ELSEVIER

Desalination 252 (2010) 186–192

DESALINATION

www.elsevier.com/locate/desal

Impact of wastewater discharge in Jimma, Ethiopia, and remediation possibilities

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Received 31 January 2008; revised accepted 15 May 2008

Abstract

Discharge of liquid and solid waste from Jimma town has resulted in a gradual degradation of the quality of the river water feeding the Gilgel Gibe dam, which was constructed for the development of the hydroelectric potential of the Gilgel Gibe River. In general, wastewater is not treated, which makes the use of river water problematic. In addition, the region around the dam mainly consists of farmlands; runoff from the fields results in pollution by pesticides, including DDT.

The current situation of waste(water) production in and around Jimma (including the campus of Jimma University) will be discussed, along with the expected impact on the water quality in the Gilgel Gibe reservoir. Possibilities for remediation will be discussed.

Keywords: Wastewater; Gilgel Gibe; Awetu; Boye Pond; Pollution; Siltation; Remediation

1. Introduction

Ethiopia is located in the Horn of Africa between 3°–15°N latitude and 33°–48°E longitude, with an area of 1.12 million km^2 and a complex topography. Its boundaries are Eritrea in the North, Djibouti and Somalia in the East, Kenya in the South and Sudan to the West [1].

The country has a very diversified climate ranging from hot and semi desert to mild and humid [2]. While the tropical zone has an average annual temperature of about 27°C and receives less than about 500 mm of rain annually, the subtropical zone, which includes most of the highland plateau, has an average temperature of about 22°C with an annual rainfall ranging from about 500 to 1500 mm. Areas above 2000 m have an average temperature of about 16°C and an annual rainfall between about 1300 and 1800 mm. The rainy season occurs between mid-June and September, followed by a dry season that may see few spells of rain in February or March.

Ethiopia is the second most populous country in Africa with a population of about 77 million people. Ethiopia ranks 169 out of 177 countries in the 2007 United Nations Human Development Report.

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Presented at the Water and Sanitation in International Development and Disaster Relief (WSIDDR) International Workshop Edinburgh, Scotland, UK, 28–30 May 2008.

0011-9164/0x/$– See front matter
doi:10.1016/j.desal.0000.00.000

Table 1
Some health and development indicators for Ethiopia, Africa, developing and developed countries [4]

Indicator	Ethiopia	Africa (Average)	Developing countries (Average)	Developed countries (Average)
Urban population (%)	18.3	39.2	43.1	78
Population growth rate	2.5	2.2	1.7	0.6
Urban population growth rate (%)	5.1	3.8	2.9	0.5
Human development index (rank among 174 countries)	170			
Life expectancy at birth (years)	45.7	50.7	62.0	78.0
Child mortality rate (per 1000)	169.8	133.3	79.8	10.2
Access to safe water (%) in 2002	22	64.4	78	100
Access to sanitation (%)	6.0	42.6	52	100
Access to health services (%) (1991)	55	61.7	80	100
Public expenditure on health as % of GDP (2001)	1.4	3.3	1.8	6.3
Adult illiteracy rate (2003)	57.3	36.9	26.6	1.2

Poverty in Ethiopia affects the majority of the population:

– over 60 million (81%) live below a poverty line of \$2 a day;
– 31 million (41%) live on less than half a dollar a day;
– each year around 10 million people are at risk of starvation [3].

The commitment made by the Government of Ethiopia towards reducing poverty is starting to have results, an impressive achievement given the rapid growth of the population. But, despite signs of progress, Ethiopia remains unlikely to meet any of the Millennium Development Goal targets by 2015. If it is to have any chance of doing so, there will need to be a significant increase in economic growth, together with substantial assistance from donors.

Table 1 summarises some comparative development indicators for Ethiopia, Africa, developing and developed countries. As can be seen from this table, most development indicators for Ethiopia lag behind the rest of the world. Although fewer people are living in urban centers, urbanization is rapidly growing indicating the need to work more in urban sanitation. The nation wide access to sanitation is extremely low (6% as compared to the African average of 43%) [4].

