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Extended Abstract

Novel Biotechnologies for Purification of Radioactive Waste Water

Vira Govorukha* and Oleksandr Tashyrev

Zabolotny Institute of Microbiology and Virology of the NAS of Ukraine, 154 Zabolotny str., 03143 Kyiv, Ukraine

Valery Shevel

Institute for Nuclear Research of the NAS of Ukraine, 47 Nauky Ave., 03680 Kyiv, Ukraine

Abstract

Extended Abstract is given.

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Extended Abstract

Based on our concept of thermodynamic prediction of microbial interaction with radionuclides and toxic metals, we developed novel environmental biotechnologies based on microbial pellets. The main properties of the pellets are the following:

- high stability of pellets (due to their structure) in water solutions,
- diversified microbial communities (natural and artificial),
- compounds necessary for active microbial metabolism,
- presence of Regulators of Microbial Metabolism (RMM),
- high concentration of living microorganisms (95–98% weight of pellets).

Due to these properties, the microbial communities of pellets carry out many types of interaction with radionuclides. The interactions are divided into three groups. The first group is outside the cell, the second is on the cell membrane of microorganisms, and the third is inside the cell. When radionuclides are added into a metabolically active culture radionuclides-oxidizers are reduced by microbial exometabolites-reducers to insoluble compounds ($^{51}CrO_4^{2-}$ to insoluble $^{51}Cr(OH)_3\ nH_2O\downarrow$ or $^{238}UO_2OH^{+}$ to insoluble $^{238}UO_2\downarrow$). Simultaneously the precipitation of radionuclides with exometabolites takes place, e.g.

*Corresponding author. E-mail: .tach2007@ukr.net.

Table 1. Efficiency of extraction of radionuclides by microbial pellets from liquid radioactive waste (LRW).

Radionuclide	Activity** of radionuclides (Ki/kg)			The order of LRW activity decrease
	Initial in LRW	In Microbial Pellets	In LRW after purification	
^{51}Cr	3.90×10^{-7}	1.18×10^{-7}	*	5
^{54}Mn	6.70×10^{-8}	4.72×10^{-8}	*	4
^{60}Co	1.09×10^{-6}	5.3×10^{-6}	5.36×10^{-11}	5
^{83}Rb	6.22×10^{-7}	4.16×10^{-7}	*	5
^{90}Sr	3.52×10^{-7}	3.39×10^{-7}	*	5
^{137}Cs	1.36×10^{-5}	7.81×10^{-5}	3.36×10^{-9}	4
^{140}La	7.01×10^{-8}	9.67×10^{-8}	*	4
^{144}Ce	6.17×10^{-6}	3.50×10^{-6}	7.22×10^{-9}	3
^{226}Ra	1.21×10^{-6}	1.11×10^{-6}	7.60×10^{-8}	2

*Indicates less than sensibility of spectrometer (1.0×10^{-12} Ki/kg).
** Radioactive wastewater of the Institute for Nuclear Research (the National Academy of Sciences of Ukraine) measured by Valeriy Shevel.

$$^{194}\mathrm{Hg}^{2+} + \mathrm{CO}_3^{2-} = ^{194}\mathrm{HgCO}_3^{2-}\downarrow \quad \text{and} \quad ^{60}\mathrm{Co}^{2+} + \mathrm{S}^{2-} \rightarrow ^{60}\mathrm{Co}S\downarrow .$$

It is also possible to bind radionuclides with exopolysaccharides, which are excreted by cells into the external space. Furthermore, the following process occurs on the external cellular structures. Radionuclides substitute stereochemical analogues in the cell wall. Thus, $^{90}Sr^{2+}$ and Ca^{2+} have equal ionic radii (IR), 0.11 nm. Similarly, ionic radii of $^{239}Pu^{6+}$ and Mg^{2+} are equal 0.075 nm that is why $^{239}Pu^{6+}$ substitutes Mg^{2+} in the cell wall. Additional radionuclides are actively transported into cells also due to stereochemical analogy of radionuclides and macroelements. The acceptor and transport systems of microorganisms are activated to transfer radionuclides together with macroelements inside cells. For example, since $^{51}CrO_4^{2-}$ and SO_4^{2-} has equal ionic radii 0.300 nm radioactive chromium is actively transported in cells. Ions of $^{90}Sr^{2+}$ are transported in the same way, since they have the same ionic radii with

Table 2. Types of interaction of microorganisms with radionuclides.

Radionuclide	Type of interaction
$^{51}CrO_4^{2-}$	– Transport inside cells (stereochemical analogue of SO_4^{2-})
	– Reduction to insoluble Cr(III) outside and inside cells
$^{137}Cs^{+}$	– Transport inside cells (stereochemical analogs of K^{+} and NH_4^{+})
$^{83}Rb^{+}$, $^{226}Ra^{2+}$	– Incorporation in cell compounds (substitution of NH_2-groups in amino acids)
$^{90}Sr^{2+}$	– Transport inside cells (stereochemical analogue of Ca^{2+})
	– Precipitation by exometabolites in insoluble compounds:
	– $Sr^{2+} + CO_2 \rightarrow SrCO_3\downarrow$ (solubility index, SI = 1.1×10^{-10})
	– $Sr^{2+} + H_2S \rightarrow SrS + 2H^{+} + S^{o} \rightarrow Sr(OH)_2\downarrow$
$^{54}Mn^{2+}$	– Transport inside cells (stereochemical analogs of Mg^{2+})
$^{60}Co^{2+}$	– Precipitation by exometabolites in insoluble compounds:
	– $Mn^{2+} + Co^{2+} + CO_2 \rightarrow MnCO_3 + CoCO_3\downarrow$(SI = 1.1×10^{-10})
	– $Mn^{2+} + Co^{2+} + 2H_2S \rightarrow MnS\downarrow + CoS\downarrow + 2H^{+}$ (SI = 1.0×10^{-13})
$^{140}La^{3+}$	– Transport inside cells (stereochemical analogue of Ca^{2+})
$^{144}Ce^{3+}$	– Precipitation by exometabolites in insoluble compounds:
	– $Ce^{3+} + H_2S \rightarrow Ce_2S_3\downarrow + 2H^{+} + S^{o}$
	– $La^{3+} + H_2S \rightarrow La_2S_3\downarrow + H_2O = La(OH)_3\downarrow$

Ca^{2+}. After transfer into cells, radionuclides-oxidizers are reduced by redox enzymes to insoluble compounds, and also precipitated by metabolites.

We were able to effectively extract radionuclides using microbial pellets, from liquid radioactive waste obtained from the Institute for Nuclear Research of the National Academy of Sciences of Ukraine. The efficiency of extraction of radionuclides was high. Within three days, the activity of the solution decreased on average by 4–5 orders due to the accumulation of radionuclides in microbial pellets (Table 1).

Based on the thermodynamic predictive method, it is possible to explain the high efficiency of radionuclides extraction by microorganisms as follows (Table 2).

Thus, we have shown the possibility of using the thermodynamic predictive method to develop effective, novel biotechnologies for purification of liquid radioactive waste from a wide range of radionuclides. Obviously, the method developed by us will be effective for biotechnologies for purification of any types of liquid radioactive waste.