Use of Geochemical Barriers for Environment Remediation after Mine Closuree

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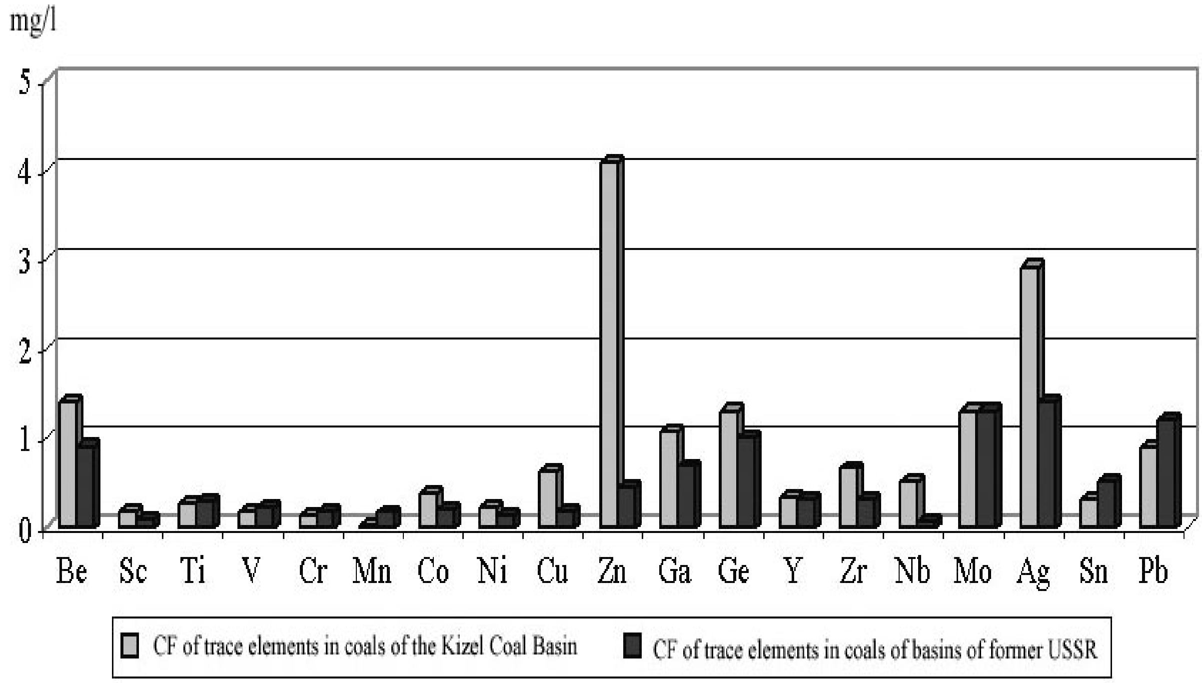
Key words: geochemistry, ground contamination, remediation, surface water

One of the most acute environmental problems of the West Urals area (Russia) is the consequences of the cessation of mining in the area of the Kizel Coal Basin. There is intensive pollution (high concentrations of iron, aluminium and trace metals), that is caused by geochemical features of Carboniferous strata. Coal of this basin differs from coal of other basins of the former USSR (Figure 1) in high contents of sulfur (5.8%, mainly as pyrite) and ash (21.5%) (Kler at al 1988).

Figure 1 *Coefficient factors (CF) of trace elements in coals of the Kizel Coal Basin and coals of basins of former USSR (Kler at al 1988)*

