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Challenges to surface water quality in mid-sized African cities: conclusions from Awetu-Kito Rivers in Jimma, south-west Ethiopia

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Keywords
Awetu-Kito river basin; mid-sized African cities; river pollution; sub-Sahel countries.

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Abstract

Rapid urbanization and industrialization, uncontrolled population growth, indiscriminate waste discharge and poor infrastructure are problems that African cities are facing. This paper describes an exemplary case study from Jimma, south-west Ethiopia. A cross-sectional study was conducted along the Awetu-Kito drainage system in Jimma town to assess the level of pollution from urban dwellers and related activities. The study indicates that the Environmental Protection Agency (EPA) norms for biochemical oxygen demand (BOD), dissolved oxygen (DO) and orthophosphates are not met downstream of the major industrial and institutional activities. Small-scale industries, Jimma University and residential areas contributed 50, 15 and 23% pollution load on the river, respectively. It can be concluded that the pollution effect in Jimma town is mainly as a result of the growing (uncontrolled) industrial activities and not to discharge of household wastewater. Given the same trends of urbanization and population growth, similar development (socio-economic) indicators and similar climatic conditions, the key findings for Jimma are transferable to other mid-sized African cities.

Introduction

Freshwater is a finite resource, essential for agriculture, industry and even for human survival. Availability of freshwater in adequate quality and quantity is one of the key requirements for sustainable development (Bartram & Ballance 1996). Diarrhoeal diseases attributable to poor sanitation kill 3.3 million people annually on a global basis, and 2.6 billion people lack improved sanitation. In Ethiopia, despite the relatively longer environmental health service history, 60–80% of communicable diseases are a result of lack of sanitation and hygienic practices (Haddis 2009).

Although environmental pollution and degradation is a major *global* problem, developing countries are at a higher risk for reasons that are related to lower socio-economic status. Rapid urban growth throughout the developing world is seriously outstripping the capacity of most cities to provide adequate services for their citizens. The challenges of achieving sustainable urban development will be particularly huge in Africa (Cohen 2006).

Africa has the highest rate of population growth in the world and is one of the regions that is most vulnerable to climate change. The Intergovernmental Panel on Climate Change (IPCC) (2007) predicts that average run-off and water availability will decline in the countries of northern and southern Africa, impacting on freshwater ecosystems and advancing desertification in the Sahelian zone and in the northern Africa. In addition, increased frequency of flooding and drought will also stress freshwater systems and pressurize water supply networks. As a result, 25 African countries are expected to experience water scarcity or water stress over the next 20 to 30 years (UNEP 2006).

Indiscriminate waste (water) discharge is a daily practice in many developing countries. For example, it is reported that 70% of industries in developing countries dispose of their untreated waste into water bodies (UN-Water 2009). A recent report of the ministry of water resources of Ethiopia indicates even much less wastewater treatment practice. Accordingly, of the 40 industries surveyed, only three have some kind of on-site wastewater treatment system (MoWR *et al*. 2004). Currently in Ethiopia, national or state criteria for contaminants in wastewater are developed by the Federal Environmental Protection Agency (EPA) but they provide a grace period until the next 3 years implying that there are no national criteria in practice yet. Hence, almost all natural waters are polluted by municipal, industrial or commercial waste of both solid and liquid nature and hazardous material, the exact load of which is, however, not known.

While some research has been reported on the streams and rivers passing *large cities* such as Addis Ababa in Ethiopia, where these water courses are described as *natural sewer lines* for domestic and industrial wastes (MoWR *et al*. 2004; Melaku *et al*. 2007), this paper aims at giving the water quality scenario in *mid-sized* urban centres in Africa like the city of Jimma, Ethiopia. Such cities are interesting to study given their complex interplay between local industrial development, population growth and urbanization.

As an exemplary case, the Awetu-Kito drainage basin in Jimma, Ethiopia, in the Horn of Africa, has been selected. The pollution load on the two rivers, namely Kito and Awetu, and their tributaries is likely to increase with the increase in population, urbanization and industrialization under unregulated conditions. However, the type and quantity of waste entering these rivers from different sources is not clearly known. To fill this gap, an in-depth baseline survey and description of the physical and biochemical water quality is performed.

