NEW APPROACH OF PERMEABLE REACTIVE BARRIERS

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Abstract. There are many sites where soil and groundwater is contaminated with various types of hydrocarbons or heavy metals. Remediation and maintenance costs of these sites, such as abandoned industrial or military areas or tailing storage areas, could be enormous if active techniques are applied. If the circumstances of the contamination and site specific parameters make it possible, passive techniques, such as permeable reactive barriers (PRB) are also applicable for remediation of the site. Applying PRB's have been widely accepted for treatment of organic and inorganic contaminants as well, while operation costs can be reduced dramatically. As a matrix material, zero valent iron, charcoal and different types of resins are generally used. Within the frame of this paper, authors are introducing a new approach of PRB system, where lignite as cheap and decent matrix material is used for remediation of groundwater contaminated with heavy metals.

Key words: groundwater remediation, heavy metals, permeable reactive barriers.

Introduction

For satisfying industrial needs and for satisfying life conditions of growing population, it is necessary to keenly produce industrial and agricultural goods. This activity endangers our most important drinking water source: groundwater. Many technical possibilities are existing to clean polluted soil as the main source of groundwater pollution. These are excavation, soil washing, thermal treatment, solidification and stabilizing. However these techniques have high energy needs and might cause other type of environmental problems. There is a claim for an effective and cost effective technology in soil and groundwater remediation.

Permeable Reactive Barrier technology is underground reactor technology whereat contaminated groundwater is flowing through while contaminant reacts the material of the barrier. This technique provides better attention for cleaning groundwater polluted with organic and inorganic compounds. PRB systems has low operational costs and they are effective enough to be competitor of Pump and Treat techniques that are the most popular techniques in this field of environmental protection. Speaking about groundwater pollution is not possible without discussing the source of pollution. In order to clean groundwater, pollution source is also had to be found and removed. Leaving the source underground might cause continuous work without real results. The most general soil/groundwater polluter sources are industry, agriculture and traffic. Various types of contaminants are leaking into the soil/groundwater from these sources. Some of them that cause problem all over the world are listed in table 1.

Table 1

Various types of contaminants

Organic compound	**Inorganic compounds**
Hydrocarbons	Heavy metals
Halogenated hydrocarbons	Nitrates
Aromatic compounds	Arsenic
Nitro aromatic compounds	Phosphates
	Cyanide

Contaminated soil used to be removed and placed into special disposal areas. The narrow capacity and high costs of these methods made them unsustainable from widespread use. Soil cleaning processes can be split into 2 main types of methods: cleaning the excavated soils (ex-situ) and cleaning the soil without excavation (in-situ).

Groundwater remediation also has to be the part of soil remediation. Flowing groundwater can transport contamination for kilometres, so it is necessary to pump out the groundwater and treat it by nature-like processes as: redox reactions, precipitation, adsorption, ion-exchange and biodegradation. If the contamination plume is large, remediation will take years. This is very expensive, continuous monitoring and supervising needed. Permeable reactive barrier technology is a groundwater remediation method which enables physical, chemical or biological in situ treatment of contaminated groundwater by means of reactive materials. The reactive materials are placed in underground trenches downstream of the contaminant plume forcing it to flow through them and by doing so; the contaminants are treated without soil or groundwater excavation. Generally this cost-effective clean up technology cause less environmental impairment than other methods. Most PRBs are arranged in either of the following two configurations:

- continuous reactive barriers enabling a flow through their full cross-section;
- funnel and gate systems in which only special gates are permeable for the contaminated groundwater.

Remediation costs using PRB systems are reported to be up to 50% lower than those of the pump and treat method use so far (Simon and Meggyes, 2000).

