Impact of engineering constructions made of carboniferous waste rock on groundwater deterioration

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Abstract Hard coal mining wastes widely used in civil engineering, although not considered hazardous, are not also neutral to the environment, mostly due to occurrence in the rock of reactive sulfides. Not only the acid (ARD), but also the neutral rock drainage (NRD) appears to exert a strong adverse impact on the groundwater chemical status. This was exemplified in the anti-flood polder, ground leveling and a structural fill constructed of the re-mined and re-disposed mining waste material after residual coal extraction. The groundwater deterioration pertain basically to sulfates, appeared to be very high, long-lasting and made it unfit to any use.

Key Words hard coal mining waste, coal re-extraction, disposal and reuse of mining waste, leachate, environmental impact

Introduction

In Poland, coal mining waste generation in 2008 reached 30.86 Mt that accounted for 37% of hard coal output and was concentrated in the Silesia administrative district. Of this amount, 89.7% was reused in civil engineering (for construction of flood banks and polders, railway and highway embankments, ground leveling, and reclamation of areas impacted by subsidence or industry), while 600.5 Mt was laying in dumps.

In the last decade, considerable progress in the waste reuse occurred. In 1998, 35% of mining waste was landfilled. In 2008, this percentage was reduced to 10.4%, while the rest of waste was re-used. Also the total amounts of waste stored in dumps show distinct declining trend, being reduced for 26% since 1998. Recently, the residual coal extraction from unburned old dumps has appeared to be a profitable option. It provides about 10% by mass of high quality coal. Waste reuse from existing dumps for residual coal extraction, and for engineering constructions results in the disturbance of primary dump layers and re-exposure of admixed material to atmospheric conditions. This leads to significant transformations of the hydrogeochemical conditions within the newly formed waste layer. Such activity requires thus an evaluation of the risk to the environment of the specific reuse options. Assessment of transformations occurring in coal mining wastes during residual coal extraction, transport and re-deposition of the granular material at the re-use destination (e.g. railroad embankment, road base, ground leveling) is of particular importance in such cases. Mining Waste Directive 2006/21/EC provides principles of the environmentally safe extractive waste management, which is within the responsibility of an operator of a mining waste facility.

This paper is focused on the assessment of the impact of selected engineering constructions from coal mining wastes on the chemical status of groundwater. It is aimed to the identification and reversal of upward trends in pollutant concentrations, in accordance to the Groundwater Directive (2006/118/EC).

Objects and Material

The character of adverse environmental impact of coal mining dumps is exemplified in data from the groundwater monitoring conducted prior and during to the waste reuse activity in the vicinity of a selected dumping site, the Bukow dump of the Anna coal mine in the Upper Silesia coal mining basin in Poland, where residual coal extraction by physical methods has been performed (Fig.1).

At the beginning of the ground- and surface water monitoring at this site in 1997, at the active, 20 years' old dump of the area 45 hectares, waste rock from coal separation, mined from the lower marine-brackish shale-sandstone Namurian A seams 600 and 700 was being disposed. The waste rock showed low potential for ARD generation (NPR = 2.37) related to the Neutralization Potential Ratio (NPR)=Neutralization Potential (NP)/Acid Potential (AP) (BREF, 2009).

Figure 1 Objects location, (1)– coal mining waste dump in Bukow; (2) – the Odra river (3) – embankments of the Bukow polder; (ZB-33) – flooded gravel quarry filled with mining waste

The long-term monitoring data confirmed that pore solutions and groundwater downgradient of the Bukow dump remained close to neutral (pH 6.38—8.09). Chemical composition of the pore solution in vertical profiles of the undisturbed waste layer of the dump shows characteristic downward redistribution of macrocomponents. Constituents migrate in the anthropogenic vadose zone along with subsequent portions of infiltrating precipitation water, which transports contaminant loads into the deeper part of the layer (Fig. 2A).The highest concentrations and loads of constituents occurred at the bottom part of the profile, close to the dump base. The pore solutions show domination of sulfates generated by sulfide oxidation and almost lack of chlorides due to multiple washing out old material.

Wastes from residual coal extraction

Residual coal extraction by physical methods comprise re-mining of disposed material, its transport, multiple sieving, separation in heavy liquids and re-disposal. Water, which is used for transportation, washing and separation, plays an essential role in this process. The water to waste ratio in this process is 1:1, and the total exchange of circulating water occurs every 10 days. Re-disposed wastes have higher water content, exposed specific surface and sulfide content than the primary rock material. This results in significant changes in generation and migration of contaminants.

