it has been held on the level of 2 mg/l, and from 1996, in connection with production stopping, it has been equal to 1 mg/l.

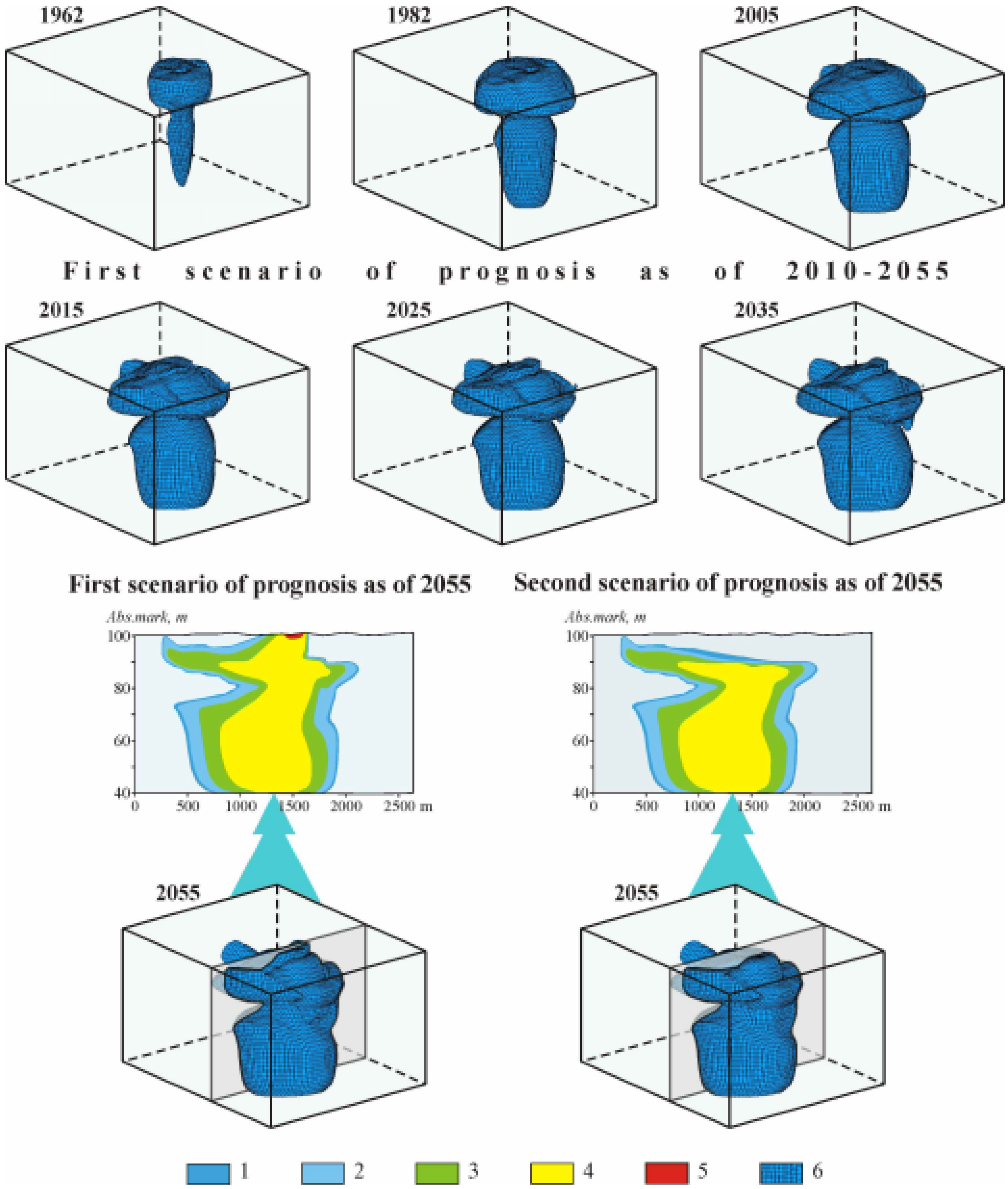


K_H – horizontal hydraulic conductivity, m/day; K_V – vertical hydraulic conductivity, m/day; μ - specific yield, nondimensional quantity; μ^* – specific storage, 1/м; n – porosity, nondimensional quantity; ρ_B – bulk density, kg/m^3; SP_1 – 1st sorption constant, nondimensional quantity

FIGURE 1. Schematization of modeled area

At 2002 mercury concentration at the source has been given as of actual data. Mercury concentration for the initial moment of modeling (year of 1953) has been selected at the process of the model calibration. It has been considered that the source of mercury had been situated at the upper part of the section, near groundwaters surface. The model has imitated a collective transfer of mercury. It has been supposed that at the third from soil surface, consisting in the greater part from dusty sands, the process of mercury sorbtion has taken place. Value of sorbtion constant has been fitted at the model calibration process.

Results of the modeling allow to make a conclusion that because of water losses out of engineering communications at the region of JSC "Radikal" flow of groundwaters polluted with mercury was directed vertically down and has reached the first from surface regional confining bed. Dissipation of this flow and groundwaters circulation had formed pollution aureole, distribution of which in southern and eastern directions was limited by the streamlet Plyakhovy. Two variants of prognostic tasks for the period of 50 years have been solved on the calibrated model. The first variant of prognosis has presupposed the pollution source conservation under decrease of technological losses of water. It has been considered that mercury concentration at the source was remained at the level of the year 2002, i.e. of the order of 1 mg/l. The second variant has supposed the complete localization of pollution source (Fig. 2).



