ORIGINAL ARTICLE

ASSESSMENT OF FACTORS CONTRIBUTING TO EUTROPHICATION OF ABA SAMUEL WATER RESERVOIR IN ADDIS ABABA, ETHIOPIA

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ABSTRACT

BACKGROUND: *Aba Samuel water reservoir which drains water from Big and Small Akaki Rivers is found about 35 kms to the south of Addis Ababa. It is showing signs of eutrophication such as uncontrolled aquatic vegetation growth, smell, change in color, etc. The aim of this study was to assess factors contributing to eutrophication of Aba Samuel water reservoir in Addis Ababa.*

METHODS: *This cross-sectional study was undertaken from January 30 to February 20 2003. Samples from the reservoir and two rivers were collected and transported to the laboratory for analysis in Addis Ababa Water and Sewerage Authority laboratory. Standard methods including stannous chloride for phosphate, Phonol-disulphonic acid for nitrate, Direct Nesslerization for ammonia were employed.*

RESULTS: *The mean concentration of phosphate, nitrate and ammonia was 12.40 mg/l, 1.00mg/l and 56.98 mg/l respectively. Biological oxygen demand level was 13.00 mg/l at the inlet and 11.8 mg/l at the out let site while level dissolved oxygen was found to decrease from 4.7 mg/l to 4.3 mg/l from the inlet to the out let. Turbidity increased from 468 Nephlometric turbidity unit in the inlet to 577 Nephlometric turbidity unit at the outlet and Secchi disc visibility decreases in that order. Regarding to the relative contribution of nutrients of eutrophication Small Akaki River has 12.00 mg/l of phosphate and 1.2mg/l of nitrate while Big Akaki River has 10.50 mg/l of phosphate and 1.00mg/l of nitrate respectively which was of similar magnitude but the concentration of ammonia is much higher in Small Akaki River (53.36 mg/l) than Big Akaki River (20 mg/l).*

CONCLUSION: *The concentration of nutrients in the reservoir was much higher than the critical value required to trigger algal blooms or create overpopulation of aquatic vegetation. Hence, the ecological integrity of the reservoir is perturbed and fish species which were once a known products have been extinct from the reservoir.*

KEY WORDS: Algal blooms, Eutrophication, water reservoir, Nutrient.

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INTRODUCTION

Aquatic plants like their terrestrial cousins require certain mineral nutrients for growth and metabolism. An excess of these essential elements however can result in a plant population explosion, which leads to a serious degradation of water quality and radical changes in the species composition of the lake, pond or stream (1). Eutrophication is defined as the process of aging of lakes and reservoirs due to accumulation of nutrients, which leads to water quality degradation (2).

The degree of eutrophication is indicated by the quantity of planktonic (phytoplankton, Zooplankton) bacteria, fungi, and detritus, reduced water transparency or clarity (Secchi disc visibility) in the water near the surface and pH. Reduced dissolved oxygen may cause the release of hydrogen sulfide, ammonia, methane, which alters physical, chemical and bacteriological quality of water (2, 3).

The high biological productivity of eutrophic system is often expressed as blooms of algae or thick growths of aquatic plants and high levels of sediment accumulation. Bacterial population also increases, fed by larger amounts of organic matter. The water will become often opaque and has unpleasant tastes and odor. The deposition of silt and organic sediment caused by cultural eutrophication can accelerate the aging of a water body enormously over natural rates. Lakes and reservoirs that normally might exist for hundreds or thousands of years can be filled with in a matter of decades (3, 4).

