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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REFERENCES

1. V. Celo, D.R.S. Lean, S.L. Scott, Abiotic methylation of mercury in the aquatic environment, Sci. Tot. Environ. 368 (2006) 126-137.
2. J.M. Benoit, C.C.Gilmour, R.P.Mason, Aspects of Bioavailability of Mercury for Methylation in Pure Cultures of Desulfobulbus propionicum (1pr3), Appl. Environ. Microbiol. 67 (2001)51-58.
3. Wagner-Döbler I., Canstein H.F., Li Y et al. Removal of mercury from chemical wastewater by microorganisms in Technical scale. Environ. Science technol., 2000, Vol.34, P. 4628-4634.