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ASSESSMENT OF HEAVY METAL POLLUTION OF RAINWATERS FLOWING DOWN THE ROAD No. 4 TAKEN FROM RETENTION RESERVOIRS

OCENA ZANIECZYSZCZENIA METALAMI CIĘŻKIMI WÓD OPADOWYCH SPŁYWAJĄCYCH Z DROGI Nr 4 POBRANYCH ZE ZBIORNIKÓW RETENCYJNYCH

Abstract: Storm sewage flowing down the roads are collected in roadside retention, infiltration and evaporating reservoirs. Those reservoirs are the elements of rainy sewage system and the pre-cleaning process of runoff from surface of road carring the considerable load of pollutants takes place in them. The aim of the study was to estimate the quality of rainwaters taken from retention reservoirs situated along the main-road No. 4 from Krakow to Bochnia section. Water samples were taken from the both sides of the road and Zn, Cu, Ni and Pb contents were determined.

Heavy metal concentrations in rainwaters collected from retention reservoirs are not high and in no cases exceed the standards admissible for surface waters. Considerable differences in the contents of analyzed metals were assessed between individual reservoirs. Higher concentrations were determined in water from tanks situated on the southern side of the route than on the northern one. Low concentrations of heavy metals in waters in the retention reservoirs may be a result of considerable amounts of organic and mineral suspension absorbing these pollutants in the bottom sediments.

Keywords: rainwaters, runoff, retention reservoirs, heavy metals, self-purification, water quality

Fast spreading urbanized areas and growing number of roads and highways lead to considerable quantities of rainwaters flowing off heavily anthropologically transformed terrains forming storm sewage [1]. They may contain great amounts of pollutants posing a hazard for the natural ecosystems [2]. The most serious agents polluting the runoffs include organic matter, heavy metals, oil derivatives or compounds extracted with petroleum ether [3]. Polish legislation [4] regards rainwaters as sewage which cannot be discharged into the receiver of water without pre-purification. The law on environmental protection describes rainwaters and snow-melt waters from polluted areas, cities,

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industrial areas, car-parks and roads, supplied to the ground or waters, by means of sewer systems. Introducing these waters to reservoirs or to the ground requires a special water supply and sewage effluent disposal consent. According to Decree of the Minister of Environment it is necessity of purification of rainwaters flowing down the roads to the level of total suspension at the outflow not more than 100 mg · dm^{-3} and 15 mg · dm^{-3} of oil derivative substances [4]. Retention, infiltration and evaporating tanks are constructed in order to collect, clean and evaporate rainwater from road drainage. They are situated, especially evaporating tanks, in the areas with high groundwater levels, where water discharge directly into the receiving water is difficult. Storing water originating from drainage of main road and highway with great throughput allows also to block these pollutants and to protect the neighbouring water ecosystems and groundwaters against pollution. Organic matter is capable of binding pollutants, particularly oil derivatives and some heavy metals, which together with the suspension become element of bottom sediments. Processes of water self-purification occurring in the reservoirs diminish the risk of pollutant penetration into the adjacent ecosystems with floodwater runoff or water overflow in the tanks.

The paper aimed at an assessment of quality of storm sewage collected in retention reservoirs situated along the national road No. 4 from section between Krakow and Bochnia.

Material and methods

Water samples were collected in May 2007 from 22 tanks. The national road No. 4 runs in the east-west direction. The water samples were taken from 11 basins on the southern side of the road and from 11 basins on its northern side. Water was filtrated and acidified with nitric acid and total concentrations of zinc, copper, lead and nickel were assessed after 10 times condensation using the inductively coupled plasma atomic emission spectroscopy (ICP-AES) in JY 238 Ultrace Jobin Yvon Emission apparatus.

Results and discussion

Lead content in rainwaters from all analyzed retention tanks ranged widely, from 0.0023 to 0.021 mg · dm^{-3}, and one may see considerable differences of this element concentrations registered in individual basins (Fig. 1).

