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The Effect of Operating Conditions on the Migration Activity of Pollutants from the Building Materials

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Abstract

It was experimentally establishedthe changing of migratory activity of pollutants from building materials derived from blast furnace slag, during their life cycle in the form of non-linear wave-like character while newly opened contact surfaces with aggressive waters appearedduring the gradual crushing of materials as a result of destructive mechanical effects on them and effect of aggressive waters with varying pH values. The regularities of the migration activity of pollutants (for example, heavy metals) are set as a direct dependence on the value of the newly opened contact surfaces of the material with water having a variable pH. It is shown the expediency of amending the order of the sanitary-hygienic assessment of building materials with the addition of industrial waste (Methodological Guidelines MY 2.1.674-97 "Sanitary-hygienic evaluation of materials with the addition of industrial waste" RU), allowing to take into account the migration of pollutants from them during the life cycle.

Keywords: Sanitary-hygienic assessment, building materials based on blast furnace slag, the migration regularities of pollutants, using of construction materials

1. Introduction

Currently the waste products are widely used instead of the primary natural materials in the preparation of building materials. Such use is due to the similarity of the chemical and mineralogical composition of many industrial wastes with rocks (Gesoğlu and Güneyisi 2012), (Siddique and Singh 2011). In particular, a blast furnace slag is widely used as a building material in the construction of road bases, strengthening of weak soils, in the production of asphalt mixes as crushed stone, sand and mineral powder instead of natural materials (Aggarwal and Siddique 2014), (Qasrawi 2014), (Pasetto and Baldo 2011), (Bouikni and Swamy 2009), (Morrison et all., 2003). The priority is given to the economic attractiveness of the use of industrial wastes as secondary raw materials. But health requirements, when using the target products obtained by adding or on the basis of waste, throughout their lifecycle, are taken into account marginally.

It is known from a practice that when using crushed blast furnace slag instead of natural gravel in contact with aggressive surface and ground waters the emission of pollutants(such as heavy metals) occur as a result of their passage into the movable form (Pugin 2012), (Pugin and Vaysman 2013), (Young and Downey 2008), (Chen et all., 2010). The period of operation of building materials derived from blast-furnace slag, can last for several decades and the concomitant emission of pollutants, in particular, mobile forms of heavy metals, can form an unacceptably high burden of pollution on the environment and the population, which can lead to a deterioration of sanitary conditions of life and adversely affect the health of the population in the area of their possible impact (Proske et all., 2013), (Stengel and Schießl 2014).

Our studies have shown that the emission is not linear throughout the life cycle of the target products derived from building materials based on blast furnace slag. These fluctuations of emissions are not considered in sanitary and hygienic assessment of building materials obtained with the addition of industrial waste in accordance with the MУ 2.1.674-97, because it do not take into account the operational and post-operational lifecycle of these materials and their products.

2. Method

Analysis of Methodological Guidelines MУ 2.1.674-97 in assessing the migration of chemicals from building

materials in aqueous environment leads to the conclusion that they are based on the account of molecular diffusion and heterogeneous physical and chemical interaction of the solid and liquid, the transition of a solid phase into a solution. It is known that the intensity of these processes depends on the specific surface area of contact of the material with an aqueous environment, its permeability, density and acidity. This suggests that the migration of contaminants from the target products (building materials) containing waste products throughout the life cycle of the end user will be affected by such processes as the formation of a new contact surface as a result of grinding material and the changes of pH in the target product location.

To obtain evidence supporting this conclusion we in Perm National Research Polytechnic University had studied migratory activity of pollutants (heavy metals as an example) from the rubble, which is used for road construction, derived from a blast furnace slag from one of a steel plants of Perm region. Chemical composition of blast furnace slag is shown in Table. 1.

Table 1 Chemical composition of blast furnace slag, (%).

element	MgO	CaO	TiO_2	SiO_2	MnO	Al_2O_3	FeO	V_2O_5	Cr_2O_3
content	12,51	30,98	9,07	25,06	0,53	15,41	1,93	0,21	0,1

Studies included both traditional technique of sanitary-hygienic assessment of building materials with the addition of industrial waste, taking into account the physical and chemical processes occurring throughout the life cycle of the target products derived from them.

3. Results

When conducting research on methodological scheme recommended by Methodological Guidelines МУ 2.1.674-97 was found that rubble of slag belongs to the fourth class of danger, and the emission of heavy metals stabilized after 10-20 day exposure of the model media.