Groundwater mercury content, mg/dm^3: 1 – 0.0005 – 0.001; 2 – 0.001 – 0.01; 3 – 0.01 – 0.1; 4 – 0.1 – 1; 5 – > 1.
6 – isosurface corresponding to the mercury concentration of 0.0005 mg/dm^3

FIGURE 2. Results of simulation of groundwater mercury contamination

CONCLUSIONS

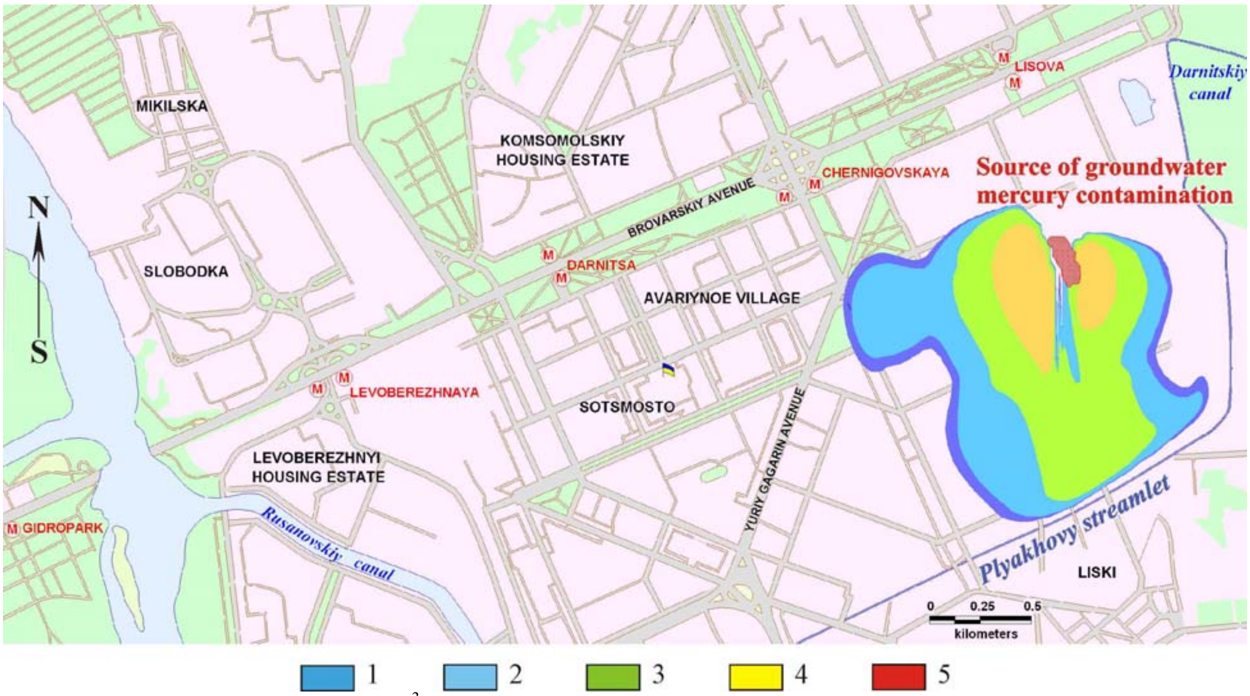
In accordance with data of modeling the pollution had distributed up to the depth of 60 m, i.e. on the whole capacity of the aquifer (Fig. 2). Taking into consideration comparatively simple hydrogeological conditions, we have limited themselves by development of one model imitating convecting transport of mercury by groundwaters with taking into consideration of sorbtion by water-bearing rocks.

Both variants forecast the decrease of pollution aureole area and migration in the western direction for 250-300 m. Aureole decrease as of the first variant of prognosis is connected basically with shutoff of groundwaters feeding source at the area of the plant. As of the second variant, presupposing the complete localization of the source at the upper part of the section, the upper boundary of the aureole would go down to the depth of 4-6 m. This is connected with localization of groundwaters mercury pollution of the source.

From the results of modeling it is possible to conclude, that a direct hazard of mercury pollution for the river Dnepr is absent (Fig. 3).Certain anxieties have evoked the forecasted discharge of groundwater polluted with mercury into streamlet Plyakhovy. But balance calculations executed have shown that this did not lead to the surface waters pollution up to the level more than sanitary standards.

It is necessary to take into consideration that even at the case of the complete localization of the source for mercury pollution the mercury in groundwaters can stay for a long time.

Therefore it is necessary to categorically prohibit the utilization of groundwaters of Upper Quaternary and Eocene depositions for the aims of economical-drinking water supply at the boundaries of distribution of forecasted aureole of mercury pollution and also in the area of two km around it. Groundwaters taken in this area from Upper Quaternary and Eocene depositions for technical purposes, can have mercury concentration above MPC. Their utilization, for example, for irrigation of plants would lead to the soil pollution.



Groundwater mercury content, mg/dm^3: 1 – 0.0005 – 0.001; 2 – 0.001 – 0.01; 3 – 0.01 – 0.1; 4 – 0.1 – 1; 5 – > 1.

FIGURE 3. Schematic map of groundwater mercury contamination based on the results of simulation as of 2055

During the years of 2003-2008 JSC "Radikal" industrial area demercurization concept has been developed; technical solutions as of its realization and technical-economical grounds, providing demontage of polluted by mercury surface building constructions, floors and their shipment to LLS "Nikitrtut'" for processing or burial together with mercury-containing wastes and also with soils, polluted with mercury above sanitary standards. Sites from which removal of soils has been made, would be filled by pure clay-containing materials. It had been also provided development of the system of after-demercurizational mercury monitoring. Now problem of source of funding for the offered work is at the process of solution.

The work as of estimation of the groundwaters mercury pollution danger on the territory of JSC "Radikal" by the methods of mathematical modeling have been funded by JV "Evrohim", Kiev, Ukraine.

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BIOFACIES ROLE OF PLANKTON AS NATURAL REMEDIATION MECHANISM OF HIGH-MINERALIZATION WATER CONTAMINATED WITH MERCURY (by the example of the Bolshoe Yarovoe lake, Altay Territory, Russia)

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Abstract – A complex of analytical methods (atomic absorption spectroscopy AAS, synchrotron radiation X-ray fluorescence SR-XRF, and instrumental neutron activation analysis INAA) were used to conduct for analyses of 40 trace elements. In compliance with the conventional biogeochemical methods, enrichment factors EF were calculated for plankton relative to the average concentrations of elements in continental clay (shale) preliminarily normalized to Sc. In order to understand the concentration specifics of trace elements in living organisms inhabiting aquatic ecosystems of variable salt composition and geochemical characteristics, chemical speciation of elements was calculated for the brines of salt lakes by the WATERQ4F (3) and Selektor-S (4) computer programs. The enrichment of plankton in Hg in Lake Bol'shoe Yarovoe is caused not only by the chemistry of the mineralized brine (bittern), as follows from the Hg speciation in it, but also by anthropogenic contamination (Hg-bearing wastes from the Altaikhimprom chemical plants in the town of Yarovoe).