New Generation Permeable Reactive Barriers (NGPRB)

Within the frame of a research project new generation permeable reactive barrier system had been developed. The reactive matrix is lignite as high humid acid containing material with decent adsorption potential. Application of easily removable multi matrix layers is also one of the novelties of the system. During matrix development, lignite samples of four different particle sizes were used (0/5 mm; 0.125/0.25mm; 0.25/0.5 mm and 0.5/1mm). Knowing the ions in exchange position was determined, because during the process some ions could get advantage on other which should be important to adsorb, and in the otherwise different ions could leach into the groundwater from the matrix. As a result, iron and transition metals are strongly adsorbed in lignite surface which could prevent toxic ions to adsorb. If there is the possibility for this process, application of secondary matrix layer is necessary to remove iron first. Sorption capacity of the lignite had been also determined. For this, using of Langmuir isotherms is widely accepted. The isotherm describes the sorption process not only mathematically, but parameters like sorption capacity and sorption strength also can be determined. For example linearized Langmuir isotherm for Cu(II) sorption on lignite (Bükkábrány, Hungary) can be seen in fig. 1 and 2.

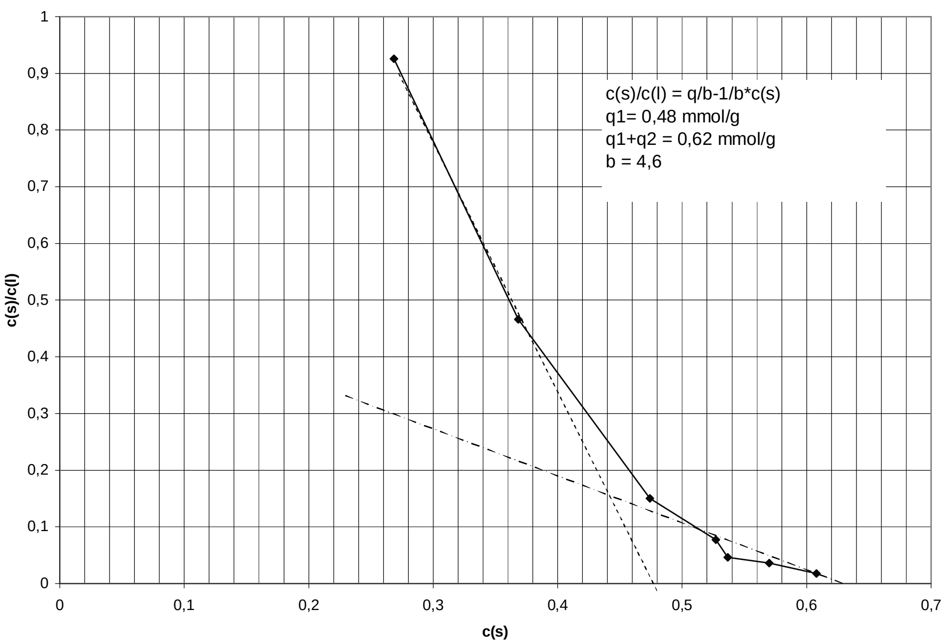


Fig. 1. Linearized Langmuir isotherm for Cu(II) sorption on lignite (Bükkábrány, Hungary).

The data revealed, that only “two layer” Langmuir equation can be used, which provide information about strong and weak adsorption. In order to safely dimensioning a PRB “wall” strong potential can be used (Lakatos et al., 2002). Results also revealed, that lignite from different origins shows only differs in weak sorption capacity and the total sorption capacity is 1 to 10 % of sorption capacity of ion exchange resins and is the same magnitude comparing it to activated carbon. The sorption velocity is low; balance is going to be reached treating 1 total pore volume of contaminated solution per four days. After this time period, balance is provided and there is no noticeable difference of sorption capacity depending on the used particle sizes.

Breakthrough curves of different ions at different matrix were also determined. As it can be seen in fig. 3.,iron ions (either Fe(II) or Fe(III)) are capable to depress Cu(II), however lignite was proven to be able to adsorb Cu(II) and other toxic heavy metal ions.

