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Heavy metal contributions of run-off waters discharging into the Ikpoba Reservoir during rainy season

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ABSTRACT: Heavy metals contributions of run-off waters from six sources discharging into the Ikpoba reservoir and the immediate upstream and downstream Ikpoba River were investigated during the rainy season months (March – October) of 1991 and 1992. In the reservoir, the results revealed that the highest contribution of heavy metals came from Okhoro road (11.028%), followed by the solid waste dumpsite (9.256%) on the bank of the reservoir. In the downstream Ikpoba section, Upper Mission Road had the highest percentage contribution of 11.67% while in the upstream section the Agricultural farm had the highest percentage contribution of 6.150%. Of all the metals, Zn had the highest percentage contribution (73.74%) while Cd had the lowest contribution (0.39%). Cd had the highest contribution in discharges from Upper Mission Road, Cr and Zn from Okhoro Road, Cu from the headworks discharge pipe, Pb from Upper Lawani Road, Mn from the Agric. farm and Ni from the solid waste site. The mean metal contributions of Cd, Cu, Pb, Ni and Zn from the six sources into the reservoir were higher than the mean contributions from upstream Ikpoba River. Cr, Mn and Ni were also higher in the reservoir waters than the downstream Ikpoba River.

Key Words: Run-off waters; Heavy metals; Ikpoba reservoir, Nigeria; Solid waste dumpsite; Environmental pollution.

Introduction

Storm water run-off flushes heavy metals from surfaces and discharges them into receiving water bodies and the resulting heavy metal loading may represent a significant amount of the total metal entering local receiving waters (Ellis *et al*., 1986). In spite of this, the evaluation of concentrations and impacts of heavy metals discharged into urban receiving waters by storm water run-off has received relatively little attention (Gast *et al*., 1990).

The Ikpoba River is the only river system draining Benin City. Recent reports on Benin City have shown that the old cultural city is becoming highly industrialized with factories using modern equipment and technology. Although some of these large-scale industries are situated some distance away from the river, the effluents are directly discharged or are brought into the river system through run-off waters during the rainy season.

Studies on the river (Oguzie, 1996) and the reservoir (Fufeyin, 1994) indicated contamination of the waters, sediment and fish by heavy metals such as chromium, copper, iron and lead. In these reports, the levels of chromium and iron were found to have exceeded the WHO recommended allowable limits in drinking water, while in some fish species Cr, Cu and Pb were found in concentrations higher than the recommended limits in food.

These studies reported levels of different metals in water, sediment and fish but did not consider the possible sources of the metals to the river and the reservoir. The present study was, therefore, carried out to investigate the contributions of heavy metals from run-off water discharges entering the Ikpoba reservoir during the rainy season months in 1991 and 1992. The metals contribution from the immediate upstream and the concentration entering the downstream Ikpoba River from the reservoir during this period were also investigated and compared.

Materials and Methods

Study Area

The Ikpoba reservoir is in Benin City, Nigeria (Lat. 6.5^{o}N, Long. 5.8^{o}E) (Fig. 1a). In 1982, the Ikpoba River was impounded to form the reservoir which now covers an area of 107.5 hectares with a crest level of 36.8m. It is about 2.15 km long and 320m wide. The reservoir is located on the Benin formation which is composed of coarse sand, interspersed with lignite and patches of lateritic sandy clay. The area is surrounded by arable farmlands. Human activities around the reservoir included washing of clothes, bathing, a poultry farm at the northern end, a refuse dump site at the western bank, small scale industries such as a foam factory, several sawmills and a colour photo laboratory.

Twelve points of discharge (Fig. 1b) were sampled from the river and the reservoir. Three points from the upstream Ikpoba River at Ekosodin village road, bridge pools and Agric. farm. Six points from the reservoir at Ute village Road, Benin Technical College Road, Okhoro Road, Ekiuwa Road, Solid waste dump site and Temboga Road. Three points from the downstream river from the head works discharge pipe, Upper Lawani Road and Upper Mission Road.

Sampling

Sampling was carried out monthly during the rainy season months of April to September 1991 and 1992. Water samples were collected directly from the points of discharge into the Ikpoba reservoir (Fig. 1b) in pre-washed and pre-dried polyethylene bottles, acidified with nitric acid (APHA, 1989) and kept in the laboratory until needed for analysis.