With around 62 million people living without sanitation provision [5]; Ethiopia has one of the lowest rates of sanitation in the world. In rural areas most people still practice open defecation, a tradition that has remained widespread through a lack of hygiene awareness and technical knowledge on the part of villagers, and inadequate policy, investment and implementation on the part of the government. Access to water and sanitation coverage is one of the lowest in the world. Most cities lack waste treatment systems, including Jimma, the largest city in southwestern Ethiopia (pop. 160,000), where this investigation takes place. For this reason there is a very high risk to human health, and pollution of the environment (air, soil, and water) is evident. Moreover, all environmental compartments are linked. For example, the uncontrolled discharge of solid waste causes land degradation and also water pollution, e.g. the leaching of heavy metals from solid waste. Other examples are oil pollution to rivers around Jimma caused by liquid waste discharge from car wash and garages, and organic pollution from coffee washing houses to the Awetu stream, due to intensive coffee production [6]. About 90% of the industrial firms in Addis Ababa discharge their effluents directly into the nearby streams without any form of treatment. Even those firms that claimed to treat waste water provided only preliminary treatment. All samples analyzed exceeded recommended standards [7].

2. Environmental effects of liquid and solid waste discharge: Boye Pond

The town administration has the main responsibility for management of urban drainage. The health bureau is responsible for the promotion and raising awareness of environmental sanitation along with the enforcement of the regulations. Nevertheless, liquid and solid waste is still discharged without any treatment into the river system. Two rivers, named 'Kito' and 'Awetu', pass Jimma town and come together at Boye Pond. Further downstream, they flow into Gilgel Gibe River, which leads to Gilgel Gibe Lake. A schematic representation is given in Fig. 1.

Boye Lake was constructed in 1967 for fishing and recreational purposes, and has now been abandoned due to eutrophication [8]. The lake was once inhabited with hippopotamus and a variety of fish and birds. Presently it is invaded by the extensive growth of aquatic vegetation, which has spread due to the overloading of organic nutrients provided by the inflow of the river through and from the town. A study [9] proved that wastewater discharged without any form of treatment in the rivers Kito and Awetu threatened the ecological integrity of Boye. Consequently, aquatic weeds now cover the major portion of the pond area leading to progressive eutrophication. This can be clearly observed in Fig. 2.

Over the years siltation has also occurred and the Awetu River's capacity to absorb the storm runoff has decreased significantly. Due to this there is a tendency for surface water to accumulate and flood in town, draining slowly to the rivers over time. The low infiltration rate of the soil has also played a significant role in the poor removal of rainwater. Therefore in many places within the town there is surface water retention.

In Boye Pond, the level of BOD was found to be unacceptably high, with typical values around