Research on identification and quantification of the contribution of pollution from point sources is scarce in Africa. This type of research is, however, crucial to pinpoint priority areas in policy, planning and management strategy development. If the loading of domestic sewage in these regions turns out to be more significant than industrial wastewater, solutions for the former need to be developed first (with an emphasis on on-site treatment whenever possible). Otherwise, legislation and, even more important, monitoring of new and existing industrial facilities should get top priority. By a timely and focused intervention, mid-sized African cities can be prevented from becoming a mirror of the large and mega cities.

Materials and methods

The study area

Jimma is the capital city of Jimma zone in the south-west of Ethiopia (located at 357 km from Addis Ababa) with an estimated population of about 160 000 in 2005 (CSA 2007) and about 200 000 in 2009. Two rivers, Awetu and Kito, cross the town flowing from opposite directions. Awetu bisects the centre of the town, and Kito flows along the western end (see Fig. 1). In Jimma, both point and diffuse sources directly discharge their untreated waste and are easily observed as one walks through the town.

The abattoir of Jimma town is incorporated with tanning activities without having an on-site wastewater treatment system and discharging its waste on the nearby river. A number of hide and skin processing points are distributed in the city also using the river for the purpose. Other point sources of pollution come from hotels, carwash and fuel stations, wood-processing enterprises, clinics, colleges, hotels, dry coffee processing plants and, to a large extent, from Jimma University (JU). The rapid increase in the number of these small-scale industries is alarming. For instance, in 10 years (2000–2010), an increase of large hotels (from 2 to 12), higher clinics and/or medium-sized hospitals (from two to nine), colleges (from three to eight), wood-processing enterprises (from one to three) and dry coffee processing plants (from one to five) has been documented.

The diffuse sources of pollution stem from a variety of human activity including urban agriculture, washing and bathing in rivers and indiscriminate waste discharge.

Jimma does not have sewers. Most people use traditional pit latrines, some use water closets and others defecate in open air, representing another diffuse source of pollution. Only few institutions have septic tanks. A considerable number of people also use communal latrines, which need to be emptied when full. The latter is a severe bottleneck because there is a lack of vacuum trucks in Jimma.

At about 2 km away from the town, Awetu and Kito end up in a pond (Boye) after which they join Gilgel Gibe River below the intake point of the water treatment plant of Jimma town. The pond, constructed to be a recreation area half a century ago, is now highly eutrophicated and completely covered by wetland plants. Water is seen only at the outlet of the pond.

Estimation of pollution load contribution

Although at an early stage of development, the major industrial activities in Jimma and, hence, its potential point source polluters are coffee processing, tannery and abattoir activities and the presence of institutions like JU. The contribution of each point source to the receiving water bodies is estimated by using the relationship:

$Q_D C_D - Q_U C_U = \sum_{i=0}^{n} L_i - \sum Losses + \sum in\ situ$ generation (Jain 2000; Jain *et al*. 2007).

where Q_D and Q_U are the downstream and upstream discharge, respectively expressed as m^3/d, and C_D and C_U are downstream and upstream concentrations expressed as kg biochemical oxygen demand (BOD)/m^3. ΣL_i represents the contribution from the point sources, estimated by the sum of the loadings imposed by each of the n point sources of pollution (i ranges from 1 to n). The losses and *in situ* generation terms complete the balance equation but are considered negligible in this case study.

As stated by Crites & Tchobanoglous (1998), for a community with piped water supply but without sewerage system as in the case of Jimma and many mid-sized African cities, the wastewater flow rate could be 60–80% (70% considered in this case) of the water consumption (40 L/c/day). The population

