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Industrial Discharges of Metals in Kigali, Rwanda, and the Impact on Drinking Water Quality

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Rwanda is a landlocked country located in Africa's Central-East Great Lakes region. It has a population of 7.5 million which occupies 26,338 km^2. Its population density (285/km^2) is one of the highest in the world and has prompted fear of a rapid degradation of the ecosystem. There are no central sewer systems in Rwanda. The use of pit latrines and septic tanks is common in urban and rural areas. People still defecate in the fields (World Bank, 1989). Less than half of the urban population is served by a central water supply. The majority of people get their water untreated from rivers that have been polluted by chemicals and human excreta. In and around the capital city of Kigali, there is a concentration of people, farms, and industries which discharge wastewater into the Nyabarongo River and its tributaries. The Nyabarongo River, a tributary of the Nile, empties into the Akagera River which flows into Lake Victoria. Nyabarongo River water is used for drinking water, cooking, bathing, and agriculture in the Kigali area. There has been very little monitoring of the water quality of the Nyabarongo River and of industrial outfalls located on tributaries of the Nyabarongo River.

As a first step in understanding the water quality of the Nyabarongo River, wastewater samples were collected in 1993 from industrial outfalls located on tributaries of the Nyabarongo River. Most of the facilities sampled had no wastewater treatment. The impact of these discharges on the water quality of the Nyabarongo River was evaluated.

MATERIALS AND METHODS

One wastewater discharge sample was taken from the outfalls of 16 industrial facilities located on tributaries of the Nyabarongo River. These 16 facilities represent about 70% of the significant industrial

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facilities in the Kigali area. The samples were collected from July 14 to September 9, 1993. All wastewater samples were analyzed for seven metals (Zn, Cu, Cr, Sn, Pb, Ni, and Cd) using a Perkin Elmer Model 373 Atomic Absorption Spectrometer at the School of Agriculture Laboratory of the National University of Rwanda in Butare. The detection limit was 0.001 mg/L. Laboratory methodology followed Standard Methods for the Examination of Water and Wastewater, 17th edition, 1989.

In order to evaluate the impact of the wastewater outfalls on the water quality of the Nyabarongo River, a simple complete mixing model was used to estimate the theoretical concentrations of metals in the Nyabarongo River from the industrial outfalls:

$$C_N = (Q_I \times C_I)/(Q_N + Q_I)$$

where C_N = metal concentration in the Nyabarongo River

Q_I = flowrate of the industrial discharge (see Table 1)

C_I = metal concentration of the industrial discharge (see Table 1)

Q_N = flowrate of the Nyabarongo River

The metal contributions from the 16 outfalls were totaled in Table 2. Upstream metal contributions are accounted for in Table 2 under The flowrate of the Nyabarongo River ranges from 561,000 to 1,658,880 m^3/day. The low flowrate was used in the calculations.

RESULTS AND DISCUSSION

As shown in Table 1, several facilities are discharging kg levels of metals per day: Kigali Hospital, Sulfo, Battery Factory, and Utexrwa. There is concern that people may use the water from the industrial outfalls. Fortunately, the color and taste deter them from using outfall water for cooking and drinking. However, there are fish ponds in the Kigali area that obtain some of their water from these outfalls.

The estimated impact on the Nyabarongo River of metals discharges in the tributaries of the Nyabarongo River is shown in Table 2. None of the total metal concentrations exceed USEPA Drinking Water Standards (DWS) shown in Table 2 because of the high flowrate of the Nyabarongo River. However, it should be noted that the lead concentration at 0.013 mg/L is quite close to the DWS of 0.015 mg/L.