The ammonium acetate buffer (pH = 4.8) which simulated the acid precipitation, and distilled water (pH = 7.0) were used as a modeling environments. The ratio of the material and the water volume was 1:2 in a study. The determination of metals (vanadium, manganese, iron) in a mobile form was held by the procedure: ПНДФ 14.1:2.4.135-98 МВИ of determining mass concentrations of metals by spectrometry with inductively coupled plasma in drinking, natural and waste waters and precipitation. Results of the study of migratory activity of vanadium, manganese and iron into the model environment are presented in Figures 1-3.

Designations hereinafter: MPC - maximum permissible concentration of pollutants according to МУ 2.1.674-97;dist. water - distilled water (pH = 7.0).

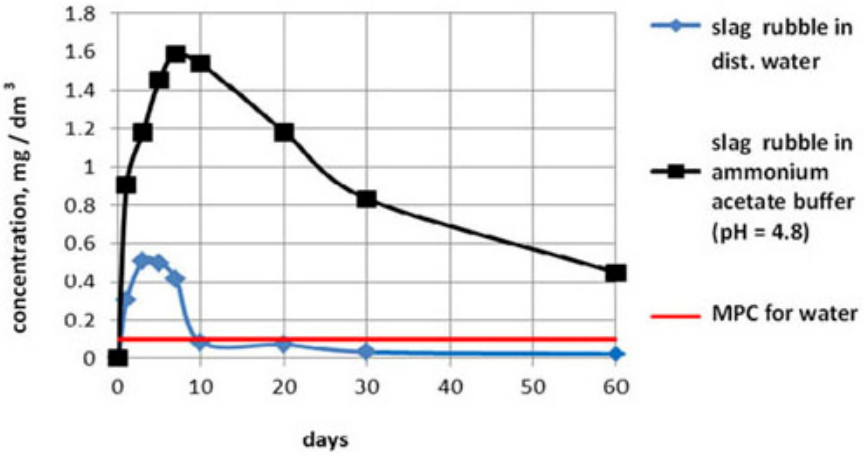

Figure 1. The migration of vanadium from the slag gravel into the model environment

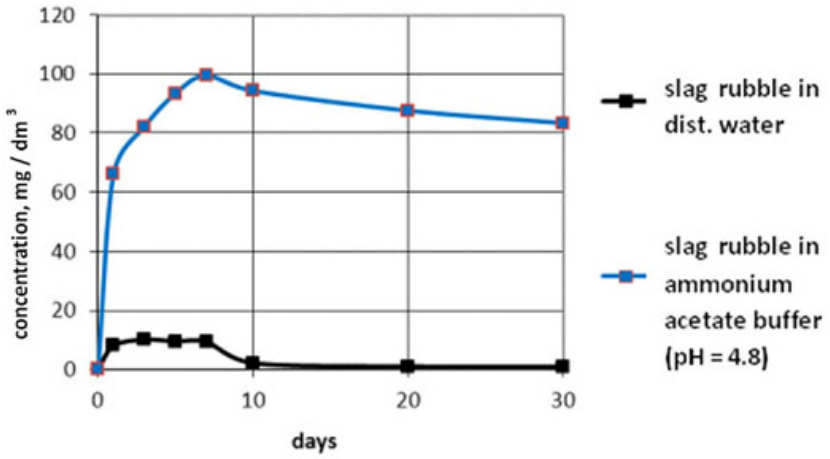

Figure 2. The migration of manganese from the slag gravel into the model environment. MPC of manganese for water bodies - 0.1 mg / dm^3