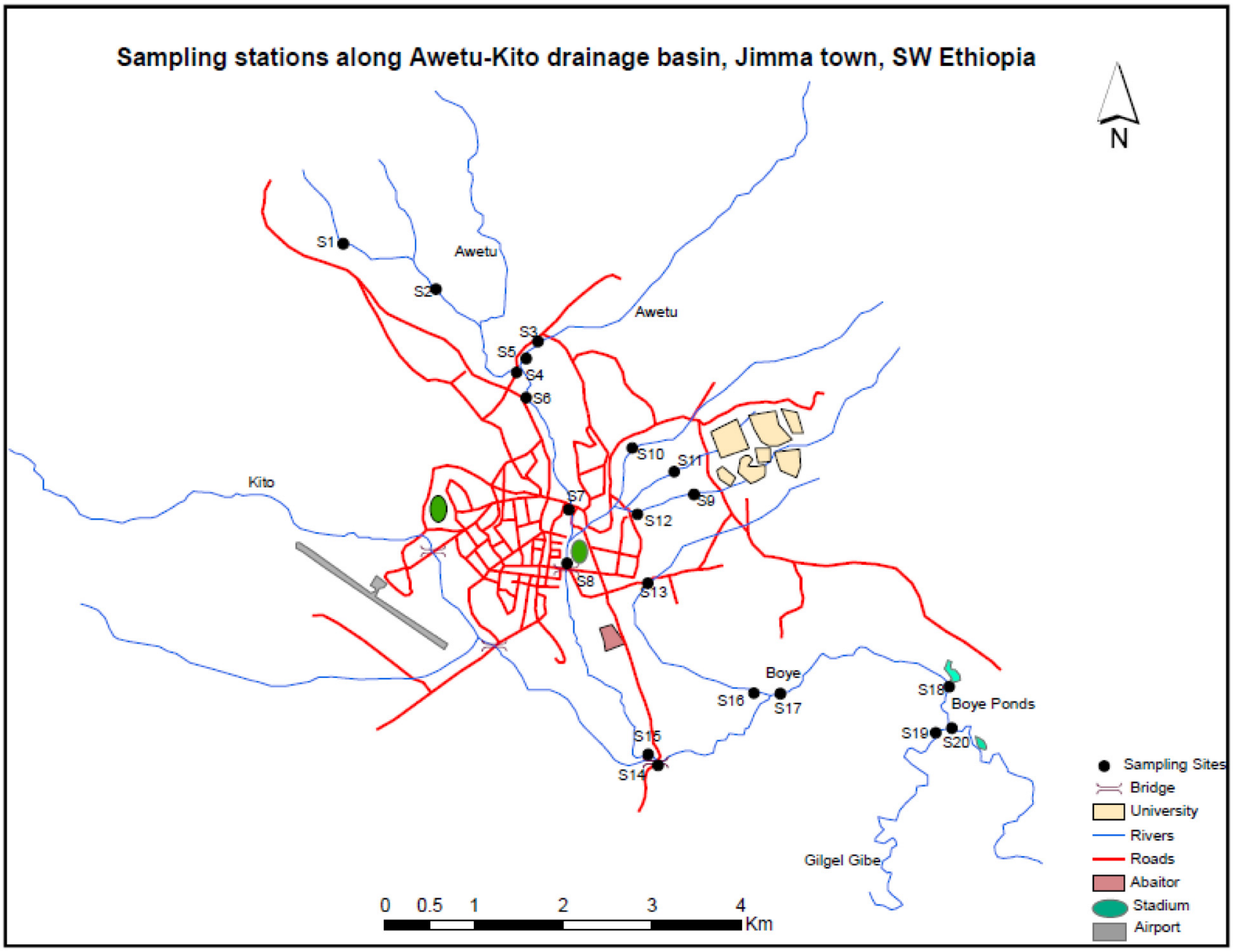

Fig. 1. Awetu-Kito drainage basin with basic reference points and sampling stations for point sources of pollution. Jimma town, March 2010.

residing within 500 m along the river course was estimated to be 65 000, and the person load was taken as 10 kg BOD/c/year (UN-Economic and Social Commission for Western Asia 2003). These data were also adapted from own experiments. Accordingly, the BOD concentration for Jimma was taken as 680 mg/L as recorded in our experiment from JU wastewater while literature suggests 200–400 mg/L. The basis for the contribution of coffee industry is taken from the fact that it produces BOD of up to 20 000 mg/L and a chemical oxygen demand (COD) of up to 50 000 mg/L. (Haddis 2009; Von Enden & Calvert 2010).

Sampling and analysis

A cross-sectional study was conducted in Jimma to assess the river water quality and to identify the major sources of pollution for possible remedial measures. The survey was carried out in two consecutive years, first in January to February 2009 and second in February to March 2010, both representing dry seasons with an average rainfall of 0.56 mm/day, compared with the wet season in June and July, having an average rainfall of 9.2 mm/day.