Relative standard deviation for all basins was 69 %. Lead quantities found in road drainage waters were not high and only in 4 cases limit values for the highest quality class waters were exceeded, while only one sample was classified to the third quality class [6]. Wisniowska-Kielian and Niemiec [7] found on average three times smaller contents of this element in waters of the Dunajec River and its tributaries. Lead content in storm sewage runoff from heavily anthropogenically transformed areas is generally very high. Gobel et al [8] registered mean contents of 0.225 mg Pb · dm^{-3} in drainage waters from German expressways, whereas this element concentrations in runoffs from German car-parks were on the level of 0.170 mg · dm^{-3}. On the other hand Gnecco et al [9] registered lead contents of 0.006–0.025 mg Pb · dm^{-3} in the runoffs from urban

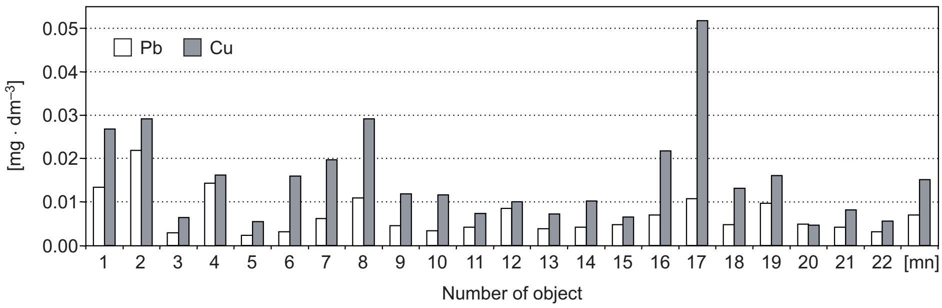

Fig. 1. Lead and copper concentration [mg · dm^{-3}] in rainwater taken from retention tanks; mn – the arithmetical mean of all measurements

roads in Italy, which approximates the values obtained in the presented research. Barret et al [10] report lead concentrations in surface runoffs from housing estates in Austin, Texas, on the level of 0.016 mg · dm^{-3}, whereas 0.041 mg · dm^{-3} was detected in runoffs from the city roads in the same place. Nordeidet et al [11] found lead content in runoffs from highways in the vicinity of Oslo on the level of even 0.7 mg · dm^{-3}. Ball et al [12] stated that vehicle traffic intensity affects lead concentrations in the surface runoffs the most, despite withdrawal of lead as the fuel supplement.

Copper concentrations in the analyzed waters ranged from 0.0046 to 0.0517 mg · dm^{-3} (Fig. 1) with mean for all objects 0.0152 mg · dm^{-3}. The average value of this element found in the Thames River water was 0.004 mg · dm^{-3} [13], whereas Wisniowska-Kielian and Niemiec [7] registered this element value in the Dunajec waters ranging from 0.0001 to 0.032 mg · dm^{-3}. Like in case of lead, considerable differences in copper concentrations were assessed between individual objects; relative standard deviation was 74 %. A similar as for lead concentrations trend for this metal level between the investigated reservoirs was observed. Concentrations of this metal were not high and only five samples were classified to the 2nd water quality class, while water from only one tank was assigned to 3rd quality class [6]. Kayhanian et al [14] found mean contents of copper in the runoffs from California roads of 0.035 mg · dm^{-3}, however the same authors point to great, sometimes several hundred-fold differences in this element levels between individual samples. Nordeidet et al [11] stated copper concentrations in the runoffs from expressways near Oslo of 0.1 mg · dm^{-3}, while its contents noted in urban areas distanced from the highways were between 0.035 and 0.05 mg · dm^{-3}.

Nickel concentrations in rainwaters collected from retention tanks were not high and fluctuated from 0.85 to 8.75 μg · dm^{-3} (Fig. 2).

