Polish Journal of Environmental Studies Vol. 7, No. 2 (1998), 71 - 73

Heavy Metals in Bottom Sediments of Artificial Water Reservoirs in the Cracow Area

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Received 20 January, 1997
Accepted 14 November, 1997

Abstract

The content of Zn, Cd, Pb, Ni, Mn and Fe in bottom sediments of water reservoirs in Cracow has been investigated. Concentrations of heavy metals appeared to be more related to reservoir type and age than location. The most polluted sediments occur in river meanders cut in present time as well as in reservoirs affected by waste disposal. Reservoirs located in open pits are not polluted. However, reservoirs without inflow and outflow are the most sensitive to the accumulation of toxic metals. These reservoirs seem to be the most suitable for recreation.

Keywords: heavy metals, pollution, bottom sediments, reservoirs, Cracow

Introduction

Cracow (pop. 850,000) is located in the Silesian-Cracow industrial region in the southern part Poland. Despite a significant decrease in dust and waste emission the atmosphere and fresh waters of the city remain threatened by pollution [1, 2]. Sojourning of Cracow inhabitants in the polluted environment has caused a search for new weekend and summer recreation places. The hot summers of 1994 and 1995 brought large numbers of Cracow inhabitants to water reservoirs in the city. Most of these reservoirs are not adapted for recreation and, moreover, they have been used for fishing. Reservoirs vary in origin and have different degrees of contamination. The increased content of heavy metals in bottom sediments is a result of the long-lasting accumulation of airborne pollutants. In 1995 wet deposition of Zn, Cu, Pb and Cd approximated 133 mg/m^2, 5.4 mg/m^2, 1.0 mg/m^2, and 5.3 mg/m^2, respectively [3]. This caused increased heavy metal concentrations (particulary of Zn, Cd and, less frequently, of Pb) in soils of almost the entire Cracow area [4]. Seepage of contaminated ground waters as well as a number of illegal, uncontrolled landfills should be mentioned as other sources of pollution [4].

This project is going to examine the contamination of sediments of water reservoirs by heavy metals. It can be helpful for evaluating artificial water reservoirs in Cracow for recreation activity.

Area of Investigation

The territory of Cracow is approximately 327 sq. km (Fig. 1). The city is located on the border of a few different physiographic regions: the Cracow Upland, the Carpathian Foothils and the Sandomierz Basin. The Vistula is the main river in Cracow, flowing from west to east over 41.2 km. Moreover, there are four considerable tributaries of the Vistula: the Rudawa, Prądnik, Dłubnia and the Wilga Rivers. Their sources are outside of the city. There are many water reservoirs in the Cracow area. Most of them are of artificial origin, located in exploited and abandoned quarries and open pits [5].

Types of Water Reservoirs

There are seven genetic types of water reservoirs in the Cracow area (Fig. 1):

I) reservoirs located in open pits (after exploitation of sands, gravels, limestones),
II) fish ponds,
III) reservoirs located in former channels (from the present, early 20 th century, and pre-industrial periods),
IV) recreational reservoirs,
V) drinking water reservoirs,
VI) industrial ponds,
VII) other.

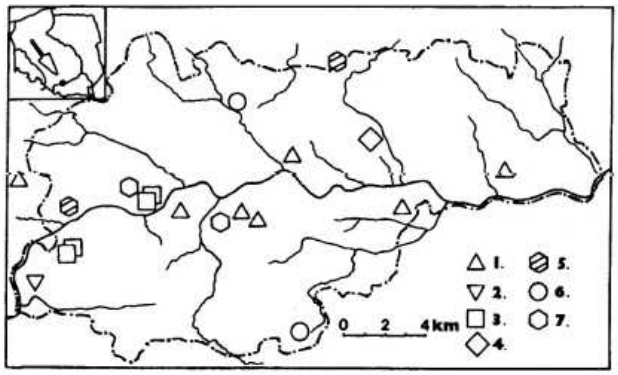

Fig. 1. Location of the sampling points in the Cracow area.
1 – reservoirs located in open pits, 2 – fish ponds, 3 – reservoirs located in former channels, 4 – recreation reservoirs, 5 – drinking water reservoirs, 6 – industrial ponds, 7 – other reservoirs

Reservoirs located in open pits are the most numerous. Some of them are used for recreation. They occur mainly in the southern and eastern part of the city (Fig. 1). There are also a lot of reservoirs located in former channels of the Vistula River in the Cracow area. They were cut during engineering works connected with an organization of navigation channels in the present time and in the beginning of the 20th century. Some of them were cut naturally during preindustrial times, [6]. Moreover, there are fish ponds and drinking water reservoirs located on the border of the city, industrial ponds in the middle, eastern and southern parts of the city, recreation reservoir in the eastern town district and other reservoirs (partly filled with industrial and municipal wastes).

Method

One set of grab samples of bottom sediments was taken from 19 reservoirs in duplicates from each one (Fig. 1). Sample sites were situated 1-3 m off shore, not deeper than 1.5 m. Each sample was placed in a clean plastic bag and dried at 105°C for 24 hours, followed by disagregation in a mortar and sieved to obtain a 0.063 mm fraction. The samples were digested in teflon bombs at 10 atm. pressure and then filtered. Obtained solutions were used for metal analysis by atomic absorption spectrometry (Varian 20). Concentrations of heavy metals were made by direct flame aspiration with an acetylene/air flame. Prepared standard no. 1648 from the U.S. National Institute of Standards and Technology were used for determining measurement precision.

