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ACTIVE POROUS MATERIALS FOR THE ABATEMENT OF HEAVY METAL IONS FROM INDUSTRIAL WASTEWATER

Porous bed made of cellular concrete has been investigated as an adsorbent of heavy metal ions. The active agents of the bed are iron filings, grinding wheel dust and steel dust. The removal efficiency of the bed has been tested in the solutions of lead and copper. The process runs satisfactorily, which opens up a possibility of practical use of the concrete bed.

1. INTRODUCTION

Industrial development in the 20th century has caused a rapid degradation of natural environment. Continuously increasing industrial activity results in enormous pollution of air, water and soil. Among chemical contaminants heavy metal ions are particularly menacing because of their cumulative behaviour in living organisms.

Numerous techniques for heavy metal removal from wastewater are recognised as useful. However, the search for the efficient and inexpensive removal methods is continued. Two sets of techniques belonging to physicochemical group are currently used in industrial practice; they are based on ion exchange and adsorption processes. A particular ion-exchange technique was developed on the basis of the well-known principle of metal potential along the electrochemical series [1]. A typical concrete pulp (cement, sand and water) was mixed with iron filings and a foaming agent (aluminium powder). The resulting porous material has the property of an ion-exchanging agent, but the process is more complex and resembles adsorption.

In that material, the porous beads contain iron as an active agent. Apart from the typical adsorption phenomenon, an additional driving force is the ion-exchange reaction between iron and heavy metal ions. A simple scheme of this process is shown below:

$$Fe + Me^{2+} \Rightarrow Me + Fe^{2+}.$$

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The exchangeability of ions in the iron–heavy metal exchange system increases as a metal's distance increases from iron's position in the electrochemical series. In this case, iron, as the less noble metal, is exchanged for metal ions having a higher normal potential. Years ago, a technique known as the cementation method was developed based on this phenomenon. This method employs ferrous scrap to recover copper from solution.

2. THE PGS CONCRETE BED

An innovative technique for removing heavy metals from wastewater is based on their adsorption at beds of porous concrete beads. This technique was developed at the Faculty of Process and Environmental Engineering of the Technical University of Łódź [2]–[5]. The research aimed at developing a commercial application of the material has been continued at the Pollution Prevention Center at the Technical University of Łodź.

The bed contains more waste materials in comparison to those beds already commercially available. It is composed of a porous skeleton of foamed concrete (formed according PGS technology, which means *piano-gazo-silikat* = foam-gas-silicate). This concrete is made from fly ash waste from coal power plants, burned lime, and double hydrated gypsum ($CaSO_4 \cdot 2H_2O$). In addition, all of the iron use as an active agent is obtained from waste materials. The primary source of waste iron is mechanical surface-cleaning operations (see table 1). For example: dust is waste material coming from steel plant processes (this ash is collected on filters), and grinding wheel dust collected from dedusting metal plate cleaning.

Table 1

Active agents used for concrete adsorbent manufacturing [2]

Symbol of active agent	Material	Origin	Iron capacity
F1	cast iron filings	machine-shop	96%
F2	grinding wheel dust	Steel mill " Ostrowiec"	56%
F3	steel dust	Steel mill "Częstochowa"	39%
F4	dust from shot-blasting process	Mining Machines Factory "Pioma"	72%
F5	dust coming from dry dedusting at a cast iron foundry	WSK Rzeszów	42%

Bed components with an adequate quantity of active agent were foamed in autoclave. This process resulted in the formation of concrete blocks, which were then crushed to satisfy bead fraction dimensions of 5–10 mm. In the following stage, the beads were layered into a bed. It appears that concrete material containing active iron agent has a bigger compressive strength compared to material without the active agent (see table 2). The research was made according to Polish Standard [6]. Table 3 presents the physical features of the crushed material (beads).

Table 2

Compressive strength [4]

Adsorbing material	Force required to destroy concrete material (kN)	Compressive strength (MPa)
B0	76.2	3.4
B3	92.2	4.1
B4	81.5	3.6

Table 3

Physical features of bed [2], [3], [5]

Adsorbing material	Active agent symbol	Material porosity	Iron quantity (%)	Bed layer porosity	Bulk density (kg/m^3)
B0	–	0.36	–	0.63	503
B1	F1	0.40	14.6	0.68	486
B2	F2	0.37	15.5	0.67	512
B3	F3	0.31	12.1	0.62	592
B4	F4	0.47	10.0	0.78	443

We conducted removal efficiency tests on the concrete beads in a periodic process. The process involved placing a bed of beads into a solution containing a known concentration of lead (40 g/m^3) or copper (30 g/m^3). The bed was shaken at a constant rate, and the metal concentration in solution was monitored over time using anodic stripping voltammetry. This process was continued until the concentrations of lead and copper in solution fell below 1.6 g/m^3 and 0.6 g/m^3, respectively. Some of the results [3], [5] are shown in figures 1 and 2.

