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Short communication

THE IMPACT OF UNCONTROLLED WASTE DISPOSAL ON SURFACE WATER QUALITY IN ADDIS ABABA, ETHIOPIA

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ABSTRACT: The main threat to the surface water quality in Addis Ababa is environmental pollution derived from domestic and industrial activities. Due to the inadequacy of controlled waste management strategies and waste treatment plants, people are forced to discharge wastes both on open surface and within water bodies. Uncontrolled (improper) waste disposal has deteriorated the quality of surface water (streams, rivers, reservoirs) by changing the chemical, physical and organoleptic properties of water. Chemical analyses of surface and shallow groundwater samples taken at various points along streams and different springs show that the level of unwanted chemical constituents such as nitrate and chromium, for example, are higher than the background level. Among the main causes are poor economy and lack of proper waste disposal systems that lead the residents to dump wastes illegally within the water bodies. Important measures to alleviate the problem are to develop the environmental awareness of the residents, proper control on industries, establishment of a widespread waste collection system and improved landfill technology.

Key words/phrases: Addis Ababa, Akaki river, toxic substances, uncontrolled waste disposal, water quality

INTRODUCTION

The city of Addis Ababa is one of the fast expanding cities in the country and presently covers an area of about 500 km^2. In many developed countries, proper urbanization takes into consideration equivalent growth in waste removal facilities. In the case of Addis Ababa, the waste collection system (both solid and liquid) did not progress in proportion to its expansion and consequently the impact of these wastes on the water environment is increasing.

Groundwater from borehole or spring is the source of drinking water in the peripheral parts of the city, where there is a shortage of a municipal water supply network. These supplies also provide the population with water during the failure of the distribution network fed by the reservoirs.

In the city, streams and rivers receive the major part of the waste produced by the residents. In the southern part of the city the same rivers serve for various purposes such as horticulture, drinking water for cattle, washing, and for other domestic activities.

A systematic environmental study has not been carried out in the city so far. The few relevant studies include that of EPA (1997), where the Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO) at limited sampling points on Big Akaki, Little Akaki and Kebena rivers, are presented and that of Adane Bekele (1999) who carried out regional sampling and presented analytical data on industrial effluents for some streams in the city.

The present work is aimed at evaluating the impact of uncontrolled waste disposal on surface water quality in Addis Ababa in an attempt to raise awareness on environmental protection in Ethiopia in general and in Addis Ababa in particular. In this regard the paper characterizes the surface water on the basis of anthropogenically induced chemical constituents. Its further impact on the shallow groundwater system is also assessed.

BACKGROUND

Geological setting

From geological point of view, the Addis Ababa region is constituted of volcanic rocks and minor amounts of fluvial sediments. Distinct volcanic centres of Plio-Pleistocene age include Mt. Wochacha (3385 m a.s.l), Mt. Yerer (3100 m a.s.l), and Mt. Furi (2839 m a.s.l). The northern part of the region is made up of Cenozoic flood basalts, felsic flows and intrusions overlain by shield volcanics. The main lithologies are basaltic, rhyolitic and trachytic, trachybasaltic lava flows and welded tuffs found at different localities and ages. They are comprised between 27 Ma and 3.2 Ma (K/Ar) (Haile Selassie Girmay and Getaneh Assefa, 1989), and are highly fractured and weathered. The main tectonic structures include small-scale joints, fractures and major normal faults such as the Filwoha Fault that was formed between 5-6.4 Ma (Haile Selassie Girmay, 1985). These features are parallel to the faults in the Ethiopian Rift and represent the western rift boundary in the region.