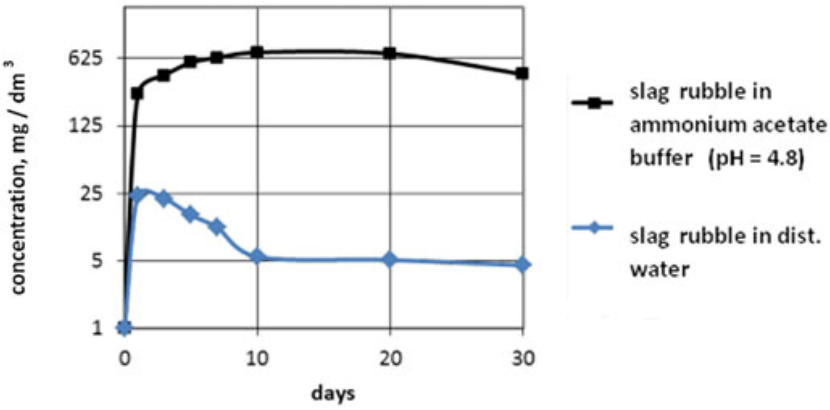

Figure 3. The migration of iron from slag gravel into the model environment

When the sanitary-hygienic evaluation of rubble derived from blast furnace slag is done according to Methodological Guidelines МУ 2.1.674-97, the migration activity test is produced in static conditions without changing ofa shape and size of the grains of gravel. Our studies have shown that during the first three days the migratory activity of heavy metals may substantially exceed the MPC. So, for example, for vanadium where the MPC = 0.1 mg / dm^3, the migratory activity exceeded tenfold. By the end of the preset time regulatory evaluation according МУ 2.1.674-97 the migration of heavy metals at day 30 is reduced in consequence of colmatation of pores on the surface of gravel grains by calcium that leads to a decrease of its permeability to water and transformation of water soluble compounds of heavy metals into insoluble upon interaction with calcium and magnesium.

The building materials during the operation of facilities (pavement, foundations, and others) are subjected to mechanical, chemical and physical effects of the environment. The main mechanical effects may include static and shock effects as a result of variable mechanical loads (e.g. vehicles), leading to a grinding of the material. The chemical and physical influences include variations of temperature, solar radiation, variable pH and chemical composition of the groundwater and surface water. Structural changes in building materials and in the structures can be significantly increased under the influence of environmental factors. Thus, the water entering the individual structural layers can disturb the material, dissolve and flush the water-soluble compounds. Over time, the gravel in the road structures collapses, thus changing its particle size and its specific surface area increases. According to A. P. Vasilev 10 years of operation of the road base, the gravel fraction 20-40mm will contain up to 25% of fraction of 0-5 mm, whereby the specific surface of the particles of the material increases in an arithmetic progression (Cetin et al., 2010).

The rubble, when operating in a constructive layer of the pavement, is constantly in motion and it is crushed, that

resulting in the opening of the new surface layers of the material and their contact with an aggressive water, which increases the migration of heavy metals into the water. In this case, the migration of heavy metals and other pollutants will take place over a prolonged period and wearing a wavy character contributing to increase the probability of formation of unacceptable levels of pollution on the environment and the population. For modeling of a lifecycle of the target product (slag rubble in the road structure) of the end user, the increase of a specific surface area and the change of pH, in experimental conditions, were produced. The rubble of 5 to 10mm size (surface area 11 cm^2 / g) was placed into the distilled water for 30 days, and then it was removed, crushed to form a new surface (up to 23 cm^2 / g) and placed again into fresh distilled water. The results are shown in Figure 4.

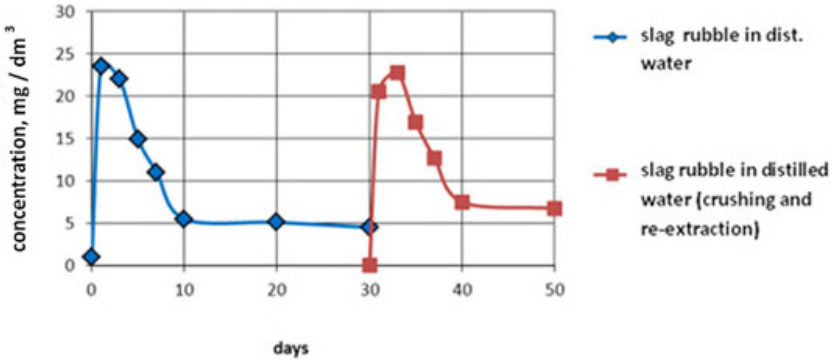

Figure 4. The iron content in a mobile form in distilled water at the initial fraction and after crushing of rubble

The curves in Fig. 4 show that after the crushing of the material particles on the 30th day and the opening of a new surface of contact, the secondary peak of increasing of the iron ions content in aqueous solution occurs. This is due to activation of diffusion processes and the solubility of the chemical compounds which are present in the newly opened surface layers of material. It is known that the diffusion and heterogeneous physical and chemical interaction of a solid and a liquid are high during the initial interaction, due to the large difference in the concentration of the substance in the material and in the aqueous solution. With that the diffusion rate is directly proportional to the surface area through which the diffusion takes place and to the concentration gradient along the way of a diffusion process. The results indicate that an increase in the migration of heavy metals due to a newly opened contact surfaces of a material with an aggressive water will occur indefinitely during the whole operation period and as a consequence the pollution load on the environment and the population will be formed during the whole period of use of the road rubble in the road structure. Accounting for operating conditions during the hygienic evaluation of materials obtained with the addition of industrial waste, is especially important for building materials as well as their products can be used for a long time (tens of years) while changing its chemical and mineralogical composition under varying conditions of mechanical stress, which may lead to a change in shape and size, both of the materials so of products from them.