Nutrients associated with eutrophication include phosphorous, nitrogen and organic carbon any one of which may be a limiting factor in algal growth. Phosphorous appears to be the most practical nutrient in eutrophication (4-6). Phosphorous determinations are extremely important in assessing the potential biological productivity of the surface waters and in many areas limits have been established on the amount of phosphorous that may be discharged to receiving bodies of water particularly lakes and reservoirs (6-9). Pierce compare phosphorous with gas pedal of a car as a limiting factor in eutrophication as follows, "The addition of a limiting nutrient acts for algal growth much as stepping on the gas pedal limits the speed of your car. All of the components are available to make the car go faster but it can't speed up until you "give it more gas". The gas pedal is a constraint or limit, against higher speed. Dumping excess phosphorous into a lake is like floor boarding the gas pedal, but nitrogen limits growth in brackish water like bays and estuaries (4).

As many as two-thirds of the lakes in United States are significantly degraded as the result of eutrophication. About one-third of the country's population lives within 5 miles of a lake where sewage effluents and surface runoffs carry large amount of plant nutrients into these lakes accelerating the eutrophication process (6). Even though such comprehensive studies have not been performed, most of the water reservoirs, ponds and lakes in Ethiopia suffered from problem of nutrient pollution. A study done in Boye pond in Jimma town reveals that the pond has completely eutrophid and the Hippopotamus which were found in the pond are not there due to change in water environment and ecological succession (10). Aba Samuel water reservoir can be also one example where its quality is degraded significantly due to eutorphication. Formerly it was designed to produce an electric power. In addition it was used for fishing purposes. According to the information obtained from Akaki Woreda Agricultural Office *Siluroidae* (Catfish) and *Tilapia* were the

common fish species in the reservoir during 1970s when fishing was carried out extensively using boats. The waste quantity and composition of Small and Big Akaki Rivers has been increasing due to rapid population growth together with improper waste disposal systems, development of industries which are discharging complex organic and inorganic wastes and the over usage of fertilizers by the farmers of the catchments area.

Therefore, the aim of this study was the assessment of factors contributing to eutrophicaion to look at the extent of progressively increasing pollution problems of Aba Samuel water reservoir and the impact on ecosystem by evaluating physico-chemical parameters so that appropriate recommendation will be forwarded to alleviate the problem.

METHODS AND MATERIALS

This cross-sectional study was conducted at Aba Samuel water reservoir from January 30 to February 20, 2003. According to information obtained from Akaki Woreda Agricultural Office the reservoir has an estimated area of about forty hectares. . Sampling was carried out at the inlet and out let of the reservoir. Samples were also taken from Big and Small Akaki Rivers at the point where they enter Aba Samuel water reservoir to determine the relative contribution of the two rivers. Standard sampling bottles were used and samples were packed in ice- box immediately and transported to laboratory. Physical parameters like pH temperature and Secchie disc visibility were determined at the site during the field visits at the sampling time.

Standard Methods for the Examination of Water and Wastewater were used to analyze the remaining parameters (11). Spectrophotometeric analysis of phosphate, nitrate and ammonia was carried out using stannous chloride, phenol- disulfonic acid and nesslerization methods respectively. Conventional titrations for biological oxygen demand (BOD), modification of Winkler's method for dissolved oxygen (DO) and Turbidimetre for turbidity determination were followed.

Data was collected by employing two methods using observation checklist and investigation of laboratory results. In laboratory analysis each of the tests were done in replicates and the results were checked twice to avoid transcription errors.