Critical value for 1st class of waters quality is 10 μg · dm^{-3} therefore, with respect to their nickel concentrations, all analyzed samples were classified to waters of the best quality class [6]. Higher content of this element was found in the Thames water [13] and in dam reservoirs and rivers in the Upper Silesia Region [15]. Gobel et al [8] stated 24 μg Ni · dm^{-3} in runoffs from German highways. The same author reports Ni concentrations of 10 μg · dm^{-3} in runoffs from roads other than highways. Kayhanian et

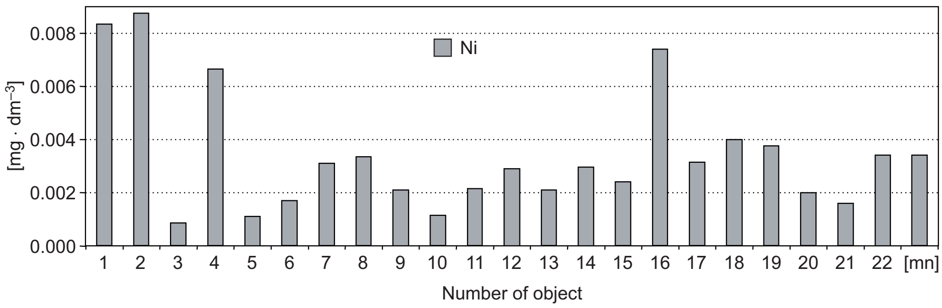

Fig. 2. Nickel concentration [mg · dm^{-3}] in water of retention tanks; mn – the arithmetical mean of all measurements

al [14] in their research noted similar mean values in runoffs from California highways to obtained in the present investigations.

The quantities of zinc in the analyzed waters ranged from 0.26 to 0.492 mg · dm^{-3} (Fig. 3), whereas relative standard deviation for all basins was 82 %. Only two samples had greater amounts of this metal than the contents admissible for the 1st class quality of waters [6]. Kayhanian et al [14] report 0.241 mg Zn · dm^{-3} in runoffs from California highways and only 0.075 mg · dm^{-3} in runoffs from uninhabited areas. The highest concentrations of zinc are found in the runoffs from roofs covered with zinc coated sheets. Gromaire-Mertz et al [16] found over 30 mg Zn · dm^{-3} in runoffs from the roofs of houses in Paris, whereas zinc concentrations assessed by Gnecco et al [9] in the runoffs from Italian roads were reaching 0.081 mg · dm^{-3} and runoffs from roofs revealed about five times greater Zn amounts. Wisniowska-Kielian and Niemiec [7] report on average about four times lower zinc content in water of the Dunajec River and its tributaries than found in the analyzed waters.

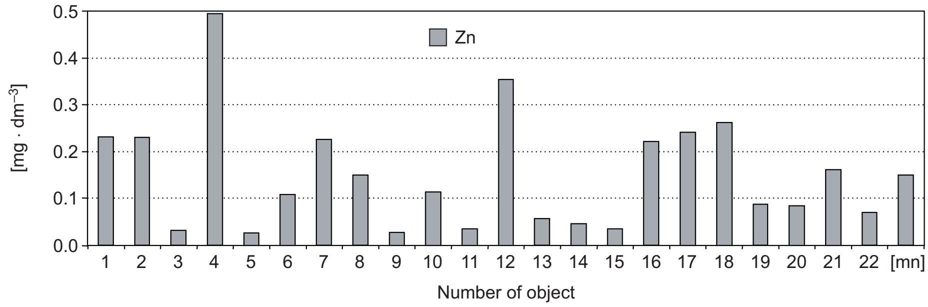

Fig. 3. Zinc content [mg · dm^{-3}] in water of retention tanks; mn – the arithmetical mean of all measurements

The studied waters collected from retention reservoirs did not reveal high heavy metal concentrations and according to legal regulations could be discharged into wastewater receivers [4]. Much higher concentrations are registered in rivers and reservoirs situated in industrialized areas. Kostecki [15] states almost five times higher concentrations of copper and zinc and over ten times greater contents of lead in the Klodnica River water flowing through the Upper Silesia Region.

