The Influence of Microbiological Processes on Subsurface Waters and Grounds in River Dam Basement

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Abstract

Microbes are ubiquitous on the Earth and take an active part in the transformation of the geological environment. Their activity can change the geochemical parameters of ground and groundwater and lead to undesirable consequences after the building of hydrotechnical facilities, especially pressure ones. The geological and chemical survey of one of the ground dams of Kama–Volga rivers cascade (The Ural, Russian Federation) revealed the unusual deviations in chemical content of drain water and the presumable suffusion process at the dam basement. The aim of our study was investigation of the dam's ground and water to reveal another deviations in their characteristics, which in turn could help to assess the stability of the dam. We investigated the composition of water-dissolved organic matter (gas chromatography–mass spectrometry analysis), the composition of subsoil gases of the dam (gas analysis), and performed mineralogical analysis of sediments settled at the bottom of the dam's drain system (X-ray diffraction analysis); chemical analysis of water of various aquifers under the dam basement was performed too; also, the microbiological investigations of the dam's ground and water samples were made. We suppose, the results of investigation demonstrate the presence of an active microbiota in dam's ground and water, and microbiota metabolism could lead to hazardous changes in physical-mechanical properties of dam's ground and, eventually, the unstable state of the dam itself.

Keywords

Ground dam • Alluvial aquifer • Microbial processes • Dam's stability

101.1 Introduction

Microbes are ubiquitous on the Earth and take an active part in the transformation of the geological environment, including the impact on ground and groundwater (Bolotina and Sergeev 1987; Kuznetsov et al. 1962; Maksimovich and Hmurchik 2012; Radina 1973). Microbial processes can change the geochemical parameters of ground and groundwater and lead to undesirable consequences after the building of hydrotechnical facilities, especially pressure ones (Koff and Kozhevina 1981; Maksimovich et al. 2001).

The geological and chemical survey of one of the ground dams of Kama–Volga rivers cascade (The Ural, Russian Federation) revealed the unusual deviations in chemical content of drain water and the presumable suffusion process at the dam basement. We supposed, the main cause of deviations observed was the existence of microbiological processes in the dam's ground and water, and tried to explain the detected phenomena from this point of view.

The aim of our study was more proper investigation of the dam's ground and water to reveal another deviations in their characteristics, which in turn could help to assess the stability of the dam.

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101.2 The Description of the Dam's Ground and Water

The studied dam is the part of Kama–Volga rivers cascade dams (The Ural, Russian Federation). The basement of the dam is presented of alluvial sediments up to 18 m in thickness. The sediments are consisted of clays, loams, sandy loams, and, in the upper part of geological column, of fine sands. Sand bands are observed in clays and loams. Sand and gravel deposits are in the lower part of geological column. The distribution and the composition of gravel-pebble strata are not uniform. Lenses of fine sand and interlayers of clays are observed in the gravel-pebble strata, peat is presented in the strata too (Mamenko 1967).

101.2.1 Hydrological and Hydrochemical Conditions Before the Dam Construction

Groundwater was widespread in alluvial deposits and located in sands and gravel-pebble rocks before the dam construction. Water table was 3–9 m below ground surface and had slope gradient to riverbed in 0.006–0.012 grad m^{-1}. Average filtration coefficient of alluvial horizon was 14, and 26–82 m day^{-1} in it gravel-pebble layer. Alluvial groundwater was weakly mineralized and HCO_3–Ca in chemical content.

101.2.2 Hydrological and Hydrochemical Conditions After the Dam Construction

Significant changes in hydrodynamical and hydrochemical conditions, which were caused by a number of factors, such as change in hydrostatic heads of groundwater, filtration of fresh water from the reservoir etc., have occurred since the dam construction. Alluvial aquifer became confined and has a local hydrostatic head at present. It water table is located at the depth of 1 m below the dam surface under it basement. Total salinity of alluvial aquifer's water is 100–200 mg dm^{-3} (up to 400 mg dm^{-3} sometimes) and it increases downstream in general; water of alluvial aquifer is HCO_3–Cl–Na–Ca in chemical content at present. The alluvial aquifer has a close hydraulic connection with the waters of the Kama River. Moreover, it seems to exist the local hydrogeological windows between alluvial aquifer and underlying aquifers, which could cause the increased content of chloride ions (up to 168 mg dm^{-3}), which was observed in individual observational wells of alluvial aquifer.

Geological and chemical survey of the dam revealed the elevated concentration of Fe^{2+} ions in drain water and the settlement of Fe–(hydr)oxides at the bottom of the dam's drain system. As well as this features resembled suffusion process, more proper investigation was done to assess the stability of the dam.

101.3 Methods

We investigated the composition of water-dissolved organic matter (gas chromatography–mass spectrometry analysis on "Agilent 6890/5973N"), the composition of subsoil gases of the dam (gas analysis on "Ecoprobe-5"), and performed mineralogical analysis of sediments settled at the bottom of the dam drain system (X-ray diffraction analysis on "D2 Phaser"). Chemical analysis of water of various aquifers under the dam basement was performed too. Also, the microbiological investigations of the dam's ground and water samples were made.

101.4 Results of Investigation

The chemical analysis of alluvial horizon's water under the dam basement revealed the presence of zone with elevated contents of Fe^{2+}, HCO_3^- and NH_4^+ ions. This water contains the high amount of water-dissolved organic matter—108–122 mg dm^{-3} (whereas it content did not exceeds 30–40 mg dm^{-3} in groundwater of the Ural region). The main features of water-dissolved organic matter were non-hydrocarbon character and technogenic origin. The content of chloroform-extracted bitumen was 1.1–1.6 mg dm^{-3} in range, and the oil-product content was less than 0.07 mg dm^{-3}. The hexane fraction of water-dissolved organic matter consisted of oxygen-containing compounds mainly, the presence of sulfide sulfur (up to 6 %) was found in the hexane fraction too.

The analysis of subsoil gases of the dam revealed the occurrence of regions with elevated contents of CH_4, C_2–C_5 hydrocarbons and volatile organic compounds.

The studies of the mineralogical composition of the sediments settled at the bottom of dam's drain system revealed a predominance of authigenic minerals' complex (calcite, amorphous iron hydroxides, goethite, hydrogoethite, and pyrite) over allotigenic one (quartz minerals). The newly-formed minerals—slices of calcite and pyrite—were detected.

Microbiological investigations of the dam's ground and water revealed the presence of an active metabolizing microbiota in them. Bacteria, isolated from the core and water samples, consumed organic matter, SO_4^{2-} and NO_3^- ions, produced gases and leached Fe ions from the dam's ground samples.

101.5 Conclusions

We suppose that the results of investigation, which were described in Sect. 101.4, demonstrate the presence of an active microbiota in dam's ground and water. Microbial activity could lead to the mobilization and removal of substances (for example, in the form of chemical elements' atoms) from the body and the basement of the dam due to the following processes and factors: bacterial formation of gases could increase tense state of the ground and cause the unconsolidation process; the removal of individual chemical elements from the ground could lead to destruction of it mineral skeleton and reduction of the mechanical firmness of ground; microbiological processes could change microaggregate and chemical composition of ground, dispergate clay minerals, increase ground's wetting ability, and decrease it filtration capacity; exometabolites, formed by microorganisms, could exhibit surface-active properties and reduce the strength of the structural bounds in the ground. So, the intensification of bacterial processes, which could be caused by supply of elevated concentrations of organic matter from anywhere, could lead to hazardous changes in physical-mechanical properties of dam's ground and, eventually, the unstable state of the dam itself.

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