Surface water system

Akaki river and four water reservoirs, namely Legedadi, Gefersa, Dire and Aba-Samuel, represent the main surface water bodies within and in the vicinity of Addis Ababa. Basically the Akaki river has two main branches: the Big Akaki and the Little Akaki. The Big Akaki river has many tributaries among which Ginfile, Kebena, Kechene, Kurtume and Yeka are all found within the eastern part of the city boundaries. The Little Akaki river basin covers the western part of the city (Fig. 1). During the rainy season the city appears cleaner from wastes as it is located on sloppy ground that increases the velocity and hence the mobility force exerted by the surface runoff, which takes away the wastes. Even though rivers and streams represent self-renewing resources, continuous input of wastes may change them into natural sewerage lines.

Surface water is the main receiver and transmitter of pollutant into the groundwater body. Hence, protection of surface water from pollution is directly related to the protection of groundwater system. It is clear that groundwater and surface water commonly form a linked system through the geologic medium. In this case, pollutants may be transferred easily through fractures, where soil cover is absent, in the upper and central part of the city. Porous geologic materials like alluvial deposits and weathered rock profiles have considerable self-purifying capacity and take out unwanted constituents including bacteria.

Waste disposal system

The most widespread waste disposal mechanisms in the city may be categorized as uncontrolled (improper) waste dumping. Forms of improper waste disposals commonly practised in the city include defective septic tanks, open dumps, surface impoundments and land application.

According to NOR consultants (1982), the solid waste distribution in the city consists of: domestic waste (76%), street sweepings (6%), commercial wastes

(9%), industrial wastes (5%), wastes from hotels (3%), and wastes from hospitals (1%). The data on housing show that a total of 380307 housing units are found in the city out of which 74.1% have a toilet facility. About 63.2% of these are dry toilets.

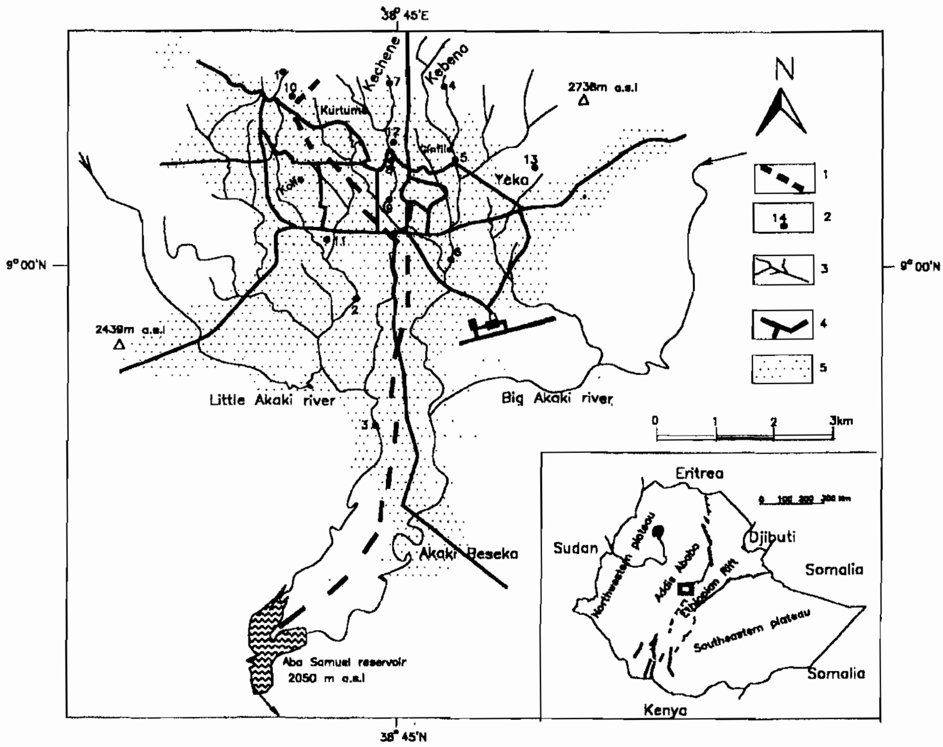

Fig. 1. Location map of streams and sampling points. 1, Surface water divide between Big and Little Akaki rivers; 2, Sampling points and sample numbers; 3, Stream network; 4, Major roads; 5, Urban area.