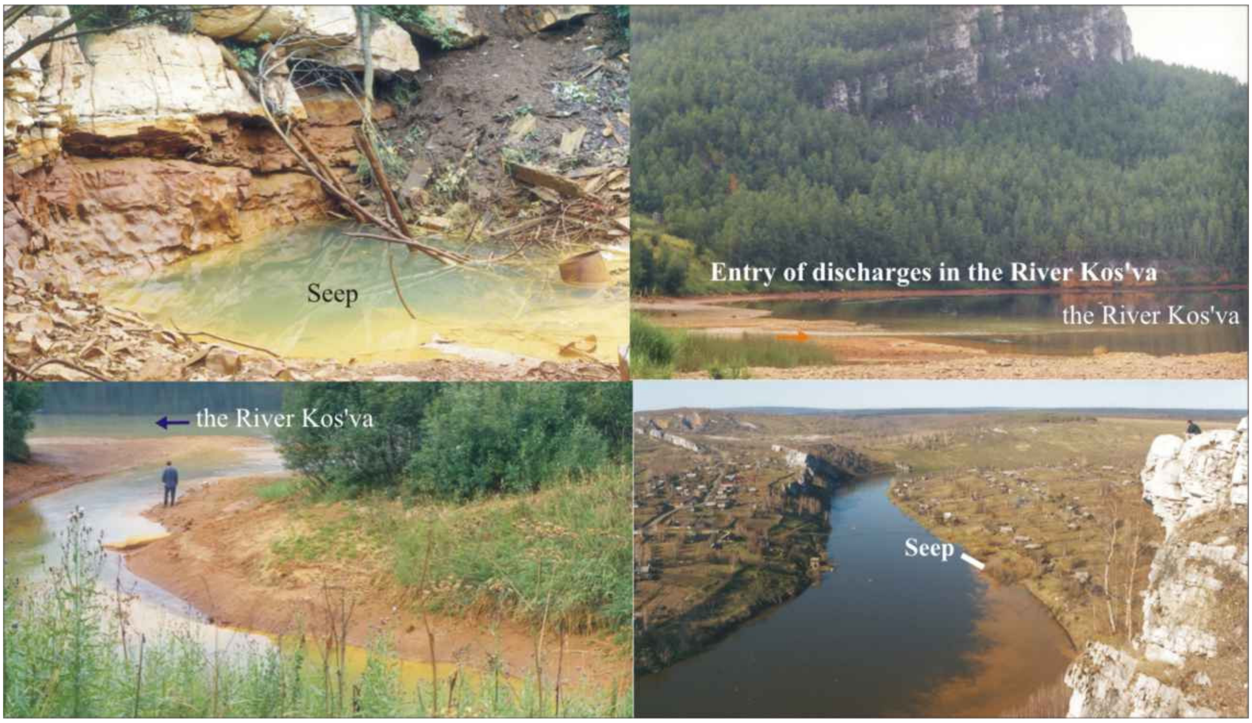


Chemistry of mine water in the basin basically depends on content of sulfide sulfur, carbonates and trace elements in Carboniferous strata. Content of pyrite (of more then 4%) determines acid water (pH=2-3) and sulfide chemistry. Mineralization of sulfide Fe-Al, Na-Ca waters of the Kisel Coal Basin was 2.5-19 g/l and used to increase during exploitation. The content of lead, copper, zinc, silver, nickel, cobalt and other trace elements in acid mine water increased in comparison with natural growndwater (Maximovich, Gorbunova 1990).

During exploitation of the basin mine waters were discharged to the surface without purification. Before the addition of mine waters small rivers had HCO_3-Ca-Na hydrochemical facies, mineralization of 90-150 mg/l and were circum-neutral. After the addition of mine waters they were characterized by SO_4-Fe-Al chemistry with mineralization ranging from 640 to 6000 mg/l, sulphate concentration - from 1000 to 3700, iron - 70 - 900, aluminium - 11 - 160 mg/l at pH 2.5-2.9 (Maximovich, Kataev & Blinov 1995)

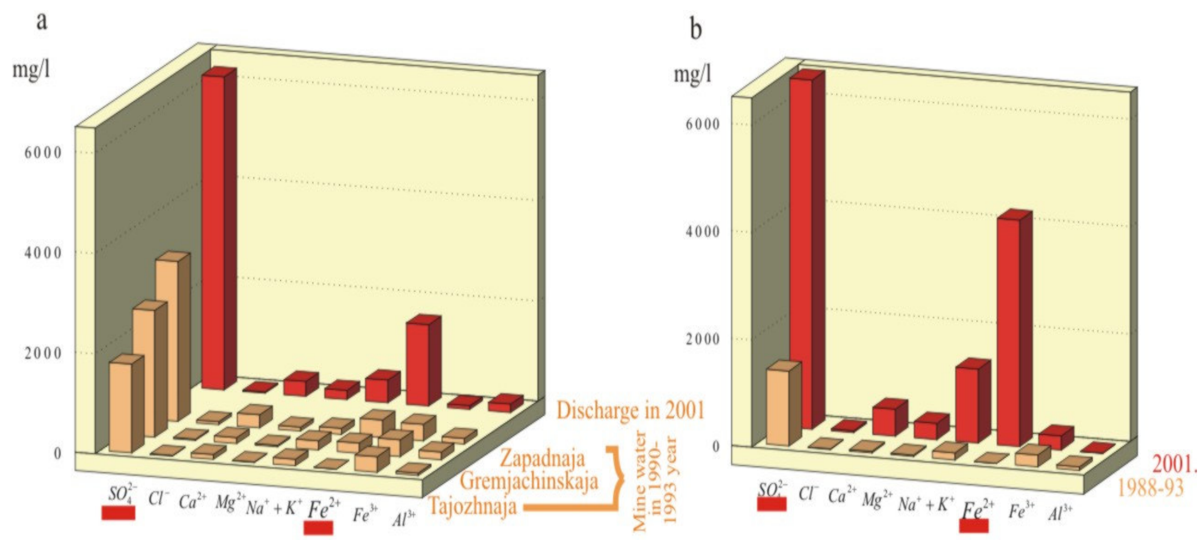
Mines closure in the 1990s did not resolve the environmental problems. Pumping of acid mine water on the surface was stopped, but after restoration of groundwater level twelve disused mine adits discharged waters to the surface (Figure 2).

