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MIGRATION OF ALUMINIUM FROM BOTTOM SEDIMENTS INTO WATER IN LABORATORY CONDITIONS

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Summary. A laboratory experiment was conducted regarding the release of aluminium from the bottom sediments from the dam reservoirs Słup and Lubachów in Lower Silesia. Apart from their flood-control function, the two reservoirs are also used for water retention. The water collected in them – following treatment – is used for drinking. The concentration of aluminium released from the sediments in the case of acidic reaction amounted to 1006.86–2462.47 mg Al dm^{-3}, for neutral to 3.28–79.63 mg Al dm^{-3}, and for alkaline to 6.18–477.97 mg Al dm^{-3}). In acidified and alkalified water the released amounts of aluminium were markedly bigger for the Lubachów reservoir sediments. In the case of neutral reaction more aluminium was released from the Słup reservoir sediments.

Key words: aluminium, water, bottom sediment, dam reservoir

INTRODUCTION

The study covered two dam reservoirs in Lower Silesia: Słup on the Nysa Szalona River and Lubachów on the Bystrzyca River. The reservoirs are used for water retention, protection against flooding the in river valleys, and for fishing by the Polish Anglers Association. The Lubachów reservoir is also used for generation of electricity and is partly available for recreational purposes. The area in which water is drawn for feeding into the water supply system is fenced off and closed to the public. As far as the Słup reservoir is concerned, all of it constitutes a protected zone. The most important function of both reservoirs is to serve as a source of water for human consumption [Szulkowska-Wojaczek and Marek 1984, Hammer 2001].

Aluminium is the main building material of the earth's crust, very common in nature. It is regarded as harmless in a neutral or alkaline environment. In soils with a pH of 6-8 aluminium is to be found in the form of poorly soluble compounds. Cation forms are more mobile and have a significant effect on the quality of soil environment. Anion forms, on the other hand, are easily soluble in water. The leaching of aluminium from soil and sediments results in boosting its concentration in surface waters. The phenomenon is dangerous for the natural environment, human health and animals, as aluminium concentration in soil and sediments is already very high [Stokes *et al.* 1985, Wood 1985, McKnight 1990, Wren and Stephenson 1991, Engleman and McDiffett 1996, Sparlin and Lowe 1996, Elangovan *et al.* 1997, Imray *et al.* 1998, Brzeziński 2004, Tanaka *et al.* 2004, Gworek 2006]. General aluminium content in soil ranges from 150 to 600 mg Al kg^{-1}, in the air it amounts up to 1.00 μg Al m^{-3}, in surface waters – up to 1.00 mg Al dm^{-3}, and in potable water should not exceed 0.200 mg Al dm^{-3}. This is of importance in regions where potable water is drawn from acidic soils and flows through contaminated water supply system piping [Regulation of Minister for the Environment 2002, Gworek 2006, Regulation of the Minister of Health 2007, Regulation of the Minister for the Environment 2008].

Because water is used for consumption purposes and because of a high content of aluminium in bottom sediments of surface waters and its relatively easy release in acidic environments, the decision was made to determine the pollution of the reservoirs with aluminium based on its content in the bottom sediments and its release from the sediments under various environmental conditions.

MATERIAL AND METHODS

The bottom sediments were sampled with an Ekman sampler. Two sediment samples from each reservoir were analysed: one collected in the backwater area, the other just before the dam. Aluminium content was determined using atomic absorption spectrophotometry by means of a Varian UV VIS unit. Additionally, the reaction of the bottom sediments in a water solution was established (PN-ISO 10390: 1997). Next, a laboratory experiment was carried out regarding the release of aluminium from the bottom deposits in water environments with various reactions (acidic – 3.27 pH, neutral – 7.40 pH and alkaline – 11.81 pH): the sediment-solution ratio was 1:50. The sediment samples were covered with distilled water and after a certain period of time (15 min, 30 min, 1 h, 6 h, 12 h, 24 h, 48 h and 96 h) the water was sampled to determine aluminium content.

RESULTS AND DISCUSSION

The sediment samples from the Lubachów reservoir were considerably more acidic (pH of 4.84–4.88) than those from Słup (pH of 7.15–1.17). Aluminium content in the bottom sediments from Lubachów was higher than in those from Słup. Aluminium content in the samples from Lubachów ranged between 3.914 and 4.969 mg Al kg^{-1}. In the case of the Słup reservoir the content was from 3.695 to 3.752 mg Al kg^{-1}. In both reservoirs there was slightly more aluminium in the sediment from the site directly before the dam than in the backwater area. The laboratory experiment concerning the release of aluminium from the bottom deposits into distilled water was done in acidic, neutral and alkaline environments. In water acidified to pH of 3.27 and alkalined to pH of 11.81 significantly more aluminium (even up to tens of times) was released into the water from the sediments from Lubachów, while more aluminium was released into the water when it had a pH of 7.40 (for the purpose of the study regarded as neutral) in the case of the sediments from Słup. However, the differences were not as noticeable as in the case of the acidic and alkaline environments. This attests to various chemical properties of the aluminium compounds found in the reservoirs studied. The biggest amounts of aluminium were released in an acidic environment. In the case of Słup the range was 1006.86–1821.49 mg Al dm^{-3} and in the case of Lubachów – 1274.66–2462.47 mg Al dm^{-3} (Fig. 1).