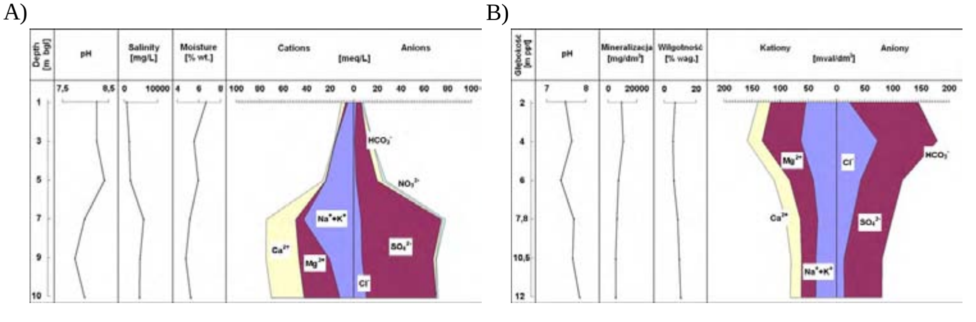

Figure 2 Hydrogeochemical profiles of pore solutions, (A) – in undisturbed layer of coal mining waste; (B) – in re-disposed layer of coal mining waste after residual coal extraction

In general, discharge of leachate from the re-mined dump and leached contaminant loads increase. The pattern of hydrogeochechemical profiles of pore solutions in the re-disposed waste layer appeared to be similar to freshly disposed material (Fig.2B). Mixing and saturation of wastes with water in the technological process results in the lack of a gradual saturation of water retention capacity in the layer and of the vertical downward redistribution. Instead, the higher concentrations of constituents occur at the top of a re-disposed layer, which is typical for a freshly disposed material. Pore solutions in the re-disposed waste layer are alkaline and have higher chloride and sulfate concentrations. This has been defined as a "waste re-activation". High salinity, mostly sulfate, makes groundwater downgradient of the dump unfit for any use, and from this standpoint the pollution potential of NRD (Neutral Rock Drainage) is high. Leachate and receiving groundwater were enriched in Mn up to 3.05 mg/L and under anoxic conditions also in Fe, up to 35.5 mg/L, while concentrations of trace metals were low and did not exceed MCL.

Waste reuse for polder embankment constructions

Coal extraction from coal mining waste provides coal and construction aggregate for engineering constructions. Almost instant change of groundwater chemical status from a primarily good into a poor one in the vicinity of an embankment of the Bukow flood polder constructed of about 120,000 m^3 of secondary waste from coal extraction, showed though a strong adverse environmental impact of this construction. In particular, sulfide oxidation and sulfate generation, along with "re-activation" of chloride leaching resulted in concentrations of SO_4, Cl, K, Na, Fe and Mn in groundwater many times exceeding MCL, at pH values within MCL range (Fig. 3).

Waste reuse for ground leveling

The reuse of "raw" coal mining waste for ground leveling (Fig. 4) also contributes to high sulfate salinity of pore solutions and in this example shows a gradual acidification of the rock material, along with release of elevated concentrations of SO_4 (580—2766 mg/L), TDS (925—4132 mg/L), K (22—79 mg/L), Ca(145—416 mg/L), Mg (77—240 mg/L) and in acid solution also Ni (up to 0.08 mg/L).

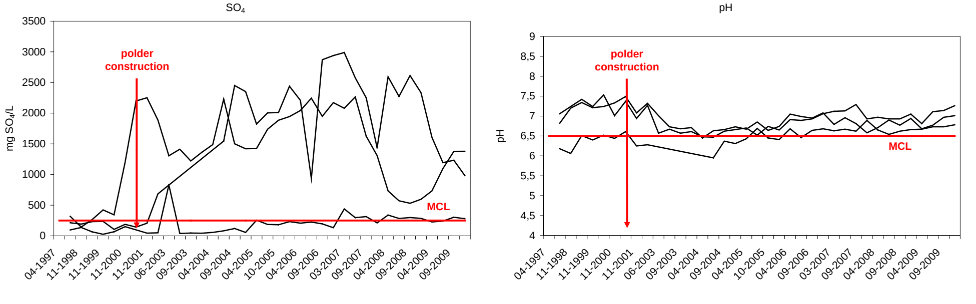

Figure 3 *Sulfate and pH distribution in groundwater up- and downgradient of the polder embankment location prior and after embankment construction*

