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Simulation of Domestic and Industrial Wastewater Disposal in Flooded Mine Workings

Yury Zakharov*, Lyubov Bondareva

Kemerovo State University, 6, Krasnaya st., 650043, Kemerovo, Russia

Abstract

The paper is dedicated to the mathematical model of domestic and industrial wastewater treatment and disposal in a flooded mine working. The goal of the research is to develop and analyze the mathematical model of suspended impurities flow and distribution. Impurity sedimentation model is under consideration. Due to the sediment compaction problem solution domain can be modified. Impurities flow and distribution patterns are presented.

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Keywords: Domestic and industrial wastewater; disposal of waste; treatment; mathematical modelling

1. Introduction

Industrial and domestic wastewater emissions into water objects can cause changes of their hydrochemical conditions, biological conditions, water quality and irreversible environmental impact [1]. Urban development results in water consumption increasing as well as increasing in wastewater volume. Wastewater should be treated or disposed. Water pollution is a key problem for such industrially developed Russian region as Kuzbass [2].

Coal preparation plants exacerbate regional ecological problems. Industrial wastes normally include flotation tailing and plant slurry water. They can be identified as slurry that consists of liquid phase, solid phase and gas phase. The liquid phase mass is about 95-98% of total mass and consists of mining water or river water used by a plant to prepare coal. Gas phase consists mostly of solute air. The solid phase consists of particles of mineral or

* Corresponding author. Tel./fax: +7 (3842)58-12-26
E-mail address: zaxarovyn@rambler.ru

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organic origin. However, 80-95% of solid phase appear to be particles sized up to 50μm [3]. Coal refineries wastewater may contain suspended particles (coal dust, rock dust, clay particles), salts of heavy metals, phenols, ammonia, nitrates, nitrites, free sulfuric acid, sulfur and other hazardous substances [4]. Moreover, industrial wastewater may contain remains of floatation reagents needed for coal preparation which are partially water dissolved and partially sorbed on suspended substances [3].

Large amount of electric power and capital funds needed for wastewater treatment facilities construction to pump out, purify, drain and dispose mining water. Nowadays great variety of wastewater treatment technologies are utilized depending on purification index, complexity of equipment required, energy costs and explicit costs [5 – 10]. It's well known that large amount of sediment with total suspended solids up to 5g\cubic decimeter develop while wastewater treatment facilities operating. Sewage sludge treatment usually takes place on sludge banks, in slurry ponds or sludge pits that enable to combine both its neutralization and storage. These facilities require much territory and appear to be potential pollution sources [11]. Nevertheless, this technology is widely used because of its ease of operation and simple structure.

Another method that requires treatment process with the help of flooded waste mining workings is also used for coal industry wastewater treatment in Kuzbass. This method is applied to purify slurry water of "Komsomolec", coal preparation plant in the waste mine workings of "Kolchuginskaya" coal mine. Natural purification of wastewater is supposed to take place in mine workings due to the water precipitation and mixture with influent underground water. This technology presupposes treatment as well as storage of sedimentary sludge in mined-out space [11]. This alternative approach is of great concern in Kuzbass. As a result of unprofitable coal producers closures large underground spaces are filled with technogenic underground water. Moreover, these flooded mine workings are normally situated within the city boundaries and can be potentially used as sewage treatment plants.

Although the method is quite simple and requires low costs it is essential to be researched to forecast possible effects of treatment processes. Volley emission of accumulated impurities is the highest priority danger that can result in short but intense increasing of impurities' concentration and volume in pumped out water. Changes of mine working internal structure caused by roof collapse or accumulated sediment solidifying; seasonal change of regional hydrological conditions resulting in influent underground water volume increase and other factors can be the reasons of the phenomenon described. To put this wastewater treatment method into practice safely it is highly important to avoid volley emission by in time putting mine workings out of operation like a wastewater treatment facility.

Flooded mine working can be defined to be a black box with only input and output data possible to be estimated. Thus, it is needed to apply mathematical simulation and numerical experiments in order to forecast potential evolution of the processes in flooded mine workings.

2. Selection of mathematical model of impurity subsidence and problem solution domain modifying due to the sediment packing

Slurries are identified to be unstable and segregate systems in response to falling out solid particles. This process is complex for analytical description as long as cohesion of gravity forces, environmental resistance, fluid flow effects and different falling velocities of mixed size particle produce an effect on settling velocity of polydispersed mixture that is slurry itself. As time passes while settling down the number of particles is decreasing and the balance between proportions of mixed size particles is changing in the unit volume of slurry top layer. Bigger particles sediment faster and their concentration in the top layers decreases faster compared to smaller particles. Obviously reserved tendency is registered in slurry low layers. Very fine particles can remain in top layers because their weight forces may appear to be so weak that environmental resistance and Brownian motion may balance them. Solids settling process is accompanied by sedimentation and consolidation of sediments [3].

To develop a model of the problem described existing models of suspended impurities flow and distribution were under examination. One of the problems that simulates the process of solid particles in a fluid flow transportation is the problem of dynamics of sediment load in a river bed. River water streams transport sand grains, sludge particles and grail that can result in sediment loading and riverbed erosion. Sediment loads are divided into two types: suspended sediment loads that are suspended while being transported by a flow and bed loads that move in bottom water. Water flow hydraulic elements such as flow velocity, depth and others have a great impact on sediment load transportation. Complete problem formulation of river bed evolutions dynamics is a complex problem which is focused on in several papers [12 – 15]. It is normally divided into three interdependent processes. The diffusion