A report of the Central Statistics Authority (1999), showed that 65.3% of the total industry in the country is found in Addis Ababa. Industrial centres play a role in polluting surface and ground water unless managed and designed with appropriate waste water purifying plants.

From visual observation in the city it is possible to say that the distribution and the services of municipal garbage tanks are not adequate. Hence, the residents have no choice but to discharge domestic refuses where there is open space, along roadsides, bridges and culverts, and directly into streams. The accumulation of solid wastes out of the permitted sites attracts rodents, insects and scavengers that pose health risk to residents.

Some of the reasons for illegal dumping are inadequacy of garbage tanks, delay of pickup services for trash and the lack of environmental awareness.

Land use in the city

The main land use pattern in the city embraces residential areas, market quarters, industrial zones, agricultural areas, forest, and quarries. The rapid urbanization requires wide areas for various purposes and hence the size of the city is increasing at high rate. Presently industrial areas are located in the southern sector along the river channels and in the outskirts of the city. The central part of the city includes residential quarters, governmental offices, churches, schools and colleges, airports, parks, sport grounds, and various sized markets. About 0.3 km^2 of land south west of the city serves as waste dumping site.

SAMPLING AND ANALYSIS

After thorough evaluation of surface water systems and hazard centres, water sampling points were identified (Fig. 1) to assess the extent of water pollution. Two to three water samples were collected in June 1999 at one time (before noon) at different points along the length of each stream found in the city. Appropriate plastic bottles and gloves were used for sample collection. This technique was designed to investigate the enrichment and/or depletion of chemical constituents in the surface waters. For comparative purposes some of the major springs found in the city have also been considered. The current work is intended to investigate spatial variation of the chemical constituents.

The samples have been analyzed for major element and selected trace elements at the Department of Geology and Geophysics, Addis Ababa University. The instruments used for analysis are Perkin-Elmer UV/VIS spectrophotometer and atomic absorption spectrophotometer. On site measurement of pH was carried out by digital microcomputer pH meter. The data were analyzed with an accuracy range of 0.56 % to 10.39%. The reported percentage values represent calculated error band for different cations and anions.

Bacteriological analysis of few water samples has been carried out in the Central Laboratory of Ethiopian Food and Nutrition Study.

RESULTS AND DISCUSSION

The analytical results corresponding to all samples collected from streams and selected springs are presented in Table 1. The data show relatively high concentrations of Cl, NO_3, COD, Cr, and Mn presumed to have been released from both domestic and industrial activities.

Little Akaki river receives large part of the waste released from the west-central part of the city including the big market centre "*Merkato*" and from a number of factories including a winery, a brewery, a soft drink factory, a liquor factory, several tanneries, a slaughterhouse, and others. This is clearly shown by the concentration of chemical constituents like Cl, Mn and Cr that increase downstream. The high abundance of such chemical constituents that do not concentrate naturally is strong evidence of water pollution by industrial wastes.

The Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) values in the upstream samples are low (8–11 mg/l). This indicates unpolluted environment with high dissolved oxygen in the water. The Big Akaki river has a BOD value of 13 mg/l (Table 2) at the inlet to the Aba Samuel reservoir, while the sample taken from the reservoir outlet shows low value of BOD (0.8 mg/l). This suggests that Aba Samuel reservoir acts as an oxidation chamber in which the water regenerates its dissolved oxygen content. During the site visit, fish and insects were observed in the reservoir, which could indicate the regeneration of dissolved oxygen in the water. From the variation of BOD, it is possible to note that Little Akaki river is more polluted than the Big Akaki river and has high nutrient enrichment and consequently low dissolved oxygen.

Table 1. Analytical results for the stream and spring samples. Zero values represent below detection limit (Analysis in June 1999).