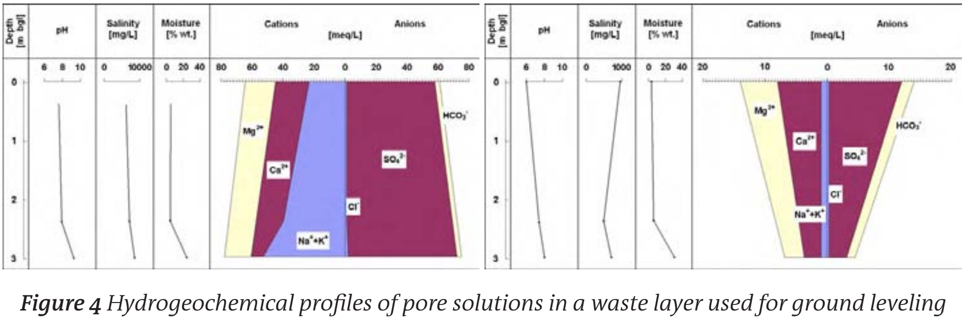

Figure 4 *Hydrogeochemical profiles of pore solutions in a waste layer used for ground leveling*

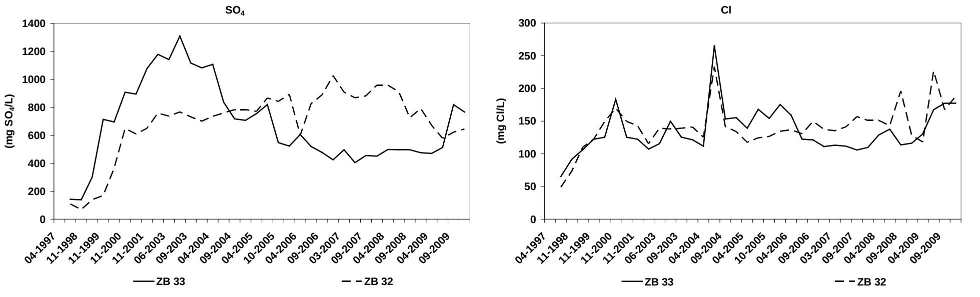

Figure 5 *Temporal changes of SO_4 and Cl concentrations in waterlogged gravel quarries: ZB 33 – quarry filled with re-used coal mining wastes; ZB 32 – disused quarry located downgradient of the groundwater flow from ZB 33*

Waste reuse as a structural fill

Reuse of coal mining waste as a structural fill in waterlogged quarries is considered one of the recommended environmentally safe methods of sulfidic waste management due to insulation of sulfide from contact with oxygen, provided the sulfidic material is permanently covered with water (BREF, 2009). A temporary decrease of the groundwater quality resulting from the release of soluble salts occurring in the material and their further migration in groundwater can be anticipated at the time of filling a quarry with wastes. This can be illustrated by the 4 years' water deterioration in the waterlogged gravel quarry ZB-33 in the Bukow area filled with the re-used non-ARD generating wastes and in another quarry ZB-32 hydraulically connected with ZB-33 and located downgradient of ZB-32. A thorough exchange of water in the filled quarry was followed with a gradual improvement of water quality in ZB-32 and with a similar time-delayed process in ZB-33 (Fig.5).

Decline of water layer below the waste surface in 2009 caused visible deterioration of groundwater quality in both quarries. The permanent cover of sulfidic wastes with water should be thus rigorously controlled.

Conclusions

In coal mining waste management practice, the major source of groundwater deterioration appears to be the high sulfate salinity accompanied by high Mn, and under anoxic conditions also high Fe release, independent of the susceptibility of a material to acidification. Therefore, groundwater protection measures should be undertaken both with respect to ARD and NRD generating waste in case of their disposal and bulk reuse in engineering constructions.

Bulk coal mining waste re-use for residual coal extraction and as a common fill in engineering constructions, including underwater disposal, results in the contaminant generation and leaching that adversely affects the groundwater chemical status and should be strictly controlled.

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