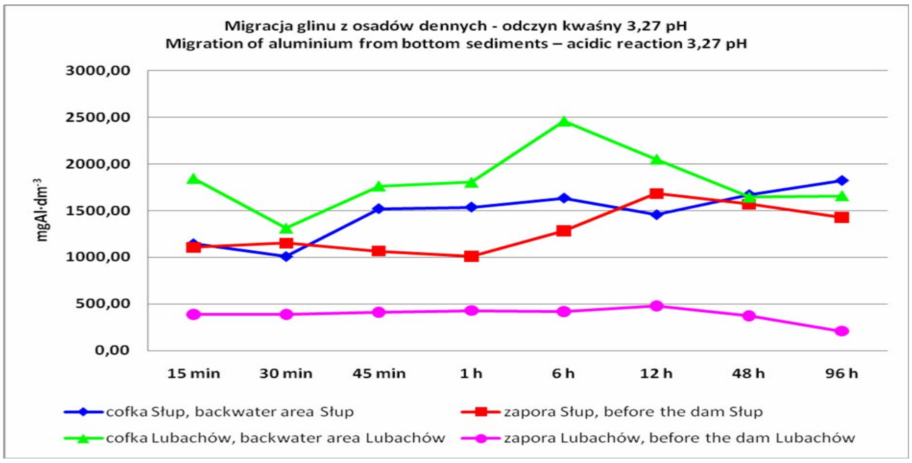

Fig. 1. Migration of aluminium from bottom sediments – acidic reaction (3,27 pH)

For Słup sediments from both sampling sites the amounts of aluminium released into water grew with time. For Lubachów sediments the amounts increased until the first (the dam) or the sixth (backwater) hour. Afterwards a small drop in the concentration of released aluminium was recorded. In an acidic environment more aluminium was released from sediments sampled in the backwater area. Where water is acidic, i.e. its pH is below 5, large amounts of aluminium are released from bottom sediments in a water environment. Reasons for acidification may be natural or anthropogenic. Natural sources of acidification include decomposition of pyrite, which is effected by bacteria in a drought environment. Under favourable conditions, during rain, the resultant sulphuric acid reaches, among other things, water environments. Anthropogenic sources mainly include wet precipitation caused by penetration of nitrogen compounds (transport, animal production) or sulphuric oxides (industry) into the atmosphere. Another source of pollution is the first spring melt which carries significant amounts of sulphur compounds. An acidic reaction of water is typical of industrial sewage, water in mine water catchment areas, natural acidified sources, volcanic or marshy areas [Sorenson *et al.* 1974, Wood 1985, Imray *et al.* 1998]. In many surface water reservoirs more aluminium is released if pH of the water drops below 6 [Jensen and Jorgensen 1984, Driscoll 1985, Nieto *et al.* 2007].

In the experiment the sediment samples released less aluminium in water with neutral reaction than in acidic or alkaline environments. This results from the fact that aluminium dissolves poorly in environments with pH from 6 to 8 [Gworek 2006]. The concentrations for the Słup samples oscillated between 4.77 and 79.63 mg Al dm^{-3}, and for Lubachów – between 3.43 and 20.65 mg Al dm^{-3} (Fig. 2). For the Słup samples the amounts of released aluminium grew up till the sixth hour (the dam) or the twelfth hour (the backwater) into the experiment. The maximum release for the Lubachów sediments was recorded for the first hour. Less aluminium was released from the samples in an alkaline environment than in an acidic one, but more than under neutral conditions. The created anion forms are relatively easily soluble in water with an alkaline pH, but not as easily as in the case of acidic environments [Gworek 2006].