It is known that a number of chemical compounds (in particular, based on vanadium) which are presented in the production waste may intensify their migration due to the cyclical variability of the pH of the environment. This is a base for a process for producing vanadium from a blend, which are sequentially placed into the alkaline, and then into the acidic environment. Due to this double impact the more complete separation of vanadium compounds from the blend are achieved.

Under natural conditions the periodic changes in the pH of atmospheric and ground water, which can affect the migration of contaminants from materials derived from the slag rubble are also possible. In order to obtain the results, confirming the possibility of changing the migratory activity of vanadium from slag rubble under varying conditions of pH of water contacting with it, the experimental studies have been conducted. As a test sample, the rubble, of 5-10 mm fraction, obtained from blast furnace slag, was used. During the first 20 days the rubble was placed into a distilled water (pH = 7), followed by the ammonium acetate buffered solution (pH = 4.8) for 20 days and then again into a fresh distilled water (pH = 7). In distilled water the stabilization of vanadium in the solution on day 10 was fixed. In the ammonium acetate buffer the output of vanadium was more active and a peak of concentration at day 7 was observed, followed by a fall of its content in the solution. In alternation neutral and acidic conditions the rises of values of the vanadium migration have been set after each alternation (see Fig. 5).

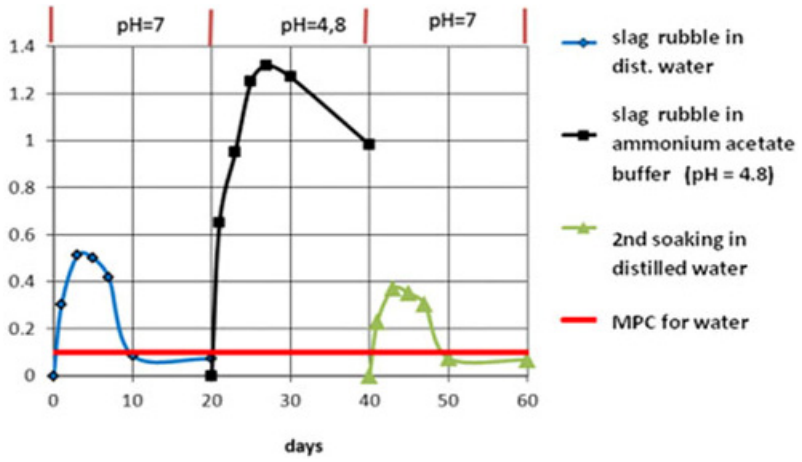

Figure 5. The changing of the concentration of vanadium as a function of the cyclical changes in acidity of environment

4. Discussion

This allows concluding, that during the operation of material, containing vanadium compounds under the influence of rainfall and ground water, which may have varying pHvalues, the total quantity of migration of vanadium would be higher, than that determined by the methods, not taking into account the variables of pH.

Our experimental studies to assess the migration of contaminants from building materials derived from blast-furnace slag with the features arising from the exploitation at the end user and established laws of formation of the emission of pollutants allow the following conclusions:

- the emission of pollutants (the mobile forms of heavy metals as an example) from construction materials derived from blast furnace slag has a wavy non-linear character and increases, at the opening of the fresh contact surfaces by grinding of material under varying mechanical and other stresses and can reach an unacceptable levels of formation loads of pollution on the environment and people throughout the life cycle of these materials, which should be considered when the sanitary assessing of the building materials, obtained with the addition of industrial waste, is made;

- it is expedient to amend the procedure of sanitary-hygienic assessment of building materials with the addition of industrial waste specified in the Methodological Guidelines МУ 2.1.674-97 for taking into account the migration activity of pollutants from these materials and their products throughout their entire life cycle, especially at the operational phase of their use at the stage of final consumer.

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