INTRODUCTION. Biogeochemical studies in 1998-2003 indicate that the Altaikhimprom plant situated on the bank of this lake is responsible for ecologically unfavorable conditions within the influence zone of the plant in the lake (5–7, 9). This plant is one of the most active producer of chemicals (including Hg oxide) in Russia (11). Near the plant, the township of Yarovoe houses one of Russia's unique physiotherapeutic mud baths, which was established with the use of the mud produced in the lake with the participation of the dying brine shrimp Artemia salina. In this context, it is particularly important to evaluate the impact of wastes from the chemical plant on the ecosystem of the lake. Its biogeochemical sampling was carried out at five sites, some of which were situated within the near influence zone of the plant (sites 2 and 3) and others located at various distances from the contamination source (Fig. 1). We also sampled the solid wastes accumulators and the holding ponds for sewage in the sanitary protection zone of the plant considering them as the as the potential point sources of Hg contamination in the lake.

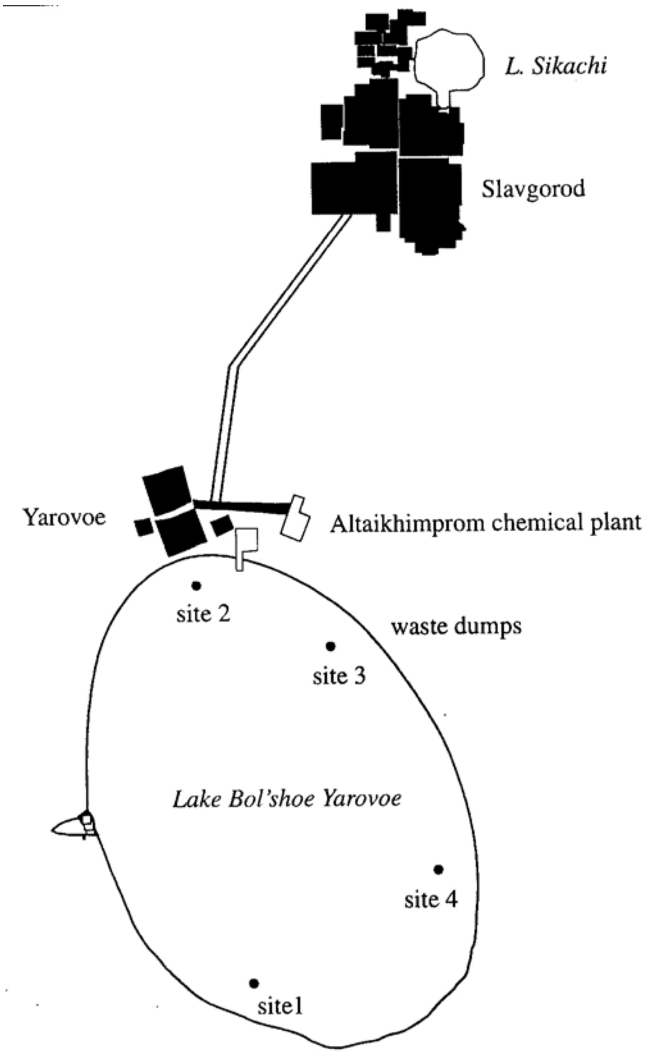

Fig. 1. Monitoring sites at Lake Bol'shoe Yarovoe.

MATERIALS AND METHODS. Salt lakes in Altai krai have long been used as sources of nonore minerals (mirabilite, gypsum, soda and halite). Sanatoria and spa resorts were constructed at the salt lakes of the Kulundinskaya steppe, which contain specific bottom deposits: medicinal ooze or mud, whose resources and reserves in the area are quite significant. The valuable medicinal materials can be produced on lakes Bol'shoe and Maloe Yarovoe, and others.

Lake Bol'shoe Yarovoe fills a deep (~25 m) depression and has neither river feeding nor outlet. The major component of the natural water budget of the lake is the spring runoff from the catchment area, outlets of groundwaters, and summer and winter atmospheric precipitates; the only water outlet if its evaporation. Its bottom deposits have a thickness of 0.6-1.5 m and consist of ooze.

Lake Maloe Yarovoe fills a deep geometrically shaped rounded depression and has no outlet. The floor of the lake is sandy, with the thickness of the ooze deposits reaching 0.1-0.2 m.

According to Alekin's classification (1), the waters of the lakes studied in the Kulundinskii steppe were ascribed to the chloride class, Na group, type III ($Cl^- \geq Na^{+)}$. The predominant major ions are Cl^- and Na^+. The overall salt concentrations in the brines (mineralization) increase in the following succession of lakes: Bol'shoe Yarovoe and Maloe Yarovoe from to 133 and 262 g/l.

In assaying the ecological state and conditions of the lakes, we used conventionally adopted geochemical criteria (12, 14), which enabled us to evaluate the anthropogenic pollution of the lacustrine ecosystems with heavy metals.

The *concentration coefficient Kc* was applied as a measure of the level of anomalous concentrations of certain elements in the bottom sediments and biological matter. The

concentration coefficient was calculated as the ratio of the concentration of element i in the material C_i to the average background concentration of this element C_b:
$K_c = (C_i)/(C_b)$,

where C_i is the concentration of chemical element i in the contaminated zone, and C_b is the background concentration of this element.

The *integral contamination indicator Z_c* characterizes the effect of a group of elements and can be used when a polyelemental anthropogenic or natural anomaly is examined
$Z_c = \Sigma K_c - (n - 1)$,
where K_c is the concentration coefficient (>1), and n is the number of elements with Kc > 1.