Chemical parameters	Kolfe stream			Kebena stream			Kechene stream			Springs			
	Minch Saloon	Near Kera	Near Behere Tsige	Up stream	Near German Embassy	Near Urael Church	Up stream	Near Ras Mekonen Bridge	Near Zewditu Hospital	Addisu Gebeya	Lideta	Ras Mekonen Bridge	Yeka North
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13
PH	6.1	7.68	7.51	6.08	7.22	7.48	6.5	7.63	7.6	6.32	6.49	6.31	5.86
Na mg/l	31	76	90	15	74	28	12	45	44	33	31	38	8.2
K mg/l	3	28	24	6	21	17	7	24	23	8	4	3	6
Ca mg/l	25	53	50	15	67	36	7	43	44	22	48	100	6
Mg mg/l	12	26	23	5	35	15	3.6	24	23	11	28	60	21
HCO_3 mg/l	57.96	219.7	176.7	6.1	219.7	122.04	18.31	152.6	158.7	30.5	146.4	61.02	42.71
Cl mg/l	49.5	109.9	102.5	8.6	106	34.2	3	70	40.6	34	194	56.5	2.2
SO_4 mg/l	Nd	8.3	0.44	23	19.7	9.26	10.2	22.11	24.11	6.5	23.1	19	0
PO_4 mg/l	0.13	3.65	3.03	Nd	Nd	2.09	0.29	3.54	3.78	0.89	0.21	0.12	0.11
NO_3 mg/l	86.19	23.51	9.66	531	188.14	8.96	99.6	17.3	9.53	184.6	728.21	481.41	55.34
SiO_2 mg/l	55.5	32.9	16.23	27	34.1	33.6	25.2	47.2	47.08	30	87.5	69.9	49.2
COD mg/l	8	80	24	14.4	27.2	20	16.5	46.12	40	17.6	11.2	6.4	20.8
Cr μg/l	0	5.5	14.1	0	0	0	5.76	0	0	0	1.88	1.18	0
Mn μg/l	34.1	123-0.2	1756.7	12.3	6531.6	1219.01	63.115	1141.6	1550.8	128.6	0.303	21.47	22.6
Ni μg/l	44.5	9.2	4.8	0	0	0	0	0	0	0	0	0	0
Zn μg/l	0	0	0	0	0	0	54.21	0	81.53	0	0	0	0
As μg/l	0	0	2.3	1.24	0	0.59	1.005	0.126	0.096	0	0.9979	0	0
Pb μg/l	0	0	0	0	0	0	7.873	0	0	0	0	0	0

Table 2. Biological oxygen demand, chemical oxygen demand and dissolved oxygen concentration in surface water bodies in Addis Ababa (taken from EPA, 1997).

	Sample location	BOD mg/l	COD mg/l	DO mg/l
	Tributary of Little Akaki near Asko Shoe factory	8	48	6.9
	Little Akaki near ALERT bridge	8	23	5.8
	Little Akaki After MedhaneAlem high school bridge	301	621	0
Little Akaki Basin	Little Akaki near Mekanissa bridge	19	56	4.4
	Little Akaki near Mekanissa liquor factory bridge	254	375	1.3
	Little Akaki inlet to Aba Samuel lake	321	708	0
	Outlet from Aba Samuel lake	0.8	15.6	7.4
	Kebena at French Embassy bridge	11	43	6.8
Big Akaki Basin	Kebena at Bole bridge	29	105	7
	Big Akaki inlet to Aba Samuel lake	13	28	5.2
	Outlet from Aba Samuel lake	0.8	15.6	7.4

The samples analyzed from springs contain extremely high NO_3 concentration as much as 728 mg/l. It is assumed that these are the result of leaking septic systems. A guideline maximum value of 50 mg/l of nitrate as NO_3 is recommended by WHO (1984) for drinking purpose. However, springs strongly contaminated by nitrate are used by residents for drinking. According to WHO (1984), high nitrate level causes methaemoglobinaemia in infants and in older age groups and may be associated with certain forms of cancer. All streams in the southern part of the city and the Aba Samuel reservoir show strong eutrophication process that has reduced the nitrate concentration in the water.