The sampling points were determined by the presence of alleged point sources of pollution and changes in flow, like upstream and downstream of sewer outfall, confluences and tributaries. Sampling stations were coded as S1, S2, S3 . . . S20 with S1 starting at the upper end in the drainage system and S20 ending at the lower end at Boye-Gilgel Gibe confluence. Data collection was assisted by an eTrex 12-channel global positioning sysytem (Garmin International Inc., KS, USA). Conductivity, total dissolved solids (TDS), pH, temperature and dissolved oxygen (DO) were determined *in situ* by using HQD Hach Lange multiparameter meters (Manchester, UK). Water samples were collected by using plastic bottles of 300 mL for BOD and of 1 L for COD, TDS, ammonia, nitrates, nitrites, chlorides and orthophosphates after cleaning and rinsing in distilled water. Samples were taken at 30 cm depth at the middle of the river and labelled on-site. Duplicate

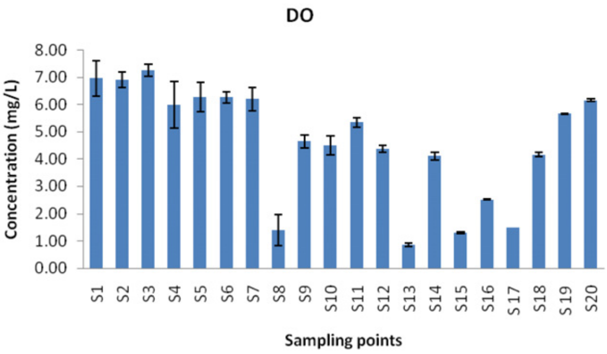

Fig. 2. Concentration of dissolved oxygen (DO) along the Awetu-Kito drainage basin in Jimma town, south-west (SW) Ethiopia (March 2010).

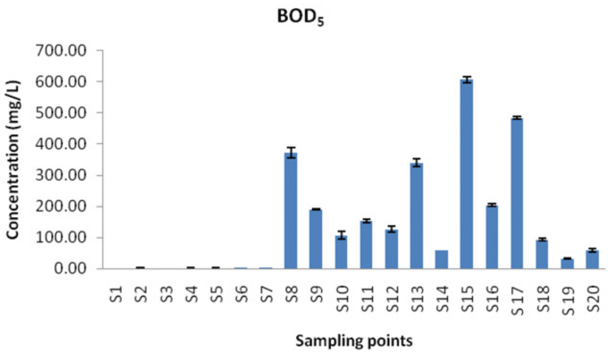

Fig. 3. Concentration of average effluent biochemical oxygen demand (BOD_5) along the Awetu-Kito drainage basin in Jimma town, south-west (SW) Ethiopia (March 2010).

Table 1 Key to sampling stations along the Awetu-Kito drainage basin in Jimma town, south-west (SW) Ethiopia

Station code	Type of flow (T/R)	Site identification
S1	R	Dale (JUCA Agricultural demonstration site).
S2	T	Shenkore
S3	R	Awetu
S4	R	Frustale Bridge (below the confluence of 2&3)
S5	T	Tributary from Seto
S6	R	JUCA Nursery
S7	R	Awetu Menafesha
S8	R	Awetu Kulo bar Bridge
S9	T	JU effluent + Streams (on the juncture down behind Aramic)
S10	T	Seto Stream (near Jehovah Witness)
S11	T	Kochi Stream (near Rift valley college)
S12	T	Confluence (9 + 10 + 11)
S13	T	NOC fuel Station (Dalelo)
S14	R	Dedo Bridge (Kito)
S15	R	Awetu before confluence
S16	T	Dalelo stream near Boye confluence (12 + 13)
S17	R	Kofele (Sedecha-Bore bridge) (14 + 15)
S18	R	Boye Bridge
S19	R	Gilgel Gibe River (at the intake of the treatment plant)
S20	R	Boye-Gilgel Gibe confluence

'T' indicates a tributary sampling point, while 'R' indicates a main river sampling point.
JUCA, Jimma University College of Agriculture; NOC, National Oil Company.

samples were collected at each sampling campaign, and the collected samples were taken to the laboratory within 1–6 h and kept in the refrigerator at 4°C. Each replicate of the sample was analysed separately making the total number of samples 40, but the average of the two results was recorded for each sampling site. The same procedure was followed in both the sampling campaigns. Chemical analysis was performed based on procedures stated in standard methods (APHA 1998) at the Environmental Health Laboratory of JU.

