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.

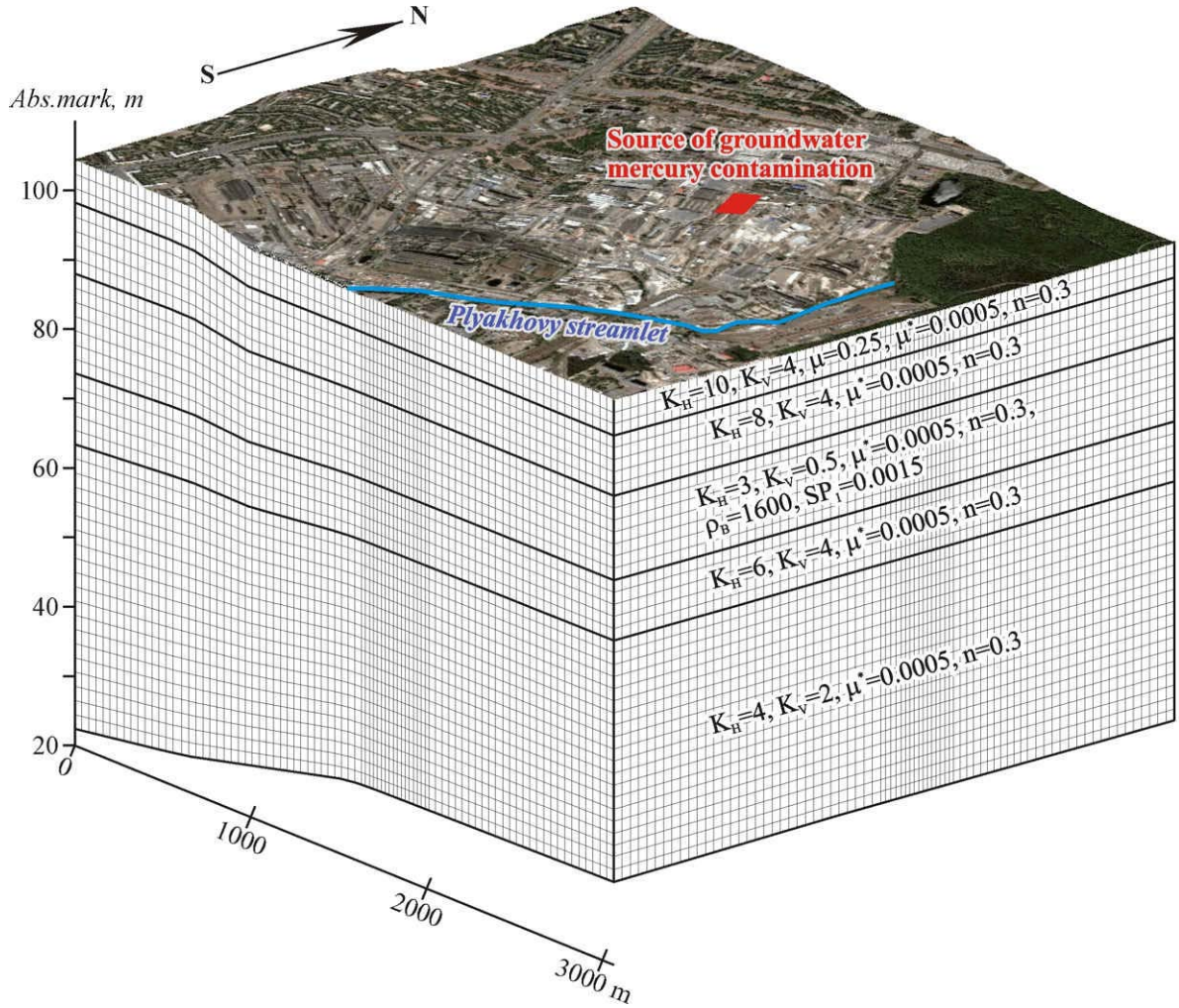
MATERIALS AND METHODS

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.

