Bioremoval of toxic metals by the microbiome of biogas waste

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In connection with the active development of various industries, including the operation of large mining and beneficiation plants, the problem of rapid pollution of ecosystems by heavy metals is relevant for all mankind. A promising metabolic pathway to solve the problem of polymetallic wastewater treatment is microbial dissimilatory sulfate reduction. The process is based on the application of sulfates by microorganisms as the terminal electron acceptor. Due to this, it is carried out two pathways of metals removal.

First is the precipitation of metal cations in the form of insoluble metal sulfides:

$$Me^{2+} + S^{2-} \longrightarrow Me^{2+}S^{2-}\downarrow.$$

The second is reduction of metals-oxidizers to insoluble compounds due to the large redox-difference in potentials between high-potential chromate ($E_0' = +555$ mV) and low-potential S^{2-}-compounds ($E_0' = -150 \ldots -200$ mV):

$$CrO_4^{2-} + S^{2-} \longrightarrow Cr(OH)_3\downarrow + S^0.$$

The aim was to investigate the patterns of heavy metals precipitation on the base of sulfate reduction on the example of Co^{2+}, Ni^{2+} and CrO_4^{2-} by the anaerobic microbiome (isolated from residues of biogas plant).

For this purpose, slightly soluble gypsum $CaSO_4$ (Klebrig, Czech Republic) was used as electron acceptors. Gelatin was used as electron donors. The source of microbiome was sludge of the biogas plant (Opole, Poland) was used. Also, in one of the variants of the experiment, an active inoculum of sulfate-reducing bacteria, previously obtained on the classic Postgate B medium, was introduced. Chalk ($CaCO_3$) was used as a solid buffer to regulate the pH value. The study of the cations precipitation via sulfate reduction was tested by adding the solution of Co^{2+}, Ni^{2+} and CrO_4^{2-} to a final concentration 300 mg/L of cations to culture medium. Cultivation was carried out in hermetic flasks with a volume of 150 mL at 25°C. The colorimetric method with 4-(2-pyridylazo)resorcinol (PAR) (0.1 %) was used to determine the metals concentration for Co^{2+} and Ni^{2+} and with 1,5-diphenylcarbazide (0.5 %) for CrO_4^{2-}.

As a result of the study, it was established that the process of sulfate reduction is quite active and contributes to the precipitation of metals. The use of gypsum prevents volley formation of sulfides, which ensures long-term and controllable process. It took 13 days for the complete precipitation of CrO_4^{2-} in the medium by the sulfide producing microbiome. Under conditions of addition of an active sulfate-reducing microbiome, the duration of metals precipitation was reduced to 11 days of cultivation. The precipitation efficiency in both variants was 100 %. The efficiency of precipitation of Co^{2+} and Ni^{2+} under the conditions of using the active microbiome of sulfate reducers was 97.5 % on the 16th day of cultivation. The efficiency of precipitation of Co^{2+}

and Ni^{2+} under the conditions of using only the microbiome of biogas waste was slightly lower and amounted to 95.8 %.

Thus, the effectiveness of the process of using sulfate reduction with the use of sparingly soluble gypsum for the precipitation of such representative metals as Co^{2+}, Ni^{2+} and CrO_4^{2-} has been experimentally confirmed. This approach can be used as a basis for the development of new biotechnologies for the treatment of polymetallic wastewater.