Manganese was found to be more concentrated in the surface water bodies than in the groundwater reservoirs. This may be partly attributed to retention of Mn by thick alluvial sediments. Manganese concentration higher than 0.1 mg/l is considered unsafe for industrial and domestic use (WHO, 1984). However, in some streams the concentration reaches as much as 6.54 mg/l (Sample No.5).

Spring samples (12 and 13) have high levels of Cr and are probably fed by Cr-rich streams that have been contaminated by surface waste. This is presumably because Cr sinks into the shallow groundwater system through fractures and feeds the Cr rich springs.

Chloride increases downstream faster than any other analyzed constituent from 49 mg/l (Sample No.1) to 109 mg/l (Sample No.2) in Kolfe stream; from 8 mg/l (Sample No. 4) to 106 mg/l (Sample No. 5) in Kebena stream; from 3 mg/l (Sample No. 7) to 70 mg/l (Sample No. 8) in Kechene stream. It is anticipated that the main sources for Cl anomalies could be domestic sewages, leather works, and slaughterhouses all of which release substantial amount of Cl into the surrounding water bodies.

Correlation coefficients (r) are determined for the selected pairs of anions (Fig. 2). A correlation value above 0.35 for Cl vs. NO_3 indicates that groundwater probably has been affected by domestic waste (Pacheo and Cabrera, 1997 and references therein). Water samples from springs have Cl vs. NO_3 correlation coefficient of 0.9026 indicating nitrate pollution derived from defective septic systems and not from agricultural runoff as the samples are collected from urban areas. For plots a, b, c, in Fig. 2 the parameters considered have a correlation indicating probably a similar source. As shown in Figure 2d, chloride increases downstream as NO_3-N decreases resulting in a negative correlation.

The bacteriological analyses revealed that at the inlet of the Aba Samuel reservoir Big Akaki river has 1010 Total Coliform per millilitre of water, while Little Akaki river contains Too Many Bacteria to count (TMC) which is above the counting range. The result indicates that Little Akaki river is more polluted than Big Akaki river. The Lideta spring, which is used as holy water (serves also for drinking purpose) contains 290 Total Coliform per millilitre of water. This is well above the standard limit (10 Total Coliform/ml) set by WHO. The same spring also contains elemental level of *E. coli*, a bacteria that causes disease.