Results

In what follows, first, the organic and nutrient loading profile is discussed, after which the chloride, conductivity and TDS evolution is highlighted. Finally, the findings are related to scenarios of other mid-sized African cities.

Figure 2 indicates the DO values of the Awetu-Kito drainage system. As can be seen from the figure, the DO concentration of the rivers in Jimma town is initially as high as 7.4 mg/L at the upper end (Dale), sharply decreases downstream of S7 where it receives coffee waste from a dry coffee processing plant and domestic waste from the community and, after some recovery, depletes again to low values of, for example, 0.8 mg/L at S13 (Dalelo stream) where the fuel station and JU waste come together and at S15 because of the discharge of untreated wastewater from the Jimma abattoir.

The biochemical oxygen demand (BOD_5) concentration in Awetu-Kito drainage system has an inverse relationship with DO (Fig. 3), which is to be expected under normal conditions. It has been clear from the sampling campaign that the organic load on Awetu is low from its upstream end at Dale until it reaches Awetu Menafesha (Park),[1] the region where DO was found to be high because of less anthropogenic activities upstream. But the BOD_5 concentration is quite high below the coffee processing plant (S8), after the intake of the combined waste from JU, the mosque and the car wash (S13), after the abattoir (S15) and immediately below the confluence of Awetu and Kito (S17), with values of 360, 330, 612 and 480 mg/L, respectively. In all these sites, the BOD_5 concentration was high because of increased pressure from point and diffuse sources of pollution.

Figure 4 shows the results of the nitrogen compounds. The assessment revealed a high level of NH_3-N at S8 (6.1 mg/L)

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[1] The drop in BOD values in Fig. 3 from S9 to S12 and at S14 reflects the value of other streams, not Awetu (see map on Fig. 1 and Table 1 for the locations).

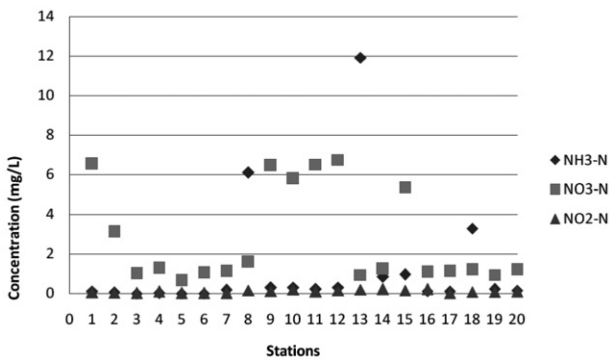

Fig. 4. Concentration of nitrogen compounds along the Awetu-Kito drainage basin in Jimma town, south-west (SW) Ethiopia (March 2010).

because of the coffee processing, at S13 (11.92 mg/L) because of JU waste and at S18 (3.29 mg/L). The high ammonia level observed at the latter point is explained by the low pH (6.57) and because of plant decay at Boye pond. A high ammonia level for this sampling site was also recorded by previous studies (Abegaz *et al*. 2005). Ammonia levels above 1.5 mg/L at 20°C are expected to affect aquatic life (WHO/UNEP 1997).

Phosphorus as orthophosphate was detected at high levels at S13 (0.56 mg/L), at S14 (0.98 mg/L), which is taken at Kito River before confluence, and at S15 (0.64 mg/L) (Fig. 5). This increase can be explained by the presence of car washing activity at S13, many agricultural activities along the banks of Kito and the entrance of phosphate additives from domestic sources at the lower ends of Awetu.

As can be seen from Fig. 6, the chloride concentration in Awetu River remained below 6 mg/L upstream of S7, after