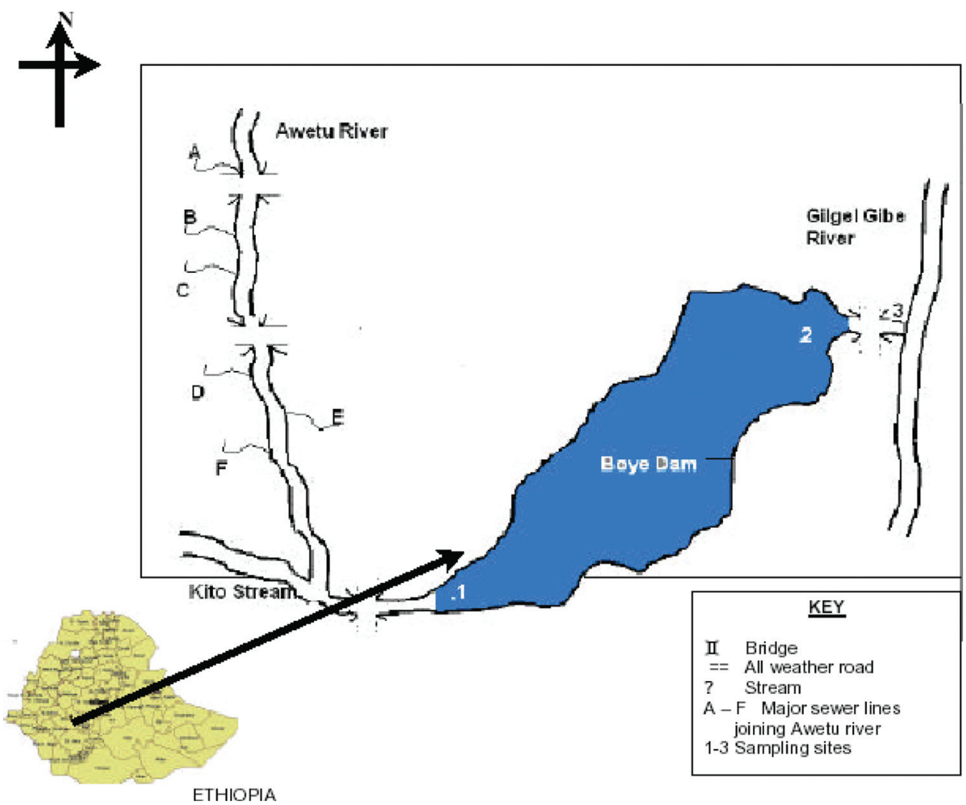

Fig. 1. Schematic representation of Boye Pond and the rivers Awetu, Kito and Gilgel Gibe [10].

Fig, 2. Eutrophication at Boye Pond.

10 mg/L but with extremes up to 100 mg/L [9]; consequently, the DO level fell far below the critical concentration required to sustain fish life even at the time of the day where photosynthetic activity is maximal to replenish it. With an estimated population growth rate of close to 3% the anthropogenic pressure on aquatic ecosystems is likely to increase in the region. Therefore, governments both at regional and federal levels should mobilize resources and the communities to start addressing the far-reaching consequences of polluting the already scarce freshwater resources of the nation. It can be assumed that Gilgel Gibe Lake may face the same fate as Boye Pond.

3. Evaluation of river quality and discharge of solid and liquid waste to Awetu and Kito River

3.1. River quality

The rivers Awetu and Kito receive a high load of organic pollutants both from the city and the surrounding activities. These include runoff from the waste disposal site, agricultural activities, open markets, household sullage and a considerable amount of sewage from both institutions and households. These all tend to end up in the Awetu and Kito Rivers. This has resulted in the river being highly turbid and overloaded with organic pollutants. According to the water quality survey by Wacho [10], Kito River was relatively better than Awetu, as can be observed from Table 2.

Table 2
Nutrient concentration of Awetu and Kito Rivers, Jimma Town [10]

S.No	Parameter (mg/L)	Awetu	Kito
1	Phosphorus	0.55	0.21
2	Nitrate-nitrogen	0.145	0.058

The major recommendations for the improvement of the quality of both Awetu and Kito Rivers include:

1. The town administration along with other stake holders like Jimma University, health bureau and NGO's (non-governmental organisations) should be able to provide communal sanitation facilities like pit latrines and waste collection skips.
2. Point and non-point sources of pollution must be identified and alternatives provided.
3. Regulation and enforcement of human activities that violate safe waste management.
4. There must be public awareness activities for people residing along the two streams on safe methods of waste disposal and about community benefits if the two streams are kept clean.

3.2. Liquid waste disposal

The town generally lacks a planned waste disposal system and from what has been observed, particularly the liquid waste disposal is a problem. Even though there is no organised study, the existing liquid waste removal system does not appropriately handle the runoff because of the number of years it has been in service with little or no maintenance (resulting in clogging of the drainage system) and because of the patchy condition of the roads.

The fuel and oil waste from fuel stations and maintenance workshops also has a devastating effect on the river water quality and aquatic life. The other major problem of uncontrolled liquid waste is the discharge of coffee waste from dry coffee processing activities in the town [6].

The major points of pollution outfall on the Awetu stream are indicated on Fig. 3. It was found that the

Fig. 3. Dumpsite in Jimma town, Ethiopia.

pollution load of Awetu stream increases as one moves downstream from sampling station A to F. The highest load was observed at stations D and E, because of the coffee hulling plant and the town abattoir waste.