The *geochemical association formula GAF* was employed to characterize the qualitative (elemental) composition of a geochemical anomaly within the influence zone of an individual source of anthropogenic contamination. GAF is a set of chemical elements ranked according to their K_c values, with these values K_c of no less than 1.5, i.e., elements with concentrations higher than 1.5 background values. The elements of a geochemical association are grouped according to the K_c values, with the boundaries of the ranges roughly corresponding to logarithmic scale with a step of 0.5 units, i.e., 0.5, 1.5–3, 3–10, 10–30, 30–100 etc., as can be seen when various objects are compared.

The *enrichment factors EF* of mesoplankton and bottom deposits from the lakes were calculated with the preliminary normalizing of the concentrations of all elements to the average concentration of Sc, a geochemically inert rare-earth element, and to the analogous average ratio in shales (according to (10), in compliance with the approach (2, 8), by the formula (13):
$EF = (x_i/x_{Sc})_{sample}/(x_i/x_{Sc})_{shale}$,
where $(x_i)_{sample}$ is the concentration of element i in the sample, x_{Sc} is the Sc concentration in the sample, $x_{i\ shale}$ is the concentration of element i in the shale, and $x_{Sc\ shale}$ is the Sc concentration in shale.

REZULTS AND DISCUSSION. The Hg concentrations of mesoplankton from lake Bol'shoe Yarovoe within the influence zone of the plant (site 3) are 5 to 10 times higher than those in mesoplankton from the "background" part of the lake (site 1) and in that from lakes Maloe Yarovoe (Fig. 2), which clearly highlights the anthropogenic sources of high Hg concentrations in the mesoplankton of Lake Bol'shoe Yarovoe (Fig. 3).

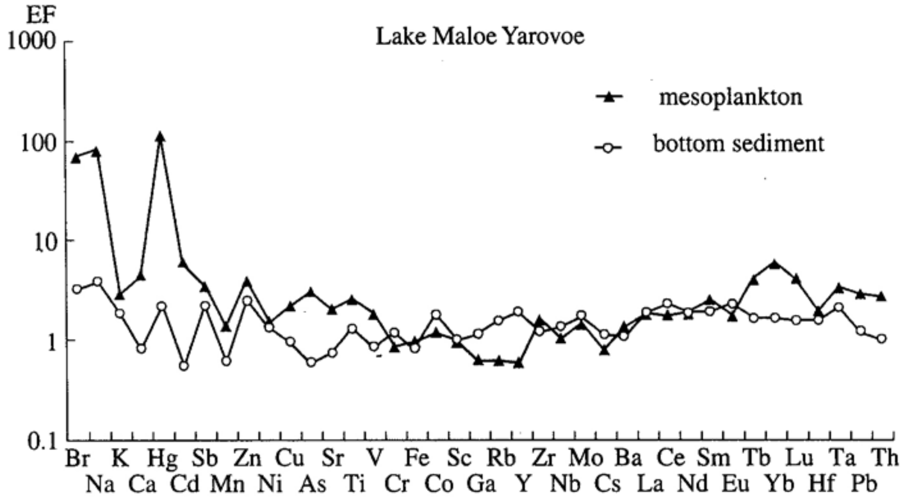

Fig. 2. Ranking of chemical elements according to their enrichment factors EF in mesoplankton (*A. salina*) and the upper layer of bottom sediments in Lake Maloe Yarovoe.

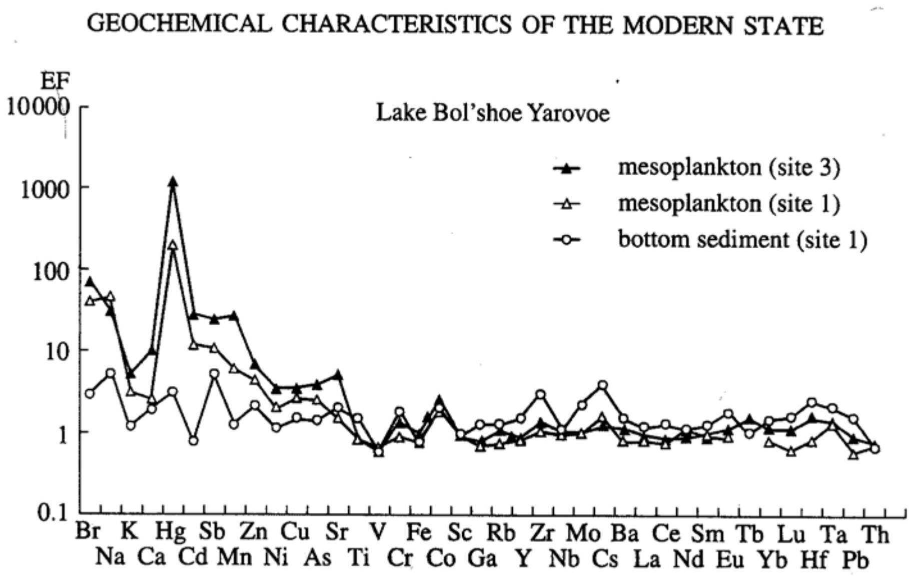

Fig. 3. Ranking of chemical elements according to their enrichment factors EF in mesoplankton (*A. salina*) and the upper layer of bottom sediments in Lake Bol'shoe Yarovoe.

The calculated concentration coefficients K_c reveal seven-fold Hg enrichment in the bottom sediments of Lake Bol'shoe Yarovoe in the nearest influence zone of the plant and five-fold enrichment in the mesoplankton relative to the background part (Fig. 4). The major diffuse sources of "anthropogenic" Hg in the lake seem to be solid-waste dumps on the lake banks, particularly during the snow-melting period, which is also consistent with the results of other researchers (11).