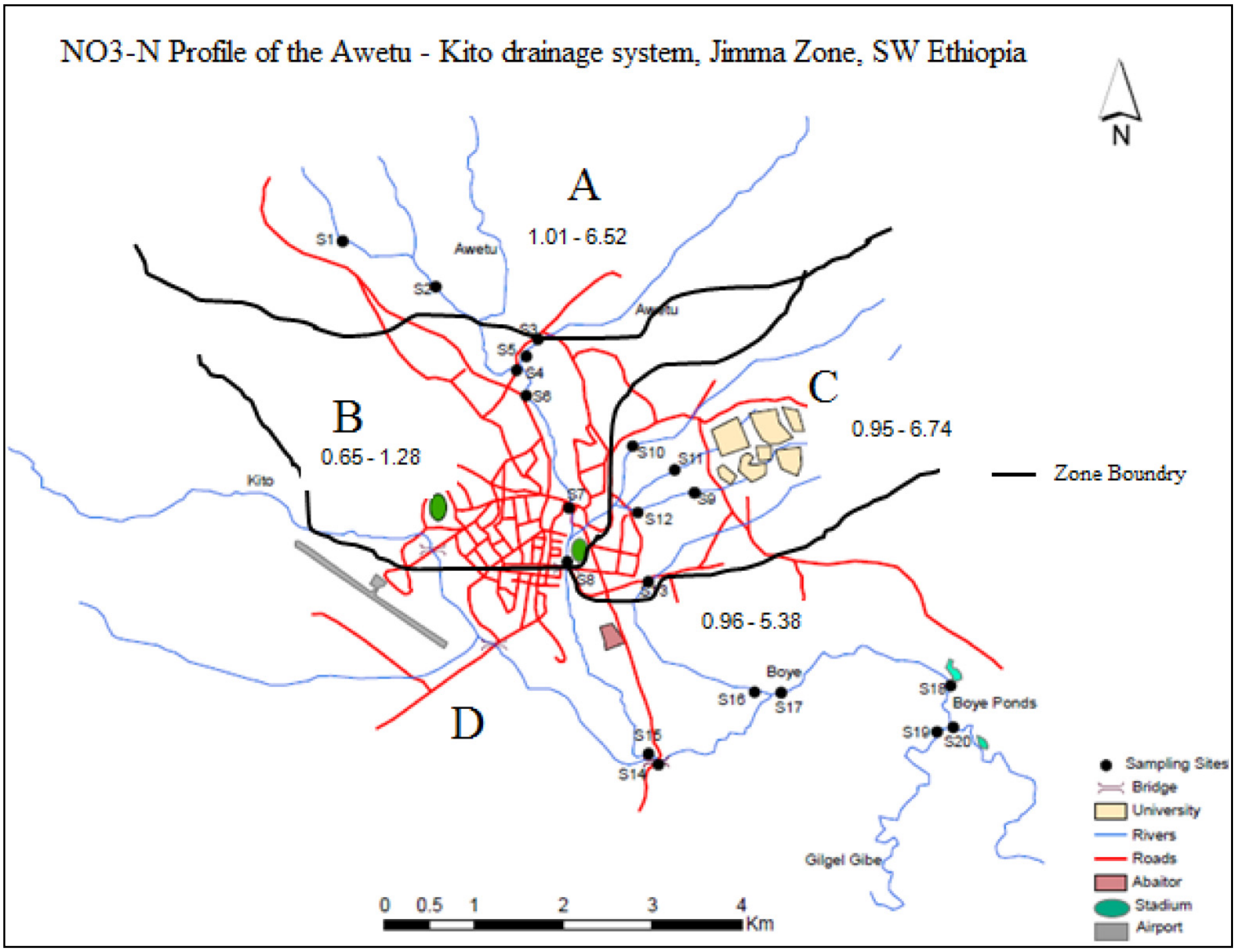

Fig. 5. Zonation of the Awetu-Kito drainage system by level of NO_3-N. Numbers in each zone represent ranges values in mg/L of NO_3-N in each zone.

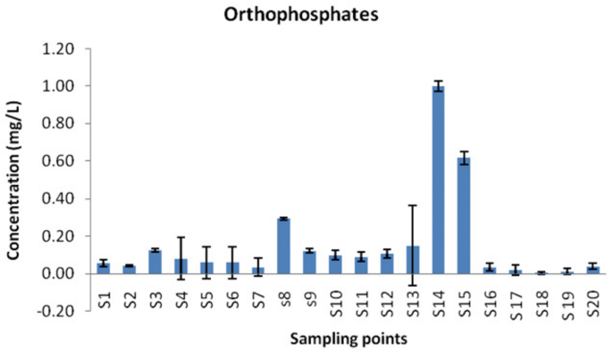

Fig. 6. Orthophosphate concentration along the Awetu-Kito drainage basin in Jimma Town, SW Ethiopia (March 2010).