Water samples were analysed for heavy metals (Cd, Cr, Cu, Pb, Mn, Ni and Zn) with a Varian Techtron Spectr-AA-10 atomic absorption spectrophotometer while Fe was determined by 1-10 phenanthroline method (APHA, 1989). All laboratory equipment and sample bottles were thoroughly cleaned with nitric acid according to the method of Martin *et al*. (1992). All analytical quality control requirements were strictly adhered to. Statistical analysis was carried out using the Student t-test.

Results

Table 1 shows the metals contributions from three points of run-off discharging into the upper and lower Ikpoba River respectively and six points of run-off discharge into the Ikpoba reservoir.

The results indicated that Okhoro Road contributed the highest percentage (11.03%) of heavy metals to the reservoir, followed by the solid waste dump site (9.26%). The other stations contributed between 5.0 and 7.4% each in the following order: Tenbogo Road > Ekiuwa Road > Benin Technical College Road > Ute Road. In the upstream station, the run-off from the agricultural farm had the highest contribution of 6.0% while in the downstream station Upper Mission Road had the highest contribution of 11.67%. From all the points of discharge, Upper Lawani Road had the lowest percentage contribution (4.57%) of heavy metals. Results of the computed mean and percentage contribution of each heavy metal revealed that Zn had the highest percentage contribution (75.75%) into the Ikpoba River, followed by Cu (1.73%). Other contributions were in the following order: Cr (4.41%) > Mn (2.22%) > Pb (1.23%) = Ni (1.23%) > Cd

(0.39%). The stations that had the highest concentration of the individual metals are Upper Mission Road for Cd, Okhoro Road for Cr and Zn, the headworks discharge pipe for Cu, Upper Lawani Road for Pb, the Agric. farm for Mn and the solid waste dump site for Ni. The mean metals concentrations discharged into the reservoir were compared to the mean contributions into the waters of the upstream and downstream Ikpoba River (Table 2). The results revealed that the mean metal contributions of Cd, Cu, Pb, Ni and Zn were higher in the run-off waters flowing into the downstream station than those into the upstream station while Cr and Mn were higher in the waters flowing into the upstream than the downstream station. A look at the profile of the three stations together revealed that Cr and Mn were highest in the upstream station, Ni in the reservoir, Cd, Cu, Pb and Zn in the downstream stations. All the metals showed ascending or descending patterns from upstream or downstream except Ni.

Table 1: Mean metal concentrations from the various points of run-off discharge into the Ikpoba reservoir.

Upstream	Heavy metals (%)							
	Cd	Cr	Cu	Pb	Mn	Ni	Zn	Total
Ekosodin Village Road	0.018	0.318	0.280	0.06	0.329	0.06	4.688	5.753
Bridge Pools	0.017	0.309	1.200	0.06	0.338	0.04	4.700	5.664
Agricultural Farm	0.026	0.266	1.500	0.04	0.390	0.08	3.700	6.002
Mean	0.020	0.298	0.066	0.053	0.352	0.06	4.029	17.419
Reservoir								
Ute Village Road	0.020	0.200	0.70	0.05	0.126	0.04	4.00	5.135
Benin Technical College Road	0.024	0.319	1.44	0.07	0.095	0.06	3.90	5.908
Okhoro Road	0.028	0.350	0.50	0.11	0.050	0.09	9.90	11.028
Ekiuwa Road	0.024	0.220	1.30	0.06	0.033	0.04	4.64	6.317
Solid waste dump site	0.026	0.297	1.60	0.06	0.033	0.24	7.00	9.256
Tembogo Road	0.026	0.309	0.40	0.04	0.089	0.07	6.50	7.434
Mean	0.025	0.283	0.99	0.065	0.071	0.09	4.323	39.943
Downstream								
Head works discharge pipe	0.016	0.152	3.10	0.05	0.022	0.02	3.80	7.060
Upper Lawani Road	0.031	0.216	0.09	0.26	0.064	0.08	3.83	4.571
Upper Mission Road	0.036	0.340	1.50	0.10	0.090	0.10	9.50	11.666
Mean	0.028	0.235	1.53	0.137	0.059	0.067	5.71	23.297
Grand Total	0.292	3.296	12.510	0.960	1.659	0.920	55.158	74.795
Percentage of grand-total	0.390	4.407	16.726	1.230	2.218	1.230	73.746	100.00
Mean	0.024	0.275	1.043	0.080	0.138	0.077	4.597	

Discussion

The effects of urban storm water discharges on receiving waters depend largely on the type of discharge, the volume and load, the terrain it flows through and the type of receiving water. The relationship between rainfall and its effect upon receiving waters is not clear. In this study, broad effects of discharges flowing through various roads, a waste disposal site and an agricultural farm on the Ikpoba River waters were investigated.