__Figure 2__ Discharge area to the River Kos'va



The total average annual flow of the mine discharges is 2500 m^3/hour. It is several times smaller then during mining activity. However, mineralization of discharges increased greatly after mine closure – up to 25 g/l and more (Figure 3). The content of ferrous iron increased sharply - up to 5 g/l. Discharges enter 19 rivers, 15 of which are out of water use.

***Figure 3** Chemistry of mine water before and after mine closures (a) mines of the city of Gremjachinsk,, (b) Kalinin mine*



On the polluted areas of rivers tonnes of man-made bottom deposits have accumulated. They are amorphous iron and aluminium hydroxides with high concentration of Mn, Cu, Ni, Zn, Pb and other metals. Small rivers wash bottom deposits down to the Kama River and the Chusovaya River, where these deposits become secondary sources of water pollution.

Since the 1980s the author was actively working on problem of purification of acid mine water and drainage from spoil heaps. The main goal was to find a method of removing elements using artificial geochemical barriers with industrial waste as reagent. Our research was based on the theory developed by A.I. Perelman and other researchers (Perelman, Kasimov 1999, Emelyanov 2005, Langer 2001, Maximovich, Osovetskiy & Blinov 2000, Sergeev at al 1996, Nuttal, Younger 2000, Mclean at al 2005.).

At the end of the 1980s alkaline waste products from the Bereznikovsky Soda Factory were offered as a reagent for neutralization of acid discharges. Utilization of alkaline waste products (so-called "white seas") was a serious problem at that time.

The simple technology of neutralization was developed by N. Maximovich, S. Holostov & V. Basov (Figure 4). Alkaline waste products consist of 70-80% of calcite ($CaCO_3$) with pH of 9-12. The average concentrations of 38 elements do not exceed maximum permissible concentration (MPC) in soils. Harmful organic compounds were not revealed. The volume of waste that is ready for using as a reagent for neutralization of acid mine water without any treatment is more then 1 million m^3.

When acid discharge is in contact with alkaline waste pH increases due to reaction with carbonate and hydroxide of calcium. It leads to decrease in concentrations of Fe, Al, Mn, Co, Zn, Cu, Ni, Pb, Cd, Ti and other elements resulting in purification of the water.

The pilot field experiment was conducted on "The 40 years of October" adit, where discharge rates of mine water range from 180-220 m^3/hour in summer to 300-400 m^3/hour during floods. Mineralization ranges from 4000-600 mg/l to 800-900 mg/l with pH of 2,6-2,9. Concentrations of some elements exceed MPC: Fe – by 400 times, Al – 46, SO_4^{2-}– 1,3, Be– 52,8, Mn– 36,9, Ni – 2,5, Cd – 1,9, Co – 1,6, Ba – 1,5 and Ti – by 1,2 times.

Experiment showed that pH of discharges increases from 2.6-2.9 to 7, resulting in a decrease of iron concentration of from 30-40 mg/l to 0,2-0,3 mg/l and concentrations of Al, Be, Li, Ni, Cd, Co and Ti do not exceed MPC.

Sediment formed as a result of this neutralization is mixture of iron and gypsum hydroxide and carbonate calcium with neutral pH. Mobile forms of Fe, Al, Mn, Pb and others were not revealed. Sediment, according V.I. Kamensh'ikova, is overgrowing with perennial grass (timothy, fescue, couch-grass, lucerne) in the same way as a control template of soil.

In conclusion, the pilot field experiment showed the prospect of use of geochemical barriers for solving environmental problems. Additionally, this technology of mine water purification helps to resolve the serious problem of utilization of alkaline waste products.

The work was financially supported by "Universities of Russia", project, grant no. UR.09.01.009

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Figure 4 *Technological schema of improving of the environment the Kizel Coal Basin by alkaline waste products from the Bereznikovsky Soda Factory*