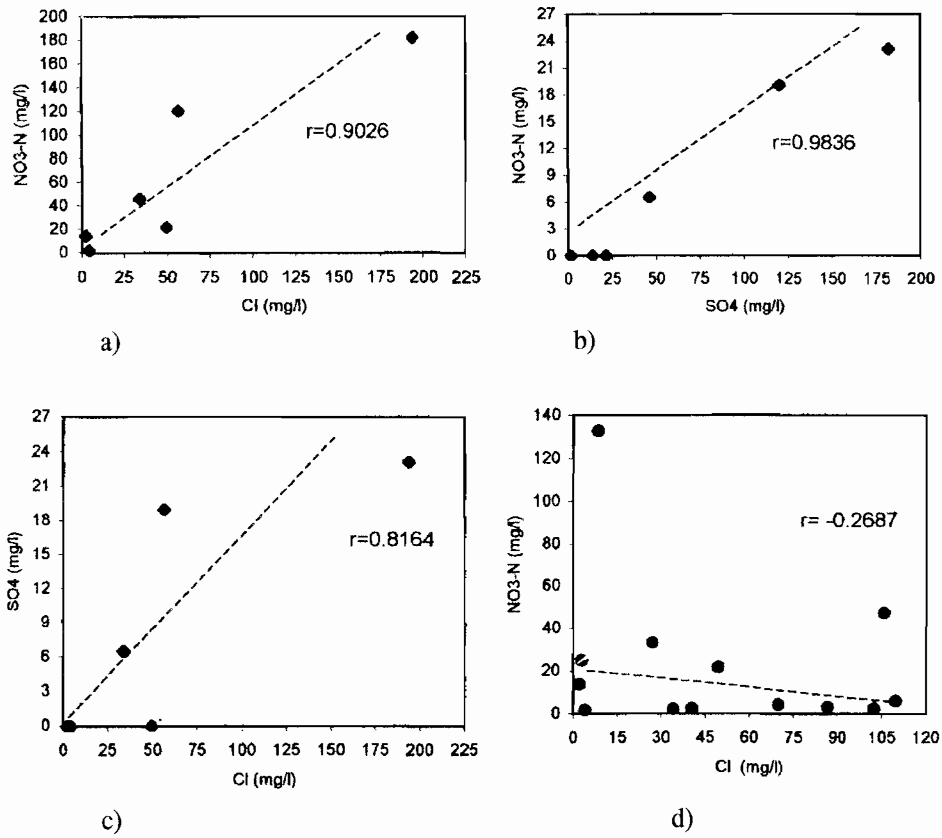

Fig. 2. Chemical constituents with correlation coefficient for spring samples (a, b, c) and stream samples (d).

CONCLUSIONS

The present environmental study in the city of Addis Ababa has demonstrated that improper and continued disposal of domestic and industrial wastes represent a serious threat to surface and groundwater systems. The results of analysis of samples from different location points indicated that there are high levels of chromium, manganese and nitrate in shallow groundwater infiltrated from contaminated surface water.

Comparison of concentration of toxic chemicals, nutrient enrichment and bacterial population revealed that Little Akaki river is more polluted than the Big Akaki river. The shallow groundwater fed by the Little Akaki river also contains high pollutant load.

The main problem that may arise from uncontrolled dumping of wastes is the infiltration by rainwater of hazardous chemical constituents and bacteria of health significance. It is therefore suggested that appropriate water treatment is necessary before water from shallow boreholes are made available for drinking.

As practised elsewhere in big cities around the world, a reduction in water pollution in Addis Ababa can be attained through the construction of low cost sewerage lines, proper control on industrial effluent, well developed and regulated garbage collection systems, establishment of proper landfill facilities and developing the environmental awareness of the population, in addition to empowering the local authorities to take an active participation in waste disposal regulations. The systematic application of these controlling mechanisms could cut down the surface and ground water pollution in the city.

REFERENCES

1. Adane Bekele (1999). Surface water and groundwater pollution problems in the upper Awash River basins. Master Thesis. University of Turku, Finland.
2. Central Statistics Authority (1999). The 1994 Population and Housing Census of Ethiopia, Results for Addis Ababa, April 1999, Addis Ababa.
3. Environmental Protection Authority, EPA (1997). Preliminary survey of pollutant load on Great Akaki, Little Akaki and Kebena rivers, March 1997. Unpublished Report.
4. Haile Selassie Girmay (1985). Shallow resistivity investigations in the Filwoha Fault. M.Sc. Thesis, Addis Ababa University.

5. Haile Selassie Girmay and Getaneh Assefa (1989). The Addis Ababa-Nazaret Volcanics: A Miocene-Pleistocene volcanic succession in the Ethiopian Rift. *SINET: Ethiop. J. Sci.* **12**(1):1–24.

6. NOR consultants (1982). Addis Ababa solid waste management study. Unpublished Report.

7. Pacheo J.A and Cabrera A.S. (1997) Groundwater contamination by nitrates in the Yucatan peninsula. *Hydrogeology Journal* **5**(2):47–53.

8. World Health Organization, WHO (1984). Guidelines for drinking water quality. Volume 2, health criteria and other supporting information, Geneva.