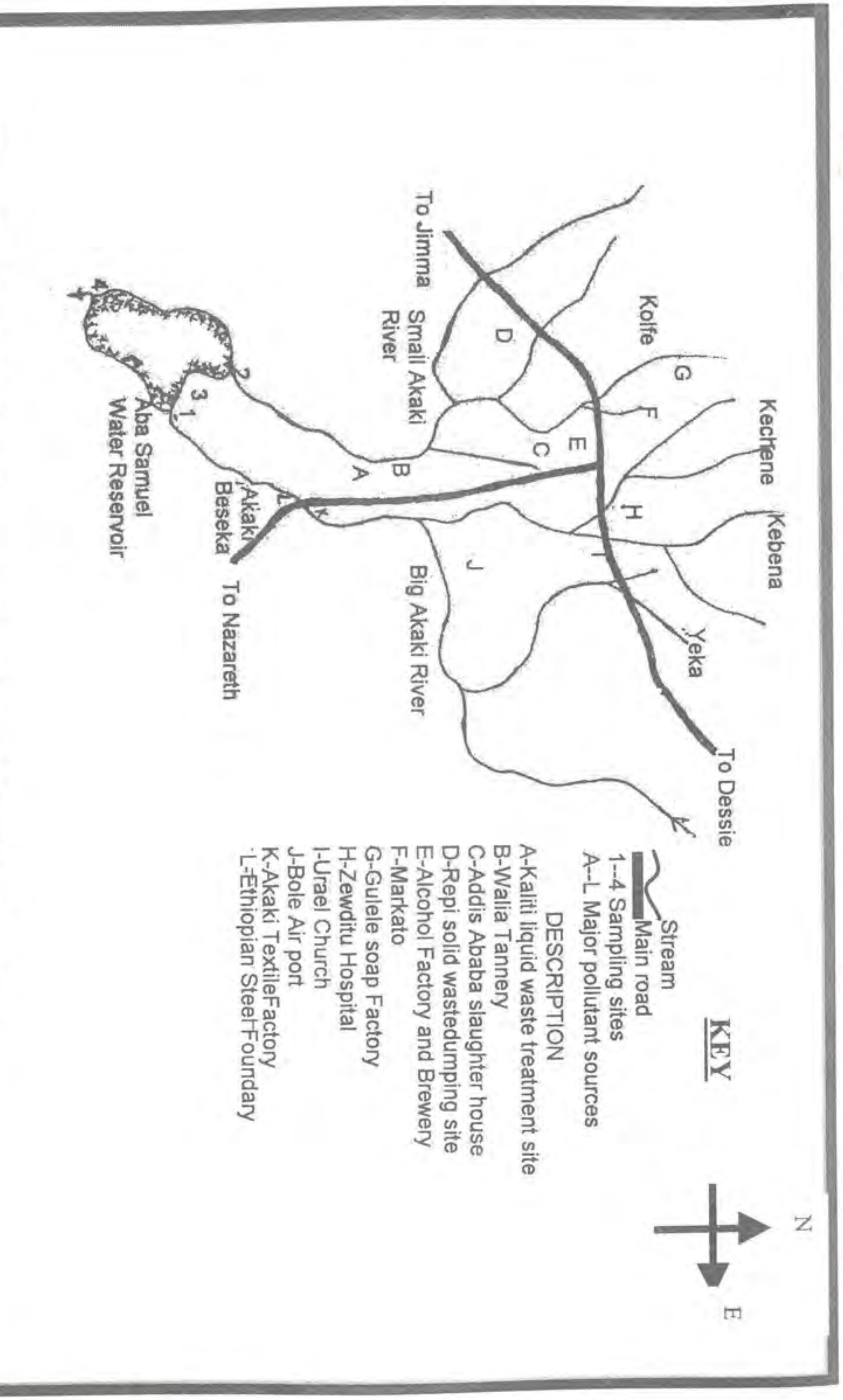

Figure 1 Sketch map of Aba Samuel water reservoir and streams with major pollutant sources

RESULTS

During the field visits it was observed that the water of the reservoir starts to subside and dried masses of water hyacinth were accumulated at shores on both sides of the reservoir. Emergent vegetations were grown on some places of shorelines and farmers use the wetted land for the cultivation of certain vegetations and grains. Fish were not observed, there was pungent smell and the color of the water is changed grey in places where water hyacinths are absent. Farmers asked during the field visits were complaining that animals often die after drinking water from the lake probably due to the toxin in the water reservoir. Regarding the two rivers Small Akaki appears dark in colour and more odorous than Big Akaki River. Both rivers are still used for irrigation purposes, animal drinking and washing of cloths as well for drinking purpose by the community after infiltrating through accumulated silts on the riversides.