Figure 3 shows a photograph of the beads. The group on the left consists of the beads before treatment, and the group on the right shows beads after the adsorption in the lead solution. The surface of the beads after treatment is visibly covered with lead.

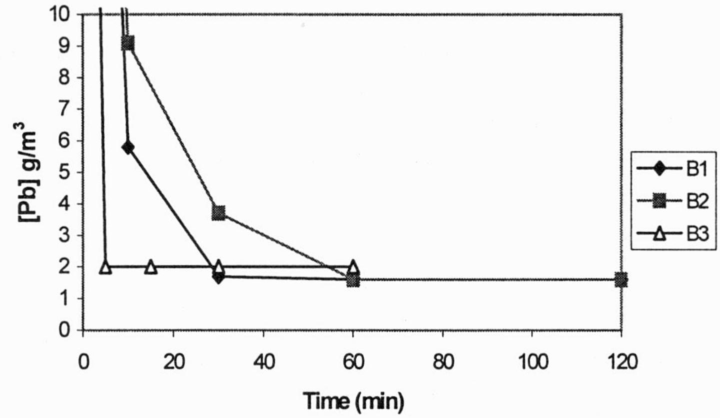

Fig. 1. [Pb] vs. time for three types of iron ([Pb] = 40 g/m^3) [3], [5]

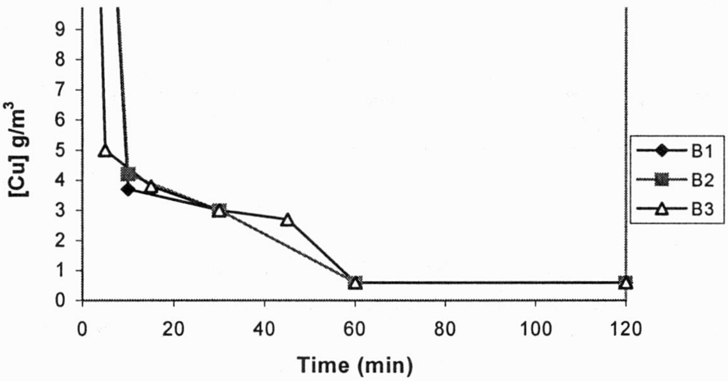

Fig. 2. [Cu] vs. time for three sources of iron ([Cu] = 30 g/m^3) [3], [5]

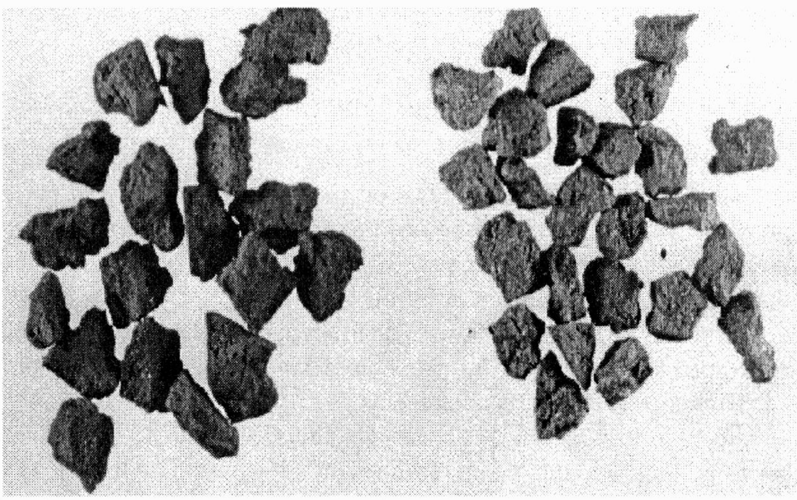

Fig. 3. Photograph of the beads before and after heavy metal adsorption

3. RESULTS AND CONCLUSIONS

The concrete beads for heavy metal ion removal are made primarily from waste materials. The resulting bed has strong heavy metal ion removal characteristics in wastewaters. However, these experiments are still in their early stages and we still need to carry out further tests to determine true effectiveness of the beads. A pilot test of this process will be conducted at an electroplating facility in the Łódź region. The results of this application, along with additional laboratory investigations, will determine the feasibility of wide spread application of the process.

Finally, the disposal of exhausted beads is worth considering. Heavy metals are deposited onto the beads in their zero valence solid state. As a result, we believe that the beads can be incorporated as a ballast into light building materials. Some preliminary trials have already been done [4]. We intend to investigate this disposal method during future studies.

LITERATURE

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AKTYWNE MATERIAŁY POROWATE W ZMNIEJSZANIU ZAWARTOŚCI METALI CIĘŻKICH W ŚCIEKACH PRZEMYSŁOWYCH

Badano adsorpcję jonów metali ciężkich na porowatym złożu z betonu komórkowego. Aktywnymi czynnikami złoża były: opiłki żelazne, pył z tarczy ściernej i pył stalowy. Efektywność złoża była testowana z użyciem roztworów zawierających jony ołowiu i miedzi. Adsorpcję uznano za efektywną, co stwarza możliwość praktycznego wykorzystania złoża betonowego.