Higher concentrations of all elements were registered in the reservoirs situated on the southern side of the road than in these on the northern side. This might have been caused by faster water evaporation in these tanks, which increased metal concentrations. Substantial differences in the contents of examined elements were found between the individual reservoirs. Wu et al [17] point to considerable differences in pollutant concentrations in runoffs from roads. Great differences of heavy metal contents in runoffs from antropogenically transformed areas are determined by precipitations, their frequency and intensity. The character of catchments is also very important, therefore element concentrations in runoffs may be vastly different between similar catchments [18]. Most elements originate from dry deposition and during rainfall are washed off the hardened surfaces [19]. The amount of metals in runoffs from roads depends on the contents of solid dust particles suspended in water, which greatly depends on traffic density [20]. Kazemi [21] found the strongest affinity of dust particles below 20 μg to heavy metals, ie the one whose largest numbers originate from vehicle traffic. Kayhanian et al [14] also point to relationships between dissolved and suspended metals. The values of suspended metals may be even several thousand times higher than the amounts dissolved in water [15, 22].

Metals, which are mostly present in a dissolved form are more mobile and bioavailable for living organisms. Lead poses the greatest hazard, while copper and nickel the smallest because these elements occur mainly in the unavailable forms. From among the investigated metals copper, zinc and lead are counted among pollutants strongly associated with intensity of motorization. Nickel assessed in runoffs from roads and highways originates mainly from other sources [12].

Conclusions

1. Heavy metal concentrations in waters collected from retention reservoirs situated along the national road No. 4 are not high and in no cases exceed the standards admissible for surface waters.

2. Considerable differences in the contents of analyzed metals were assessed between individual reservoirs.

3. Higher concentrations were determined in water from tanks situated on the southern side of the route than on the northern one.

4. Low concentrations of heavy metals in waters in the retention reservoirs may be a result of considerable amounts of organic and mineral suspension absorbing these pollutants in the bottom sediments.

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OCENA ZANIECZYSZCZENIA METALAMI CIĘŻKIMI WÓD OPADOWYCH SPŁYWAJĄCYCH Z DROGI Nr 4 POBRANYCH ZE ZBIORNIKÓW RETENCYJNYCH

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Abstrakt: Ścieki opadowe spływające z dróg są zbierane w przydrożnych zbiornikach retencyjnych, infiltracyjnych i odparowujących, Te zbiorniki są elementami systemu kanalizacji i zachodzi w nich proces podczyszczania spływów z dróg niosących znaczny ładunek zanieczyszczeń. Celem badań była ocena jakości wód opadowych pobranych ze zbiorników retencyjnych usytuowanych wzdłuż drogi krajowej nr 4 na trasie Kraków – Bochnia. Próbki pobierano z obydwu stron drogi i oznaczono w nich zawartość Zn, Cu, Ni i Pb.

Stężenie metali ciężkich w wodach opadowych pobranych ze zbiorników retencyjnych nie było duże i w żadnych przypadku nie przekroczyło wartości dopuszczalnych dla wód powierzchniowych. Stwierdzono wyraźne różnice zawartości analizowanych metali w próbkach z poszczególnych zbiorników. Wyższe zawartości metali oznaczono w wodach opadowych ze zbiorników usytuowanych po południowej stronie drogi niż po północnej stronie. Małe stężenie metali ciężkich w wodach opadowych ze zbiorników retencyjnych może być wynikiem dużej zawartości zawiesin organicznych i mineralnych absorbujących te zanieczyszczenia w osadach dennych.

Słowa kluczowe: wody opadowe, zbiorniki retencyjne, metale ciężkie, samooczyszczanie, jakość wody