Results

Results of heavy metals analyses are shown in Table 1. In general, the sediments of artificial water reservoirs are not rich in metals and they do not exceed two-times Clark values. The lowest concentrations of investigated metals occured in sediments of reservoirs located in a sand pits and in limestone quarry closed a few years ago. The concentrations are similar to background ones (Table 2). Higher concentrations of heavy metals occur in sediments of reservoirs located in former sand and gravel pits. This can be explained by the presence of significant quantities of Fe and Mn constituting hydroxides affecting the sorption process. Dusts emitted by one of the greatest steelworks in Poland (Nowa Huta, in Cracow) also strongly affected the concentration of heavy metals in the sediments of these reservoirs.

Maximum levels of all metals were detected in sediments of Vistula River meanders cut in present time. This is in agreement with the results of investigations of heavy metals carried out in the Vistula River channel [7]. The industrial sewage input is the biggest source of heavy metal contamination in the meanders. A major source of Zn, Cd, and Pb results from Silesia industrial region transported by

Table 1. Heavy metal concentration in sediments of water reservoirs in Cracow area (ppm) in July 1992.

Type of water reservoir	Zn	Cd	Pb	Cu	Ni	Mn	Fe [%]
I) In cavities:							
– sand-pits	29 – 50	0.2 – 0.3	14 – 20	13 – 25	8 – 14	63 – 99	0.56 – 0.73
– former sand-pits	132 – 174	0.5 – 0.9	41 – 45	26 – 49	20 – 23	106 – 328	1.04 – 2.07
– former gravel-pits	77 – 114	0.6 – 1.1	16 – 40	20 – 31	16 – 39	254 – 896	1.27 – 3.71
– former limestone quarry	31	0.6	17	18	14	68	0.23
II) Fish ponds	80 – 118	0.8 – 1.5	23 – 38	19 – 35	16 – 35	324 – 439	1.36 – 3.37
III) Former channels of the Vistula river:							
– cut in preindustrial time	54	0.7	18	23	19	260	1.3
– cut in the beginning of the 20 th century	71	0.9	20	23	19	264	1.2
cut in present time	2019	36.5	260	161	58	577	3.26
IV) Recreation reservoirs	574	4.5	79	33	28	283	2.12
V) Drinking water reservoirs	47	0.6	20	20	17	320	1.43
VI) Industrial ponds	53– 69	0.7 – 1.4	18 – 26	19 – 72	12 – 20	197 – 1500	1.0 – 1.85
VII) Other	132 – 435	2.9 – 7.4	53 – 139	37 – 64	34 – 98	146 – 618	2.08 – 5.9
Contemporary channels (after [7]):							
– of the Vistula River	4600	90	440	350	80	950	3.7
– of the Wilga River	1200	15	150	530	260	630	1.3

Table 2. Heavy metals in some reference rocks (ppm) after [9*, 10].

Rock type	Zn	Cd*	Pb	Cu	Ni
Continental crust	70	0.5	15	60	50
Limestones	20	0.08	5	5	20
Sandstones	30	0.07	10	12	1
Shales	100	1.3	22	35	70

the Vistula River, mainly from Zn and Pb ore mines located about 150 kilometers upstream.

Discussion

In general, heavy metals concentration in the reservoirs appeared to be more related to reservoir type and their age than location. Reservoirs located in open pits are not polluted and they seem to be the most suitable for recreation. Most of them have considerable dimensions and they are placed on the borders of the city. They could be adapted for recreation only by abiding by rules of environmental protection and first of all protection against waste disposal. Water reservoirs without inflow and outflow are the most sensitive to the accumulation of toxic substances in water as well as in bottom sediments. Air constitues the primary pathway of metals to these reservoir sediments.

Reservoirs located in the river meanders cut in present time should be exluded as recreation reservoirs. These reservoirs and other (type VII) are the most polluted in the investigated area. Water transport constitutes the primary pathway of the metals to these reservoirs sediments. The wastes thrown to reservoirs are also significant sources of pollution. Freshwater ecosystems are particularly sensitive to external trace metal input. The volumes of meander reservoir ecosystems are not large, and small additions from antropogenic sources can alter the size of a reservoir's metal load and, hence, the distribution and flow of metals in the ecosystem. The forms of trace metals in sediments are often available to the biota, and seemingly small concentrations may accumulate to high levels in the food chain. Metals in aquatic environment may cause the problem of toxicity to the valuable fish population. They might enter the aquatic food chain via ingestion by filter feeders. The bioaccumulation factor for copper, for example, in worms in the food chain is about 50X [8]. Heavy metals can be transported through the food chain to man. Besides, reservoirs located in the river meanders are not attractive as they are located close to the strongly polluted Vistula River and they are overgrown with vegetation.

The results of this study suggest that there are possibilities of adapting existing artificial reservoirs for recreation in the Cracow area. However, reservoirs located in the Vistula River meanders and reservoirs partly filled with industrial and municipal wastes should be excluded.

The basis for modern management of water reservoirs should be enforced by local laws protecting water and air quality and administrating appropropriate penalties for failing to observe these laws. It is also important to organize recreational facilities in the vicinity of water reservoirs designated for this type of activity.

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