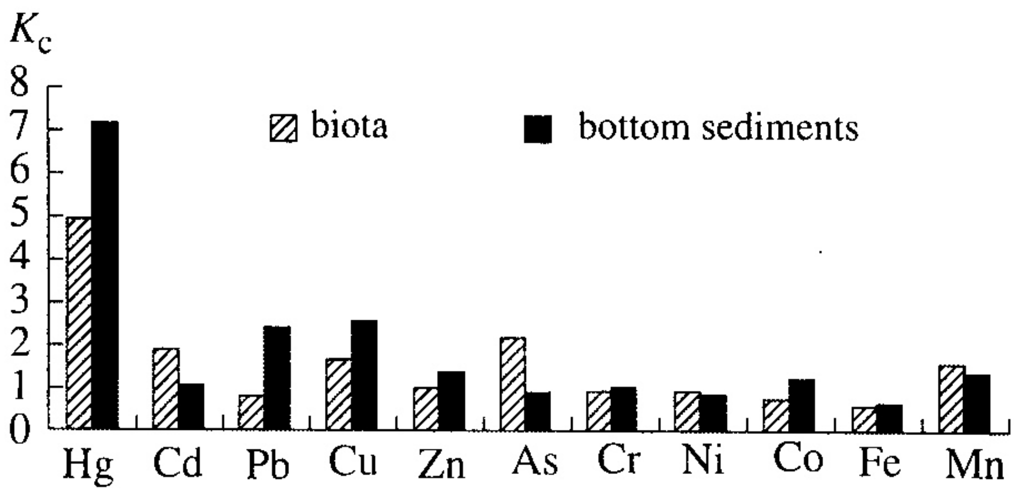

Fig. 4. Concentration coefficients Kc for mesoplankton (*A. salina*) and the upper layer of bottom sediments within the influence zone of the Ataihimprom chemical plant in Lake Bol'shoe Yarovoe (site 3).

Using the calculated concentration coefficients K_c, we developed formulas of geochemical associations for both the mesaplankton and the bottom sediments. In these coefficients, numerals near element symbols denote the values of the concentration coefficients $K_c > 1.5$.

Geochemical Association for the Mesoplankton of Lake Bol'shoe Yarovoe

Site 2: $\mathbf{Hg_{2.43}}$
Site 3: $\mathbf{Hg_{4.98}} > As_{2.24} > Cd_{1.93} > Cu_{1.69} > Mn_{1.65}$
Site 4: $\mathbf{Hg_{1.83}} > As_{1.65} > Cd_{1.56}$

As can be seen form this formula, the major contaminant of mesaplankton in the lake is Hg at all of the sites. The broadest spectrum of contaminating elements (Hg, As, Cd, Cu, and Mn) with $K_c > 1.5$ was detected in mesoplankton from site 3 near the lakefront dumps of the Altaikhimprom chemical plant.

Geochemical Association of Bottom Deposits in Lake Bol'shoe Yarovoe:

Site 2: $\mathbf{Hg_{5.5}}$
Site 3: $\mathbf{Hg_{7.17}} > Cu_{2.58} > Pb_{2.43}$
Site 4: $\mathbf{Hg_{2.5}} > Pb_{1.57}$

It should be emphasized that the K_c of elements in the association in both the living matter and the bottom sediments are generally relatively low, but nevertheless, they indirectly testify that the elements, particularly Hg, are potentially hazardous for the ecosystem of the lake.

The calculated integral contamination indicators Z_c (Table 1) were ranked according to the classification proposed by Yanin (14) (Table 2). This allowed us to class the bottom sediments of Lake Bol'shoe Yarovoe within the influence zone of the chemical plant (site 3) with medium contaminated ($10 \le Z_c < 30$) and weakly contaminated (sites 2 and 4; $Z_c < 10$). These integral contamination indicators Z_c are characterized as moderate and permissible in terms of toxicological hazardousness.

Table 1

Integral contamination indicator Z_c for the bottom sediments of Lake Bol'shoe Yarovoe

Site	Integral contamination indicator for the bottom sediments **(Z_c)** of Lake Bol'shoe Yarovoe
2	6.60
3 (contamination zone)	**11.54**
4	4.01

Table 2

Qualitive scale for river contamination according to the intensity of the accumulation of chemical elements in bottom deposits (according to Yanin (14)

Contamination indicator	Anthropogenic contamination level	Toxicological hazardousness level
$Zc < 10$	Weak	Permissidle
$10 \le Zc < 30$	Intermediate	Moderate
$30 \le Zc < 100$	High	Hazardous
$100 \le Zc < 300$	Very high	Very hazardous
$Zc \ge 300$	Extremely high	Extremely hazardous

It should also be stressed that the situation with contamination of mesoplankton and bottom deposits in the lake did not change with time during our biogeochemical monitoring (in 1998–2004) (Table 3).

Table 3

Hg contents in the mesoplankton (*Artemia salina*)* and bottom sediments** from salt Lake Bol'shoe Yarovoe

Sampling site	**1998 year**	**2004 year**
site 1 (background)	0.64* 0.054**	0.46 – 0.84* 0.006 – 0.017**
site 3 (influence zone of the chemical plant)	1.5* 0.77**	1.1 – 2.3* 0.019 – 0.12**

It is also important to mention that Hg is contained in the brine of Lake Bol'shoe Yarovoe predominantly in solute form, and only its minor amounts are contained in the particulate matter. Inorganic Hg species in this system are chloride complexes: ~92–96% $HgCl_4^{2-}$, ~2.7–5.9% $HgCl_3^-$, and ~0.25–2.5% $HgCl_2^0$. These species predetermine the elevated biological accessibility of Hg, which makes this element toxic for living organisms, including the halophilic brine shrimp *Artemia salina*.

To determine mercury speciation in salt waters sediments and zooplankton of the Lake Bolshoe Yarovoe the method of thermal analysis with atomic absorption spectrometry detection was applied (Table 4). A Lumex RA-915+ mercury analyzer equipped with pyrolytic attachment RP-91C was used.