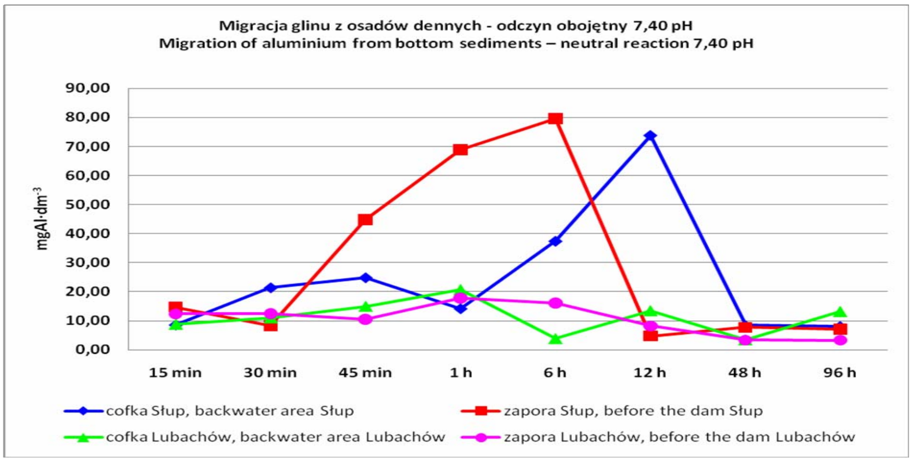

Fig. 2 Migration of aluminium from bottom sediments – neutral reaction (7,40 pH)

Aluminium concentration in the Słup sediments ranged from 6.18 (the dam) to 22.76 mg Al dm^{-3} (the backwater) (Fig. 3). Much higher values were recorded for the Lubachów reservoir (from 163.63 to 477.97 mg Al dm^{-3}). In the case of Lubachów, throughout the experiment more aluminium was released from the sediment collected in the backwater area. The amount of released aluminium

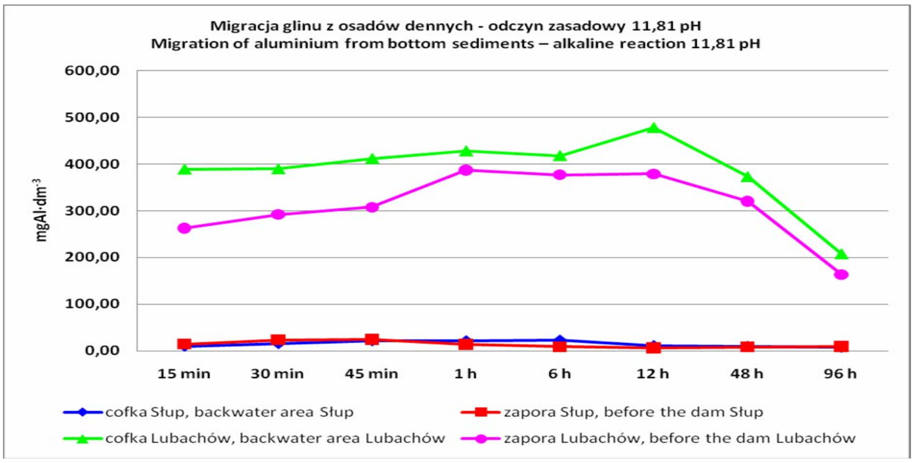

Fig. 3. Migration of aluminium from bottom sediments – alkaline reaction (11,81 pH)

grew until the 12th hour into the experiment and then dropped. In the case of the Słup samples the amounts of released aluminium grew up to the 45th minute (the dam) or the sixth hour (the backwater) into the experiment. Afterwards the amount of aluminium released from the bottom sediments fell.

CONCLUSIONS

1. The aluminium release rate, irrespective of the reaction of the environment, increased until the 6th hour into the experiment.
2. The release of aluminium from the Lubachów reservoir sediments was intensive and fast, especially in an acidic environment. For the Słup sediments the process was slower, not so variable, and the released amounts of the metal were smaller.
3. The risk of large amounts of aluminium from the Słup reservoir sediments finding their way into the water is regarded to be small. In the case of the Lubachów reservoir (acidic reaction of the sediments) an external acidifying factor might bring about a release of large amounts of aluminium.

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MIGRACJA GLINU Z OSADÓW DENNYCH DO WODY W WARUNKACH LABORATORYJNYCH

Streszczenie. Przeprowadzono eksperyment laboratoryjny nad uwalnianiem glinu z osadów dennych pochodzących z dolnośląskich zbiorników zaporowych Słup i Lubachów. Oba zbiorniki pełnią funkcję przeciwpowodziową oraz retencyjną. Zgromadzona w nich woda po uzdatnieniu jest wykorzystywana jako pitna. Stężenie glinu uwalnianego z osadów przy odczynie kwaśnym wynosiło 1006,86–2462,47 mg Al dm^{-3}, w obojętnym 3,28–79,63 mg Al dm^{-3}, w zasadowym 6,18–477,97 mg Al dm^{-3}. W wodzie zakwaszonej i zalkalizowanej poziom uwalnianego glinu był zdecydowanie wyższy w osadach ze zbiornika Lubachów. Przy odczynie obojętnym większe ilości notowano w osadach ze zbiornika Słup.

Słowa kluczowe: glin, woda, osad denny, zbiorniki zaporowe