

SUMMARY

Assessment of sediment contamination of rivers, lakes and reservoirs due to cooling water discharge from power plants

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Today's power industry, which relies heavily on thermal power plants, requires cooling systems to dissipate excess heat generated during electricity production. Cooling systems are essential to ensure the safety and optimum performance of power plants. Nevertheless, their operation involves significant impact on the water environment into which cooling waters are discharged. In thermal power plants, only part of the generated heat is converted into electricity, the rest is discharged as waste heat. Depending on the availability of water in relation to the demand of the power plant, two main types of cooling water circuits are used: open and closed. Water in an open cooling circuit is taken directly from reservoirs such as lakes, rivers, or sea and return heated water back to the source. A special case of an open circuit is the reservoir circuit, where a reservoir or a lake is used as a source of cooling water. The water returns to the reservoir and is again drawn from it.

In a closed system, water circulates in a closed circuit and is cooled in cooling towers. Heated water is sprayed at the top of the structure using nozzles to form fine droplets. The atomization makes the surface area of contact between water and air bigger, which promotes more efficient heat transfer and cooling. The cooled water falls to the lower part of the cooler, where it is collected and redirected to the cooling system. The air, which has captured the heat and some of the moisture from the water, rises to the top and is released through the chimney of the cooling tower.

To date, most research work on the impact of power plant cooling systems on surface water has focused on the aspect of induced thermal changes in the reservoirs into which the cooling waters are discharged. The study of chemical effects on water and aquatic sediments has practically not been addressed. The research undertaken in the present work is primarily aimed at expanding the knowledge on the subject.

The paper uses the results of research obtained within the framework of the task "Assessment of sediment contamination of rivers, lakes and reservoirs due to the discharge of cooling waters from power plants" financed from funds allocated to the statutory activities of PGI-PIB.

Determinations of major elements (Al, Ca, Fe, K, Mg, Na, P and S) and trace elements (Ag, As, Ba, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, Sn, Sr, Ti, V and Zn) have been carried out by inductively coupled plasma optical emission spectrometry (ICP-OES). Mercury has been tested by atomic absorption spectrometry (AAS), and in the case of samples for which results were obtained outside the method's measurement range, atomic absorption spectrometry combined with cold vapour generation (CV-AAS) has been used. Total organic carbon (TOC) has been determined by coulometric titration.

The work aims to study aquatic sediments in the area of 12 selected thermal power plants, with the aim of assessing the impact of these plants' cooling systems on the quality of aquatic sediments in rivers and lakes. Samples have been taken at representative locations for each cooling system.

An open river cooling system has been sampled:

- in the cold channel,
- in the warm channel,
- in the river upstream of the cold channel, i.e., the place supplying water to the cooling system,
- in the river downstream the warm channel i.e. the place where heated water is discharged.

Open reservoir cooling system has been tested in lakes and channel included in the cooling circuit of the power plant.

A closed cooling system has been sampled:

- sediments from the bottom of the cooling tower sump,
- water reservoirs upstream of the power plant discharge site and wastewater,
- water reservoirs downstream of the site of discharge of water and wastewater from the power plant.

In order to assess contamination by selected elements, element concentrations were analysed under geochemical criteria (Bojakowska, 2001) ecotoxicological criteria, including TEC (Threshold Effect Concentration) and PEC (Probable Effect Concentration) (MacDonald et al., 2000), and geoaccumulation index (Müller, 1969). Using these indices, an assessment of the quality of sediments from water reservoirs incorporated into the cooling system of power plants has been carried out.

Sediments from the power plant's open river cooling system, in terms of geochemical criteria, were mostly classified as uncontaminated. Only five samples were classified as mediocly contaminated, two as contaminated, and one as heavily contaminated. In terms of ecotoxicological classification, most were assessed as having no harmful effects on organisms (the value of elemental concentrations was below the TEC value). In the case of six samples, the concentrations of elements in the sediments allowed them to be classified in a group with concentrations above the TEC, but not exceeding the PEC value, the level above which toxic effects on organisms are observed. The PEC value was exceeded for two samples. In terms of the geoaccumulation index, most of the samples from the open river system were classified as uncontaminated or moderately contaminated sediments.

Sediments from the open, reservoir cooling system of the power plant, in terms of geochemical criteria for most of the channel samples, were classified as uncontaminated, only three samples were classified as moderately contaminated sediment. In contrast, samples taken from lakes showed much higher concentrations of trace elements. Three samples were rated as mediocly polluted, nine as polluted, and six as heavily polluted. Due to the ecotoxicological classification, most of the sediment samples from the channels contained concentrations of the analysed elements below the TEC values. For three samples, the concentrations of elements in the sediments allowed them to be classified in a group with concentrations above the TEC, but not exceeding the PEC. For samples taken from lakes, most exceeded the PEC value. In terms of the geoaccumulation index, most of the channel samples were classified as unpolluted or moderately polluted sediments. For samples from lakes, sediments were classified from heavily to very heavily contaminated.

Sediments from the closed cooling system of the power plant, were characterized by higher contamination. In terms of geochemical indicators, most of the samples were classified as heavily contaminated sediment. Three samples were rated as contaminated, seven as moderately contaminated. According to the ecotoxicological classification, only two sediment samples contained concentrations of analysed elements below TEC values. In the case of eleven samples, the concentrations of elements in the sediments made it possible to classify them into a group with concentrations above the TEC, but not exceeding the PEC value, the level above which toxic effects on organisms are observed. The PEC value was exceeded for eight samples. According to the geoaccumulation index, samples taken from cooling towers were classified as highly contaminated sediments. For the remaining samples, i.e. those taken from rivers upstream and downstream of power plants, the geoaccumulation index varied and ranged from unpolluted to heavily polluted sediments.

The obtained results make it possible to assess the impact of power plant cooling systems depending on the type. The closed system has been assessed as having no impact on the quality of water sediment in the rivers into which the water and wastewater from the power plant is discharged. In this type of cooling, the waters circulate in a closed circuit and are not discharged directly into reservoirs. The sediments generated in cooling towers do not enter the environment either. They are used as a bed in fluidized bed boilers., forming a closed circuit of the resulting waste.

In the case of the open river cooling system, it has been found that increased concentrations of all analysed major and trace elements were found in river sediments downstream of the power plants, compared to sediments upstream of the plants. The elevated concentrations of these elements indicate their migration from elements in contact with the cooling water during the cooling process. Heat exchangers, condensers and sprinklers, made of materials such as copper, copper-zinc alloys, and galvanized steel with added metals such as nickel, lead, copper and tin, are exposed to corrosion, leading to the release of trace elements. These elements are then leached out and can accumulate in water and further infiltrate sediment. However, the Mann-Whitney U test showed no statistically significant difference in trace and major element content between sediment samples taken upstream and downstream of the power plants.

For power plants with reservoir open cooling system, significantly higher concentrations of elements are observed in lake sediments compared to the geochemical background for Poland (Lis and Pasieczna, 1995), which indicates the influence of the elector on the chemistry of water sediments in the reservoirs into which cooling water from the power plant has been discharged. This relationship applies to: calcium, magnesium, sulphur, barium, copper, manganese, nickel and titanium. The source of elevated levels of these elements in the aquatic environment can be caused by prolonged water discharges, causing them to leach from components that build the power plant's cooling system, such as piping, condensers and heat exchangers. An additional source of copper in lakes may be the use of compounds that limit the growth of microorganisms, such as copper sulphate in cooling systems.