Table 1. Outfall metal concentrations (mg/L), metal discharge rates (g/day), and flowrates (m^3/day)[a]

Industry	Zn	Cu	Cr	Sn	Pb	Ni	Cd
NPS Q = 3	3 9	0.1 0.3	0.15 0.45	0.8 2.4	0.6 1.8	0.25 0.75	BD
Sakirwa Q = 1500	0.04 60	0.05 75	0.1 150	0.1 150	0.4 600	0.1 150	BD
SH Q = 2100	0.04 84	BD	BD	BD	BD	BD	BD
Tolirwa (ironsheet) Q = 2.5	69.5 174	BD	BD	BD	BD	BD	BD
SF Q = 500	0.42 210	0.1 50	BD	BD	BD	BD	BD
HK Q = 400	4.6 1840	BD	BD	0.02 8	0.5 200	BD	BD
Sirwa Q = 4.5	0.1 0.45	BD	BD	BD	.001 .005	BD	BD
Sulfo Q = 700	18.6 13E3	24.5 17E3	1 700	BD	8.5 5950	4 2800	0.5 350
Bralirwa Q = 120	0.15 18	BD	BD	BD	BD	BD	BD
BF Q = 10	520 5200	0.16 1.6	1.5 15	BD	6.9 69	BD	BD
CT Q = 10	0.29 2.9	025 0.25	BD	BD	BD	BD	BD
Prison Q = 115	6.4 736	025 2.9	.625 72	BD	3.1 357	BD	BD
Ovibar Q = 150	1.21 182	.175 26	0.05 7.5	BD	BD	BD	BD
Q = 5	30.8 154	0.2 1	0.65 3.3	BD	1.4 7	BD	BD
Tannery Q = 1000	0.11 110	0.1 100	3.75 3750	BD	BD	BD	BD
Utexrwa Q = 500	15 7500	0.18 90	1.48 740	BD	BD	BD	BD

[a] The first number in each cell refers to metal concentration in mg/L. The second number in each cell refers to metal discharge rate in g/day. Q refers to outfall flowrates in m^3/day. BD = below the limit of

detection of 0.001 mg/L. NPS = National Printer Set; Sakirwa = Soap Factory; SH = Slaughterhouse of Nyabugogo; Tolirwa = Iron Sheet Factory; SF = Sugar Factory; HK = Hospital of Kigali; Sirwa = Paint Factory; Sulfo = Soap Factory; Bralirwa = Sweet Beverage Factory; BF = Battery Factory; CT = Chillington; Ovibar = Banana Factory; RP = Rwanda Paints; Utexrwa = Textile Factory.

Table 2. Estimated metal concentrations in the Nyabarongo River at low flow resulting from industrial discharges into its tributaries (mg/L x 10^{-5})[a]

Industry	Zn 5	Cu 1.3	Cr 0.1	Sn none	Pb .015	Ni 0.1	Cd .005
NPS	1.6	0.053	0.080	0.43	0.32	0.13	BD
Sakirwa	11	13	27	27	107	27	BD
SH	15	BD	BD	BD	BD	BD	BD
Tolirwa	31	BD	BD	BD	BD	BD	BD
SF	37	8.9	BD	BD	BD	BD	BD
HK	328	BD	BD	1.4	36	BD	BD
Sirwa	0.08	BD	BD	BD	8E-4	BD	BD
Sulfo	2320	3060	125	BD	1060	500	62
Bralirwa	3.2	BD	BD	BD	BD	BD	BD
BF	926	0.28	2.7	BD	12	BD	BD
CT	0.52	0.045	BD	BD	BD	BD	BD
Prison	131	0.51	13	BD	64	BD	BD
Ovibar	32	4.7	1.3	BD	BD	BD	BD
RP	27	0.18	0.58	BD	1.3	BD	BD
Tannery	20	18	668	BD	BD	BD	BD
Utexrwa	1340	16	132	BD	BD	BD	BD
Total	5223	3122	970	29	1281	527	62

[a] The numbers under the metal symbols refer to USEPA primary drinking water standards in mg/L.

REFERENCE

World Bank (1989) Rwanda Public Expenditure Program, Vol II, Washington.