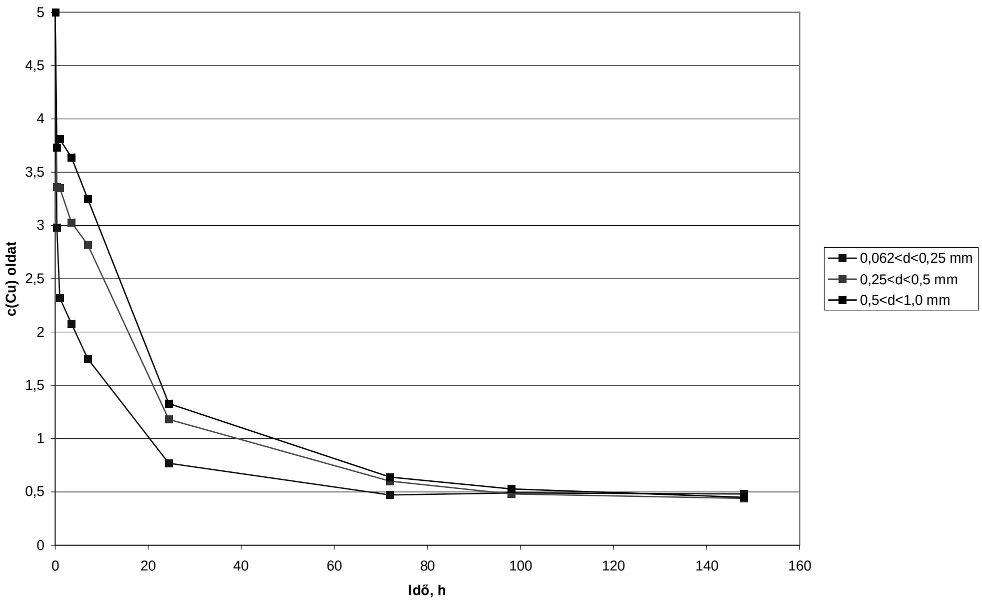


Fig. 2. Sorption velocity of Cu(II) at lignite with different particle size.

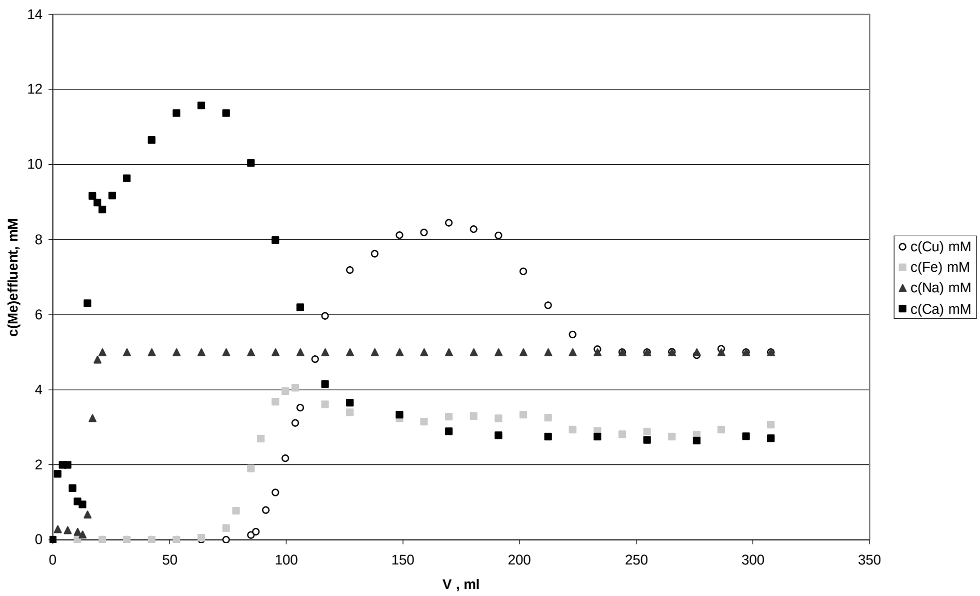
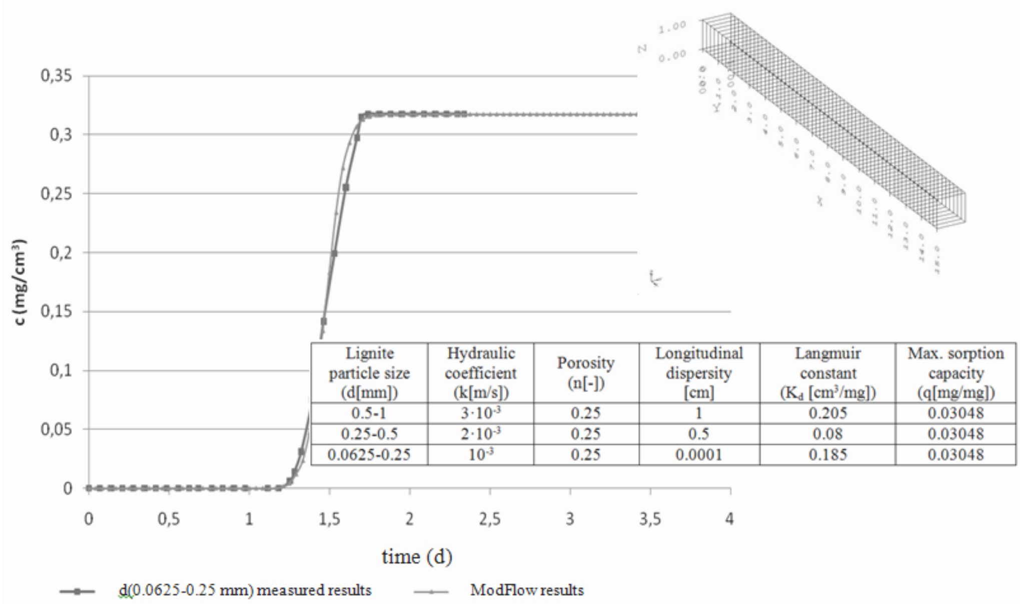