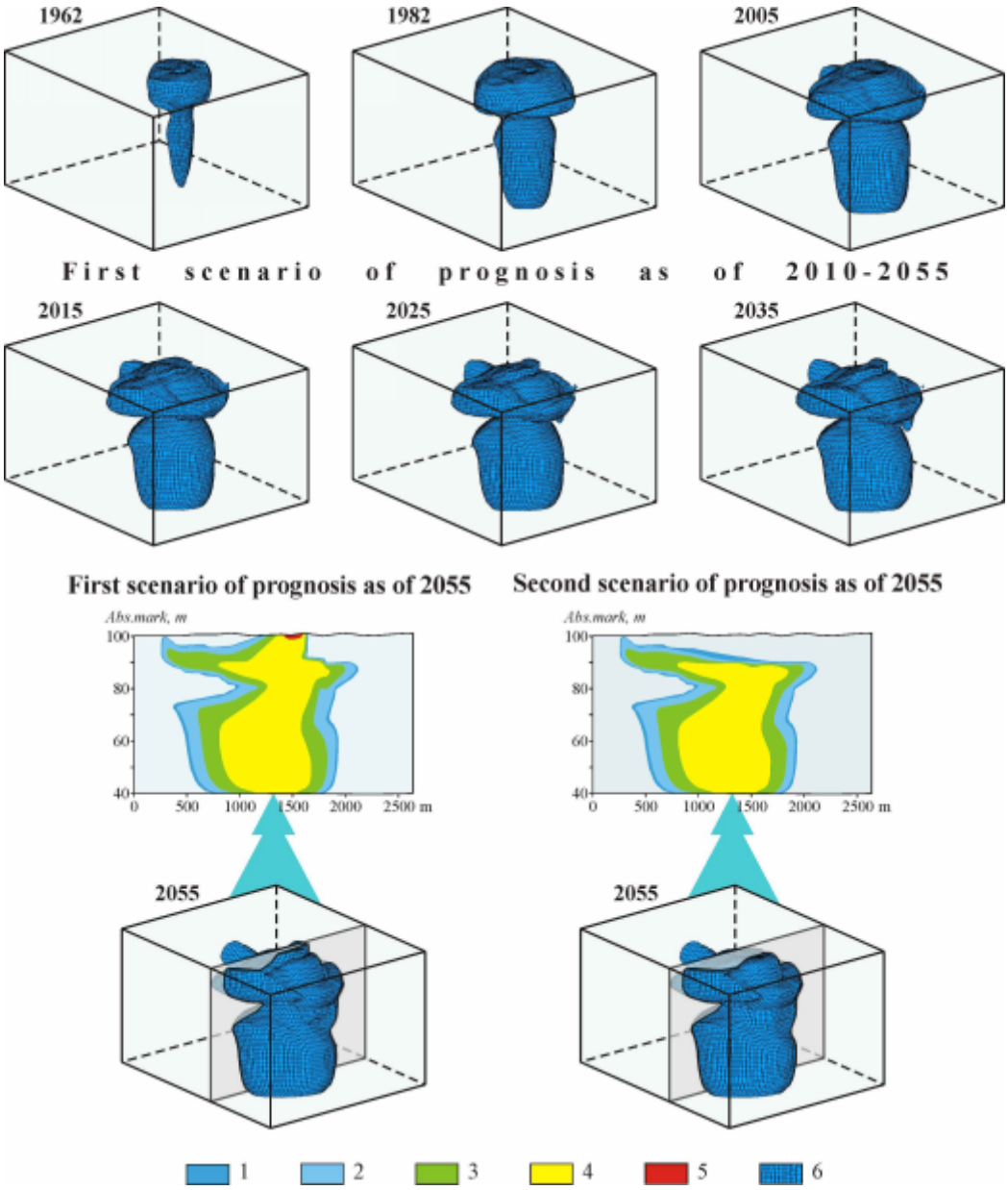


K_H – horizontal hydraulic conductivity, m/day; K_V – vertical hydraulic conductivity, m/day; μ - specific yield, nondimensional quantity; μ^* – specific storage, 1/м; n – porosity, nondimensional quantity; ρ_B – bulk density, kg/m^3; SP_1 – 1st sorption constant, nondimensional quantity

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.

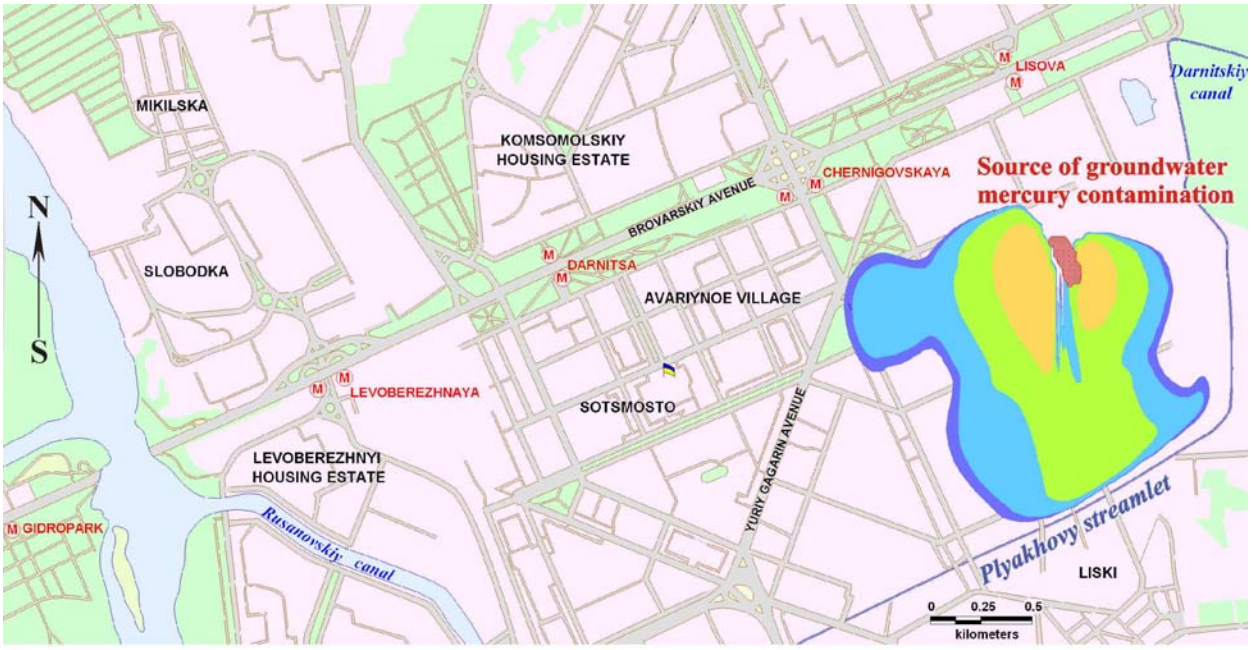


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FIGURE 3. Schematic map of groundwater mercury contamination based on the results of simulation as of 2055

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.

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