The concentration of phosphate, nitrate and ammonia was found to be 12.4 mg/l, 0.7 mg/l and 54.73 mg/l at the inlet and 12.55 mg/l, 1.3mg/l and 59.23 mg/l at the outlet of the reservoir respectively. Turbidity and temperature increase downstream from 468 NTU to 577 NTU and 20.8°C to 24.1°C respectively. In contrast, other pollution indicator parameters like BOD, DO, pH and Secchi disc visibility decrease as the water leaves the reservoir (Table 1).

Table 1. Selected physical and chemical parameters related to eutrophication in Aba Samuel water reservoir, January 30 - February 20, 2003

Parameters	Aba Samuel water reservoir	
	Site 1 (inlet)	Site 2 (outlet)
Phosphate (mg/l)	12.40	12.55
Nitrate (mg/l)	0.7	1.3
Ammonia (mg/l)	54.73	59.23
BOD (mg/l)	13.00	11.8
DO (mg/l)	4.7	4.3
Turbidity (NTU)	468.00	577.00
Secchi Disc Visibility (Cm)	8	5
Temperature (°C)	20.8	24.1
pH	7.62	7.58

Contribution of factors of eutrophication from the two rivers is almost similar in phosphate and nitrate. Small Akaki River has 12.00 mg/l of phosphate and 1.2 mg/l of nitrate while Big Akaki River has 10.50 mg/l of phosphate and 1.00 mg/l of nitrate (Table 2).

Table 2. Selected physical and chemical parameters in Big and Small Akaki Rivers, January 30-February 20, 2003

Parameters	Big Akaki River	Small Akaki River
Phosphate (mg/l)	10.50	12.00
Nitrate (mg/l)	1.00	1.20
Ammonia (mg/i)	20.33	53.36
BOD (mg/l)	10.20	13.60
DO (mg/l)	2.5	0.2
Turbidity (NTU)	150	63
Secchi disc Visibility (Cm)	21	30
Temperature (°C)	20.1	22.3
pH	7.78	7.67

Table 3. Some physico-chemical standards of drinking water quality

Parameters	Value
Turbidity	5 NTU
Color	15 TCU
Sulfate	200 mg/l
Nitrate (N)	10 mg/l
Nitrate (NO_3)	45 mg/l
Nitrite	1.5 mg/l
Chloride	250 mg/l
pH	6.8-8.5

NTU = Nephelometric turbidity unit
TCU = True color unit

DISCUSSION

The mean concentration of phosphate in the reservoir was 12.48 mg/l. Sawyer et al (7) indicated that the critical concentration of phosphate to trigger algal growth could reach to a minimum of 0.005 mg/l . Thus, the concentration of phosphate in the reservoir was found to be nearly 2500 times the critical concentration, and thus can create progressive eutrophication. Many literatures indicate that concentration of phosphate more than 0.02 mg/l can potentially create algal blooms (9, 12). A study done on *Boye* pond (a pond found in Jimma town) showed the concentration of phosphate was 0.2 mg/l that causes eutrophication of the pond (10). The increased concentration of phosphate in Aba Samuel water reservoir may be due to the uncontrolled discharge of domestic and industrial wastes as well as the excessive use of detergents in the City, which are the main sources of phosphate.

According to research done on the efficiency of stabilization pond of Addis Ababa, the effluent discharge, which is directly released to Small Akaki River, had 6.2 mg/l of phosphate with a dramatic increase of this nutrient to 14.0 mg/l in the influent. This indicates sewage is one of the major sources of phosphates as most of literatures support this idea.

The total inorganic nitrogen (ammonia plus nitrate) concentration of the reservoir is also at the level that can cause algal bloom. Concentration of inorganic nitrogen greater than 0.3 mg/l can cause algae to grow in abundance (13-15). Thus, the reservoir has more than enough inorganic nitrogen (57.98 mg/l) for growth of algae and other aquatic weeds. The concentration of nitrate is too much lower than the concentration of ammonia that may be attributed to the decay of dead algae and other aquatic weeds as well as continuing discharge of organic wastes to the reservoir both of which can produce ammonia (16).