Fig. 3. Break through curve of different ions at lignite–sand mixture: (m(lignite) 2 g, c(Cu): 5 mM, c(Na): 5mM, c(Ca): 5mM, c(Fe(II)): 5 mM, flow rate: v: 0,1 cm^3/min (0,5 pore volume/h)).

Hydraulic modelling

In order to prevent groundwater flow by-passing the PRB or to prevent groundwater to be dammed, hydraulic conductivity of PRB have to be larger than its environment, where it is installed

(Szűcs et al., 2006). During the experiment mixture of lignite and sand were produced (at the rate of 90/10%; 50/50%; 30/70%; 10/90% in every examined particle size range) with keeping sorption capacity at constant rate and hydraulic conductivity had been determined. For mathematical modelling, Processing ModFlow software was used. Transport modelling of break through curves using break through curves determined by the dynamic batch experiments, optimal transport parameters were identified (fig. 4). By this way, a reliant tool for PRB dimensioning was created which is able to predict break through time, so called matrix change cycle time as well.



Lignite particle size (d[mm])	Hydraulic coefficient (k[m/s])	Porosity (n[-])	Longitudinal dispersity [cm]	Langmuir constant (K_d [cm³/mg])	Max. sorption capacity (q[mg/mg])
0.5-1	$3 \cdot 10^{-3}$	0.25	1	0.205	0.03048
0.25-0.5	$2 \cdot 10^{-3}$	0.25	0.5	0.08	0.03048
0.0625-0.25	10^{-3}	0.25	0.0001	0.185	0.03048

Fig. 4. Break through curve determined by transport model and corresponding transport parameters.

Conclusions

During the development of the NGPRB system, it was proven that lignite is able to adsorb toxic heavy metal ions from groundwater plumes at a stable rate. It was also determined, that at certain circumstances, its sorption potential has to be defend against competitive ions using protective multi-layer shields in NGPRBs. During the development a dimensioning tool also had been introduced, and a design protocol was created.

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