Table 4

Methylmercury and total mercury ($\mu g g^{-1}$) in the mesoplankton (*Artemia salina*) and bottom sediments from salt Lake Bol'shoe Yarovoe

Sample	Methylmercury	Total mercury
Mesoplankton (site1)	1.50 ± 0.30	1.60 ± 0.20
Mesoplankton (site 2)	1.60 ± 0.30	1.30 ± 0.20
Mesoplankton (site 3)	2.50 ± 0.50	2.30 ± 0.30
Lake sediment (site1)	0.53 ± 0.10	0.53 ± 0.07
Lake sediment (site 2)	0.30 ± 0.05	0.32 ± 0.04
Lake sediment (site 3)	0.27 ± 0.05	0.22 ± 0.03
Lake sediment (site 4)	0.19 ± 0.05	0.22 ± 0.03

CONCLUSIONS. (1) The accumulation of potential ecological toxicants (Hg, Cd, Zn, and Cu) is related to the fact that their predominant species in the brines of salt lakes are mobile chloride complexes and free ions, which can be readily consumed by plankton.

(2). The calculated EF values point to 100-fold enrichment of the mesoplankton of lakes Maloe Yarovoe in Hg and 1000-fold enrichment of the mesoplankton of Lake Bol'shoe Yarovoe in this element. This obviously demonstrates an anthropogenic source of Hg in the ecosystem of Lake Bol'shoe Yarovoe.

(3). The concentration coefficients @K@c calculated for components of the ecosystem of Lake Bol'shoe Yarovoe demonstrate the seven-fold enrichment of the bottom sediments in Hg within the nearest influence zone of the chemical plant and the five-fold enrichment of this element in the mesoplankton relative to the values for the "background" area. According to the anthropogenic contamination level of bottom deposits in the influence zone of the Altaikhimprom chemical plant in Lake Bol'shoe Yarovoe, these deposits were provisionally classified as moderately contaminated. The deposits at the "background" area were classified as weakly contaminated. In terms of toxicological hazardousness, these sediments are ascribed to moderately and permissibly hazardous, respectively. The major diffuse anthropogenic sources of Hg are lakeside dumps of solid wastes (which become particularly hazardous during snow melting).

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Mercury in biochemical cycle of the Bratsk reservoir and Program of demercurization of chlor-alkali production in Baikal region, Russia

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Emission of the anthropogenic mercury to the Bratsk reservoir is for all related to the operation of mercury electrolysis shop of the enterprise “Usoliekhimprom” at the period 1970-1998. Studies, that we conducted at the last ten years (1998-2008) and annual monitoring research of the mercury accumulation at the various elements of reservoir’s ecosystem allowed us to trace changes occurring in the biochemical cycle after diminishing the mercury burden, to define dependencies and regularities of the toxicant’s migration in the aquatic environment and trophic chains of hydrobionts. The summary of the research is the following:

- We have defined that, against a background of the general reduction of mercury’s content in water, the main source of mercury contamination are the bottom deposits. They contain large amounts of mercury, with it’s concentration up to 2 $\mu g \cdot g^{-1}$ dry weight. The heterogeneity is often the main cause of mercury accumulation in hydrobionts.
- It is determined that even after the end of the mercury electrolyses at the enterprise “Usoliekhimprom”, its wastewater still contains high level of mercury concentration, at the average 6 $\mu g \cdot L^{-1}$. The main part of suspension, contaminated with mercury is transferred by thin argillaceous suspended particles that have a large sorption potential. Suspension, contaminated with mercury accumulates mainly in zone of main sediment geochemical barrier, thus creating areas of focal sediments contamination. 2008, there were registered maximal levels of total Hg accumulation in plankton (0,722 $\mu g \cdot g^{-1}$ dry w.), benthos (0,476 $\mu g \cdot g^{-1}$ wet w.), aquatic plants (0,83 $\mu g \cdot g^{-1}$ dry w.), nonpredatory and predatory fishes (1,542 and 2,484 $\mu g \cdot g^{-1}$ wet w.).
- Mercury content in the total plankton in inverse proportion with the water level of Bratsk reservoir. As the biomass of plankton increases, the content of mercury in water decreases, that is caused by absorption and accumulation of mercury by planktonic organisms. With the increase of the plankton biomass the level of mercury concentration in total plankton becomes higher, and vice versa, with the prevalence of phytoplankton in tests, the content of mercury decreases. Depending on the specific structure, zooplankton accumulates 2-2,5 times more mercury than phytoplankton. The content of mercury in filtering zooplankton (Cladocera) s higher than in predators (Copepoda).
- Differences in mercury accumulation by various organs and tissues of various fish species is caused by differences in food items, physiological particularities of fish and hydro chemical environmental conditions. Mercury content analysis for muscles, larvae, blood and bolus, as well as the defining of food composition for fishes of different trophic directions could give a prior express-estimation of mercury contamination of water and of ways of mercury transfer in food chains.

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SpS 12: Identification, Characterization, and Remediation of Mercury Contaminated Sites

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- 1960 – The beginning of power engineers training in Kazakhstan started by establishing of power engineering faculty in the Kazakh Polytechnical Institute (KazPTI)
- 1975 – Power Engineering faculty of KazPTI became an independent institute of higher education – Almaty Institute of Power Engineering and Telecommunications (AIPET)
- At present AIPET comprises the following faculties:
  1. Heat Power Engineering Faculty
  2. Power Engineering Faculty
  3. Faculty of Radio Engineering and Telecommunications
  4. Faculty of Part-Time Education and Specialists Retraining
  5. Faculty of Pre-High School Training
- Along with the academic process a research work is carried out at AIPET according to 5 priority fields:
  1. Problems of environmental protection
  2. Energy saving and renewable energy sources
  3. Investigation and development of water-chemical procedures and technologies of water processing
  4. Development of scientific and technical offers and recommendations in satellite and ground systems of communication
  5. Development of modern education, continuous qualification improvement and specialists retraining
- The BG Chair of Environmental Technology of AIPET was established in 1995 jointly by Southampton University, United Kingdom and "BG Kazakhstan" company for study of environmental protection problems. There is master degree program on specialty "Life Safety and Environmental Protection" at the BG Chair
- At the BG Chair more than 30 international projects on water conservation and elimination of consequences of mercury pollution in Kazakhstan and other former republics of the Soviet Union have been implemented on the international programs such as 6th Framework Program of European Union, INCO, INTAS, ISTC. The basic results of these research are at the websites: http://Hg-Kazakhstan.narod.ru, http://Hg-Pavlodar.narod.ru and http://Hg-Kiev.narod.ru