It was suggested that the point and non-point source of pollution should be identified further and both solid and liquid wastes be disposed of properly. The industries located along the river should also be forced to develop their own onsite waste treatment system.

3.3. Solid waste disposal

Solid waste disposal is one of the major reasons for the clogging of the drainage system and the resulting poor disposal of the liquid waste. The town has a system of disposal through collection and final open dumping disposal. There are seven skips located at key locations in the town and wastes are disposed off elsewhere by the use of a waste disposal truck. It is estimated that less than 40% of the waste reaches the final disposal site. Only few parts of the waste are decomposed at household level even though 60% of the waste is possibly decomposable. The remaining waste ends up in the streets and within the storm drainage system.

There are however encouraging initiatives that need strengthening such as youth groups that work on the management of solid waste through charging for collection and disposal. The "green and clean Jimma initiative" is a civil society organised from concerned professionals who wish to see an improved environmental sanitation situation in the town.

The amount of solid waste generated in Jimma Town was estimated as:

Per capita generation rate – 0.37 kg/c/d
Amount daily generated – 37933.51 kg/c/d
Combustible fraction of SW – 48.37%
Non-combustible fraction – 51.63%
Biodegradable fraction – 73.51%
Non-biodegradable – 26.49%

Of all the waste generated, 21.90% was open dumped in the yard, 44.52% was open dumped outside of the yard, some 10.22% was buried in refuse pits and open burning accounts to 14.60%. This implies that the municipal service only collects 8.76% of the waste generated. An impression of the municipal dumpsite is given in Fig. 3. It is also important to note that about 74% of the solid waste generated in Jimma Town is biodegradable. It means that, if appropriately employed, waste recycling options such as composting would help to significantly reduce the waste management burden of the municipality of Jimma Town.

One can see from the data presented that the solid waste management system of Jimma town is one of the poorest in the country. Most cities in Ethiopia have a collection efficiency of 40% as compared to 9% in Jimma town.

The most important recommendations are:

- Improvement of the waste management unit in the municipality
- Intensification of private sector participation in waste collection processing and disposal
- Market assessment for intensification of waste recycling like composting

3.4. Excreta disposal

Excreta disposal is a serious problem in the town. It is estimated that 63% of households use poorly constructed traditional pit latrines while 28% practice open defecation and 2.3% is estimated to use pour flush latrines. However, there is a major space problem in the town for the construction of improved latrines. There are two suction trucks each of them managed by the water department and the city administration. There is a demand for the sludge on local farms as organic fertilizer.

There are a number of households and institutions (hotels and offices), which are connected and dispose of their sewage and sullage directly to the drainage system. These are particularly old buildings constructed during the Italian occupation in the 1930s. A sample survey of 140 households in Jimma Town for the assessement of excreta disposal and other waste water treatment facilities indicated that the facilities were scarcely available: 49.3% of the houses have no waste water facility.

3.5. Health situation

The health situation of the population is related to low level of hygiene awareness, poor personal sanitation at household level and inadequate drainage of the surface runoff. The most commonly reported diseases are malarial disease, intestinal parasites including typhoid dysentery, these being strongly linked to poor environmental sanitation. There are numerous stagnant water sources that are suitable for the growth of mosquitoes and the spread of malaria. The situation is exacerbated by rapid population growth as a result of which more people lack sanitation and hygiene facilities now than it was 30 years ago.

4. Construction of the Gilgel Gibe dam

In contrast to many countries in the industrialised world, hydroelectric power in Africa is still underdeveloped. Ethiopia may have a large potential in this area, mainly for exploitation of the Nile River [11]. As for many other countries, the potential of generating hydroelectric power is hardly used (Fig. 4).

The Gilgel Gibe dam is a large construction of a water reservoir on the Gilgel Gibe River, where 184 MW hydroelectric power is produced. The dam is located approximately 260 km southwest of Addis Ababa, Ethiopia and had a cost of ca. US$80 M. It comprises the construction of a 40 m high, 1600 m long basalt rock fill dam plus appurtenant works; two river diversion tunnels, an intake structure followed by a 8950 m long 5.5 m diameter tunnel, a 110 m deep and 16 m diameter surge shaft, a 600 m long penstock, an underground power house incorporating three turbine/generator units, and a 630 m long 6.5 m diameter tailrace tunnel. A view of the artificial lake created by the Gilgel Gibe dam is given in Fig. 5.