The relative contribution of nutrients of eutrophication by Small and Big Akaki Rivers was almost similar in phosphate and nitrate since all the tributaries of the two rivers pass through the City carrying those nutrients from domestic and industrial discharges as indicated on the sketch map. Small Akaki River has higher concentration of ammonia, which indicates the recent discharge, or organic wastes that can increase the amount of ammonia.

Regarding the pollution indicator parameters BOD slightly decreased down the reservoir that is 13.00 mg/l at the inlet site and 11.8 mg/l at the out let site. Even though it showed slight decrease the BOD was still high suggesting the presence of organic wastes as well as dead algae and aquatic weeds (4, 17). This result does not coincide with study done by Tamiru Alemayehu, which indicated the reservoir serves as an oxidation chamber for wastes discharged to it (18). This might be attributed to the decrease in retention time of the water in the reservoir. Small Akaki River has higher BOD than Big Akaki River which may be attributed to the nature of wastes the river is receiving from Slaughter house, Markato, leachate from solid waste dumping site, etc that are more of organic in nature.

The reservoir was observed to be highly turbid which is 468.00 NTU at the inlet and 577 mg/l at the out let. The increased turbidity is due to the slightly increased flow rate of the water as it enters the reservoir due to sediment scouring action. This was observed during the field visit that the reservoir becomes too shallow and the water starts to subside that decreases the retention of water in the reservoir and disturbed the deposited silt.

The pH value shows slight drop down the reservoir (Table 1). This may be attributed to the algal population increase down the reservoir, which can create alkaline condition by up taking CO_2 (17). Most aquatic organisms can survive in a pH range of 6-9.5. Hence the pH of the reservoir is not harmful. The temperature also increased at the out let relative to the inlet, which might be attributed to the altitude difference of the two sites.

DO level in the reservoir is found to be less than the minimum amount of DO required by most aquatic lives for survival and reproduction. Many literatures indicate a minimum of 5mg/l DO is required for most aquatic lives. Cold-Water fish require stringent limitations, 6 mg/l with a minimum of 7mg/l at spawning times (19). Therefore DO level in the reservoir is not suitable for aquatic lives.

Even though BOD slightly decreases down the reservoir, DO level do not increase. Instead it slightly decreases as the water passes the reservoir. The slight depletion of DO at the outlet of the reservoir may be attributed to the decrease of rearation capacity due to the presence of floating masses of algae (20) on the surface of the reservoir and slight increase in concentration of ammonia which can be produced by the use of oxygen (6,7,19).

Aba Samuel water reservoir was one of the first electric power generating stations in the country. But due to human interferences it has lost the intended purpose and the ecological integrity is perturbed. This can be evidenced by the absence of fish in the reservoir that were once known products by the local name of "Dube Asa", *Tilapia* and additionally the reservoir covers large area with out any use to the surrounding farmers. Most probably the uncontrolled waste management in the city creates such adverse problems on the surface waters, which can be supported by the excessive nutrient levels in Big, and Small Akaki Rivers that are responsible for the eutrophication of the reservoir. Even though it is very difficult to restore the reservoir to its former condition, it is necessary to sustain the ecological integrity and / or make use of the land for the agricultural production. Generally, the recommendations forwarded are; the water in the reservoir should be released so as to allow the natural purification process and there should be proper collection and treatment of domestic wastes and control of industrial discharges for effluent standards. There should also be a control of the use of phosphate detergents and concerned sectors like Ministry Of Health, Ministry Of Agriculture, Ministry Of Water Resource Development, and Environmental Protection Agency should work together to create public awareness and formulate applicable laws for the control of pollution of surface water. Finally further study is recommended on three- dimensional ecological eutrophication model of the reservoir, which includes nitrogen, phosphorus and carbon cycles; phytoplankton and zooplankton dynamics, and dissolved oxygen balance.

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