The Institute of Microbiology and Virology, Ministry of Science and Education of RK (IMV)

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THE INSTITUTE OF MICROBIOLOGY AND VIROLOGY DOES RESEARCH IN THE FIELD OF FUNDAMENTAL AND APPLIED MICROBIOLOGY AND VIROLOGY. MICROBIOLOGICAL STUDIES ARE RELATED TO DEVELOPMENT OF REGULATIVE PRINCIPLES OF MICROBIAL SYNTHESIS OF BIOLOGICALLY ACTIVE SUBSTANCES, MICROBIOLOGICAL TRANSFORMATION OF COMPOUNDS WITH A VIEW TO CREATE NEW PREPARATIONS FOR MEDICINE AND AGRICULTURE AS WELL AS ENVIRONMENTAL PROBLEMS SOLVING. RESEARCHES IN VIROLOGY ARE CONNECTED WITH STUDY OF MOLECULAR AGGREGATION OF VIRUSES AND THEIR DAMAGING ACTION ON CELLS AND AN ORGANISM, DEVELOPMENT OF PROCEDURE OF VIRUSES' EXPANSION CONTROL AND CREATION OF NEW ANTIVIRAL COMPOUNDS (VACCINE, TEST SYSTEMS, DRUGS).

Laboratory of Ecology of Microorganisms

The main scientific direction of the laboratory is study of mechanism of microorganisms' resistance to heavy metals including arsenic and mercury, development of biological ways of industrial effluent and natural water clean-up from ions of toxic metals, isolation and study of carbohydrates acidating microorganisms on purpose to create a preparation for bioremediation of soils contaminated with petroleum.

Personnel of the laboratory participate in research on international projects: NTAS 97-30723 "Microorganisms in mercury polluted soils and sediments: changes in the biodiversity, spread of resistance plasmids and biochemistry of microbial resistance"; INCO-Copernicus IC15-CT96-0110 "Development of options for damage limitation and environmental restoration of mercury-contaminated areas in north-central Kazakhstan"; INTAS KZ 96-1864 "Study of parameters for optimisation of the design and performance of waste stabilisation ponds in extreme continental climates"; ISTC K-756p "Development of bioremediation techniques for mercury contaminated groundwater in Northern Kazakhstan"; ISTC K-1477p "Application of native bacteria for in situ bioremediation of mercury contaminated groundwater occurring in Northern Kazakhstan as a result of operation of the former PO "Khimprom" chemical plant in Pavlodar".

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The Institute is the Certification Centre of the Federal Administration for the Supervision in Area of Consumers' Rights Protection and Human Wellbeing of the Ministry of Public Health and Social Development of Russian Federation.

Main directions of activities are:

- Development of basic problems of human ecology and environmental health, identification of the most urgent tasks and development of scientifically grounded foundations for environmental medicine;
- Investigation of mechanisms and general regularities of the impact of environmental factors with different nature to living organisms;
- Elaboration of the ecological-sanitary standards for environmental factors and assessment of their isolated, integrated and combined effects and evaluation of safety of new production and technologies;
- Improvement of risk assessment methodology for population health for prevention and reduction influence of environmental factors;

Laboratory of Genetic Monitoring

The main task of the Laboratory is investigation of genetic safety (mutagenicity with prognosis to carcinogenicity, teratogenicity and embryotoxicity) of all products, materials, etc. may contact with human during his industrial and household activity: preclinical examination of new drugs and their components, chemicals and their compositions, new materials, including nanopmaterials and nanoparticles for medical, industrial, agricultural, and environmental purposes, etc. For these activities laboratory is certificated by Academy of Medical Sciences as well as Ministry of Public Health and Social Development of Russian Federation.

Scientific investigations has fundamental character, too. They are, mostly, in sphere of monitoring and prognosis of human (children' and adult's) genetic health. For this goal the unique methodology and experimental approach, including evaluation of genome instability in both cultivated blood cells and buccal cells in complex with evaluation of social, economic and psychologic statuses as well as evaluation of the effects of environmental pollution from air, water and soil, was create. This approach and all of the types of these data are used for risk assessment risk and risk management.

Institute of high technologies of the National atomic company "Kazatomprom" of the Republic of Kazakhstan (IHT NAC "Kazatomprom" RK)

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IHT NAC "Kazatomprom" RK carries out investigations regarding improvement of existing technologies and working out of new ones for underground boreholes leaching (UBL) of uranium, application of methods to improve efficiency of extraction and obtaining of highly pure metal, modeling of UBL processes depending on geological and hydrogeological conditions of a deposit, working out of modern methods of measurements of substances content in environment objects. The institute staff has an many years experience in joint investigations with foreign partners within the program of the International scientific-technical center.

Department of geology, geophysics, and drilling technology

The department staff members participate in the investigations purposed for application of geophysical and geochemical methods during solving geological tasks in uranium sphere, working-out of norm-methodical documents for geophysics, ensuring of radiation safety of staff during works implementation, etc. Currently the department carries out ecological investigations in the team of Supervision Engineer in the international project for the Nura River Basin Mercury Clean-up. The staff of the department had participated in the investigations for the projects MNTZ №451.2 "System analysis of Kazakhstan area environment objects which suffer from the negative affect of "Baikonur" spaceport activity" , №526 "Working out of vacuum technology and equipment for mercury clean-up of the mercury contaminated soils of "Pavlodar chemical plant" JSC", №472 "Determination of chemical and radiation load on children's organism in the area of ecological disaster of Priaralie and development of rehabilitation tsrategy", etc. Employee had been implementing ecological investigations for the programs Intas, INCO-Copernicus, etc.