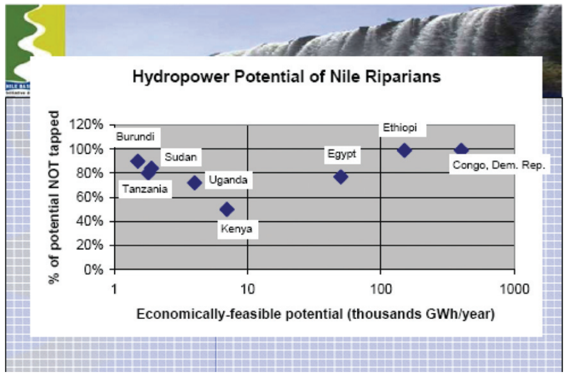

Fig. 4. Potential of developing hydroelectric power from the Nile River [11].

The construction of the dam required moving about 3000 people (including people living under or near the power line connecting the power plant to Addis Ababa) to new areas. Employing 307 expatriates from 32 countries and 4015 local people, the plant was completed in 2004 and became Ethiopia's largest power plant. The second phase of the development of the Gibe-Omo hydropower potential started with the Gibe II plant. The flows, regulated by the Gilgel Gibe dam, will be conveyed through a 26 km long hydraulic tunnel, the longest in Africa, to the Omo River about 150 km downstream of Gibe I dam. The plant will produce about 420 MW without requiring resettlement actions. The third phase of the Gibe cascade (Gibe III) is foreseen as the largest hydropower plant in Africa with an

Fig. 5. The artificial lake created by the construction of the Gilgel Gibe dam.

installed power of about 1870 MW. This plant will comprise a 240 m high dam on the Omo River. The plant is expected to be operational in 2011. Together, all three plants are expected to increase Ethiopia's electrical coverage from its current 17–50%, as well as supply electricity to the neighboring countries of Sudan, Djibouti and Kenya [12].

The creation of the Gilgel Gibe Lake has many benefits other than power generation, since the lake is a water source for agricultural activities and for drinking water supply. This can be seen in the farmland around the lake, which is much greener than farmlands farther away. The risk, however, is that the quality of the water may rapidly degrade due to pollution from runoff and untreated municipal wastewater, similar to Boye Pond.

5. Technological solutions and impact on Gilgel Gibe Lake

Possible technological solutions to reduce the pollution load on Gilgel Gibe River in Ethiopia and to improve local sanitation conditions are to be found in low cost waste water treatment systems. In view of the diffuse sources of liquid waste discharged into the river system, wastewater treatment systems should be on small scale. Septic tanks have been evaluated, but it was found that these were not satisfactory because of insufficient pollutant removal (only 25–40% of BOD removal can be obtained, and the effluent still contains nutrients, pathogens, worm eggs and cysts) and because of lack of maintenance.

Conventional waste water treatment systems that may be applied are constructed wetlands (waste stabilisation ponds or lagoons), (slow) sand filtration and adsorption on low cost materials. These techniques were selected for further evaluation in this context, in view of protecting the water quality in Gilgel Gibe River and the constructed lake at Gilgel Gibe dam. In parallel, water quality in Gilgel Gibe Lake needs to be monitored to study possible progressive effects due to wastewater discharge in Jimma.

Constructed wetlands have a good removal capacity for BOD (85% expected) and nutrients (20–80% of nitrogen), but require a large land area. Slow sand filtration is an alternative, also requiring a lot of space, where disinfection is more effective due to the filtration step. Adsorption allows a larger flow and is more efficient for removal of organics, but is more complicated and does not have a capacity for disinfection. Therefore, each of these techniques needs to be investigated in parallel, in view of avoiding further degradation of the water quality in the river system and in Gilgel Gibe Lake.

Acknowledgments

The authors would like to thank VLIR-UOS (Flemish Interuniversity Council – University Development Cooperation) for financial support through the current project in Jimma, Ethiopia.

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