Table 2: Mean metal levels from the points of run-off discharge into the Ikpoba reservoir, the immediate upstream and downstream sections of the Ikpoba River.

	Heavy metals (%)						
	Cd	Cr	Cu	Pb	Mn	Ni	Zn
Upstream	0.020	0.298	0.066	0.053	0.352	0.060	4.029
Reservoir	0.025	0.283	0.990	0.065	0.071	0.090	4.323
Downstream	0.028	0.235	1.530	0.137	0.059	0.067	5.710

Okhoro Road contributed the highest percentage of metals to the reservoir and this was attributed to the presence of industries and factories which all discharge their effluents into gutters that empty directly into the Ikpoba reservoir. The solid waste dumpsite was also found to contribute the next highest percentage of heavy metals. This could be due to the presence of different materials which were sources of heavy metals and which find their way into the water system and continue to pollute the environment even after dumping activities have ceased. It was observed during sampling that the heap of refuse on the western bank of the reservoir had materials such as asbestos, empty bottles and cans, batteries, waste paper, iron rods, wood etc. which were ready sources of heavy metals.

Of all the heavy metals, Zn had the highest mean and hence the highest percentage contribution. This finding was not surprising because it was observed that the inhabitants around the reservoir, especially around Okhoro Road and immediately after Upper Lawani Road use this place as a convenient dumping site for human waste. This is in line with the finding of Forstner and Prosi (1979) who reported that Zn is relatively high (7 – 20 mg excreted per day) in human excrement. Solid waste also has been reported by Barcellos *et al*. (1991) to have high concentrations of Zn. On the other hand, high concentrations of Cu may be explained by the fact that there is high enrichment or flushing effect through inputs from run-off coming from the surroundings especially from the solid waste on the bank of the reservoir.

The high concentrations of Cr from Okhoro Road may be attributed to the presence of the colour photo laboratory which discharges its effluents into the reservoir. Mn has been associated with domestic waste and agricultural run-off. Therefore, its high concentrations in the waters from the Agric. farm is not surprising. One major source of Pb to the aquatic habitat has been traced to automobile exhausts (Enk and Mathis, 1977; Mombeshora *et al*., 1981). The exhaust fumes (with Pb and Cd) are deposited on the soils and washed by run-off waters into the aquatic environment. The Upper Lawani bank therefore has been known to be a bus stop and car wash depot for over a decade, hence its high content of Pb is expected. The presence of batteries, household appliances, welded rods, paper, etc. may have contributed to the high concentrations of Ni from the solid waste dumpsite.

The results presented here also show that the mean concentrations of the metals discharged into the reservoir (except Zn) were higher than those in the reservoir waters, and this confirms high anthropogenic input especially for Cu, Mn and Ni. Fufeyin (1994) reported that precipitated metals (resulting from dissolution of readily soluble air borne solids) are generally present in low concentrations but tend to be swamped in storm water by the abundance of metals in road dusts. Although Cu and Pb rapidly form complexes by adsorbing to suspended solids, they are released back into the water column during the rainy season. The waters may therefore have high metal concentrations depending on the available metals in the sediments and further releases of these metals occur under heavy flow conditions (Morrison *et al*., 1990).

Cr, Mn and Ni were also found in lower concentrations in the lower Ikpoba River waters than the reservoir waters indicating entrainment of these metals from the reservoir waters to the bottom sediment before leaving the reservoir.

The partitioning of metals between water and sediment depends on a number of environmental sensitivity factors such as the state of the metal. Morrison *et al*. (1990) reported that Cd showed tendencies to remain in the ionic state which makes it a considerable threat to receiving waters, biota and the general water quality. The prevailing physical and chemical conditions of the water and its ability to combine with other organic compounds to form complexes are also factors that affect metal distribution between water and sediment. Cu has been reported by Gast *et al*. (1990) to be fairly evenly distributed between the soluble and insoluble phases with about 34 percent present in weakly complexed dissolved forms. Pb was, on the other hand, reported to be predominantly associated with suspended solid and with only about 12 percent found in the dissolved phase.

Fufeyin (1994) reported that metals enter the aquatic system either in the solid or aqueous form. In this study, Pb and Mn were suspected to enter the reservoir in the solid form while Cd and Zn were suspected to enter in the aqueous form. Cd, Cu, Pb and Zn increased from upstream to the downstream station while Cr and Mn decreased in the same order. The high metal concentrations in the downstream station could be attributed to addition effects from upstream station, the reservoir and from anthropogenic inputs.

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