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IHG RK executes fundamental investigations at the field of hydrogeology and geoecology. They include study of formation conditions, territorial distribution, preservation and complex utilization of water resources of the Kazakhstanic mineral resources; estimation of groundwaters resources and solution water supply problems of population, industry and agriculture of this country at the expense of groundwaters; geoinformational and mathematical modeling of hydrogeological processes; investigation as of forecasting of ecological-hydrological conditions of territories and their changes under influence of climatic and technogenic factors.

Laboratory of hydrodynamic and geological processes modeling

This laboratory conducts investigations in the field of geoinformational-mathematical modeling of hydrogeological objects and processes. The workers of this laboratory are busy with development and improvement of the methods and technologies of mathematical modeling, with problems utilization of the modern informational technologies for the solution of actual hydrogeological tasks, with the development and exploitation of mathematical models of hydrogeological objects, situated both on the territory of Kazakhstan and also outside of its boundaries.

Now modeling for technogenically loaded hydrosystems acquires the particular actuality. There are created in this laboratory the models of groundwaters mercury pollution of northern part of Pavlodar industrial region (Kazakhstan), of the city Kiev (Ukraine), and Usol'ye-Sibirskoe (Russia); the model of hydrogeological-meliorative conditions of irrigation massif Akdalinski (Ili-Balkhash region), systems of models of hydrogeological conditions of Priaralye and of Kazakhstanic part of the shore of Caspian Sea a.s.o.

The workers of laboratory participate in works on grants: (i) INCO-Copernicus (ICA2-CT-2000-10029) Development of cost-effective methods for minimising risk from heavy metal pollution in industrial cities: A case study of mercury pollution in Pavlodar; (ii) US AID/CDR/CAR (TA-MOU-01-CA20-021) Sustainable development and protection of water resources in the irrigated land of the Ily river delta, Kazakhstan; (iii) UNESCO (18314208 KZH) Establishment and development of the national informational net in Kazakhstan by water problems of Aral region; (iv) UNESCO (27212604 KZH) Support and improvement of the national informational network in Kazakhstan by water resources of Priaralye and other regions with tense water balance; (v) ISTC (K-1240) Post-containment Management and Monitoring of Mercury Pollution in Site of Former PO "Khimprom" and Assessment of Environmental Risk Posed by Contamination of Groundwater and Adjacent Water Bodies of the Northern Industrial Area of Pavlodar.

The site "Informational net "Water problems of Kazakhstan"" (http://www.water.unesco.kz) has been created under the aegis of UNESCO for acquaintance of the public with the most critical ecological-hydrogeological problems and results of investigations, executed at this laboratory for their solution.

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Institute of Geology and Mineralogy Russian Academy of Sciences Siberian Branch (IGM SB RAS)

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Institute of Geology and Mineralogy of SB RAS is a scientific research organization conducting fundamental and applied research in the field of general geology,tectonics, geochemistry, mineralogy, geoecology, environment protection, etc. Exploration expeditions are a significant and integral part of the geological work. The primary areas of exploration are Western and Eastern Siberia, Yakutia, the Far East, the adjoining territories of the former Soviet republics, Canada, Mongolia, Vietnam, African countries. In several lines of research the Institute holds leading positions in the country. The results of the research are annually added to the list of the most significant achievements of RAS and SB RAS. At the disposal of the Institute there is a system of unique eguipment facilitating advanced analytical and experimental research.Fof the most part, the analytical equipment is amassed in the Analytical Center.

Analytical Center. The analytical potential of the Center is determined by a great variety of methods of structural, elemental and isotope analisis of geological objects and environmental components:

- Microprobe and scaning microscopy;
- Radio-fluorescence numerical assay of the principal rock-forming and rare elements;
- Multi-element ICP-MS analysis;
- Multi-element neutron-activation analysis including instrumental and radiochemical;
- Atomic absorption of cold measuring of background mercury concentration in environmental objects et all.

In the course of its activities the Analytical Center is involved in the following lines of analysis and research:

- Development and production of modern and fundamentally new precise higly sensitive methods for identifying elements and isotopes;
- Development and implementation of rapid and mass methodologies of identification of rock-forming, rare, radioactive, precious and toxic elements;
- Geochemistry of radioactive nuclides, rare and high-density metals in natural and technogenic systems (rocks of weathering crust - soil - bottom depositiv - biota (plankton and plants) in relation to environmental issues

The results of the research are related, first of all, to the main theme - “Principal Mechanisms of Siberian Climate and Natural Environment Development in Cenozoic Period and Prognosis of Their Influence on Eco- and Geosystems Stability”: Cflculation and specification of annual mercury balance for Siberria (340t/y) on the basis of analyzing the principal soerces of incoming and outgoing mercury for an area of 10 million km^2.

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Pavlodar State University named after S Toraigyrov was established in 1996 on a basis of an Industrial University which in turn was set up based on a resolution of Council of Ministers of the USSR of 20th September 1960 and opened of 1st December of the same year. Industrial University occupied two casernes and one-storied barracks of former 24th military college. There were 400 studied at three faculties such as machine-building, construction engineering and power engineering ones. There were 16 lectures including only one associate professor.

Today S. Toraigyrov Pavlodar State University is multiple-discipline institution of higher education with a post-doc educational program on two specialities, PhD program on 17 specialities, master courses on 34 specialities as well as 54 specialities for doing bachelor's degree and 21 specialities - for college degree. At present more than 12 thousands of students study variety of technical, social and economic, natural scientific, humanitarian and pedagogical sprecialities.

Pavlodar State University has had a developed material and technical basis including 6 educational buildings, a scientific library with 6 reading rooms, 4 atonements with reserve of 1 million books, a museum, lots of laboratories, state-of-the-art computer classes, a professional architecture and design station, a media library equipped with PENTIUM-VI grade computers with LaserJet printer and video, an information storage and retrieval system “Patents of Kazakhstan” as well as an internet point.

There are 46 professors, 156 candidates of science, 52 doctors of science and 94 associate professors at 45 chairs and 12 science and practical centers of the university.