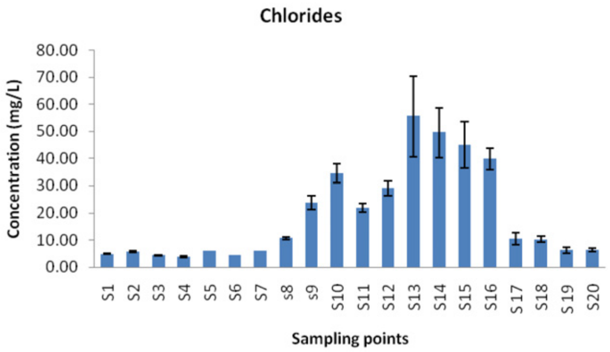

Fig. 7. Concentration of chlorides along the Awetu-Kito drainage basin in Jimma Town, SW Ethiopia (March 2010).

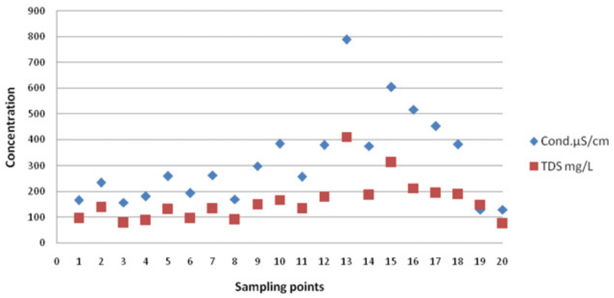

Fig. 8. Conductivity and TDS concentration along the Awetu-Kito drainage basin in Jimma Town, SW Ethiopia (March 2010).

which it rises, reaching a peak at S15 (51 mg/L). From here, it starts to decline again reaching 5.5 mg/L at S20.

Figure 7 shows the trend of conductivity and TDS. The similarity of the conductivity profile with the chloride concentration profile is evident. The maximum observed values are 876 µS/cm and 411 mg/L, respectively at S13. This sharp increase is possibly a reflection of a combination of wastewater drainage from JU, the wash water from the fuel station together with the discharge from the mosque joining Seto stream, which in itself has a very high conductivity. S15 is another sensitive point. This is the point where Awetu comes to join Kito carrying an increased organic waste load from the abattoir.

Figure 8 indicates the percentage contribution of major point sources of pollution to the rivers in Jimma town, calculated as explained in the Materials and Methods section. Of the 7650 kg BOD that is discharged to the river everyday, it was found that the abattoir that serves as a slaughtering, and hide and skin processing plant exerts 1840 kg BOD/day (24%). JU contributes 1120 kg BOD/day, which is 15% of all the other sources. It is not difficult to assume the contribution of the tanneries (14 %) and the coffee plant (12%) to be as high as indicated because, additionally, both nearby sampling points encompass diffuse sources of pollution from hotels, clinics and other small-scale institutions.

Discussion

The level of DO in this catchment of high industrial, institutional and commercial activity was found to be as low as 0.8 mg/L, a much lower level than the EPA guideline of 5 mg/L, which is the minimum requirement to support aquatic life.

The BOD_5 values recorded at S15 and S17 in Fig. 3 are so high that they are almost equal to BOD_5 values in public sewage waters. The EPA BOD_5 limit for fresh waters is 30 mg/L. By this definition, only the upstream of the rivers before they pass Jimma town (S1–S5) meet this guideline value confirming that Awetu is being used as a carrier to the indiscriminate waste discharge of Jimma residents, industry and institutions.

Based on the NO_3-N results, the Awetu River can be divided into four distinct zones (Fig. 9) namely zones A, B, C and D. Zone A lies in the upper catchment and is characterized by a high level of NO_3-N because of agricultural fertilizer input from the coffee nursery of Jimma college of agriculture, reaching its lowest level at S3. Zone B, stretching from S3–S8 is characterized by a low level of nitrate pollution with a maximum value of 1.5 mg/L at S8. The third zone (C), from S9 to S12 is characterized by high nitrate levels (as high as 7 mg/L NO_3-N) that comes from the wastewater from JU and surrounding communities. The conversion of NH_3-N to nitrate because of the high DO level in this region is another reason for the presence of high level of nitrates. In the same line of reasoning, the peak in NH_3-N and drop in NO_3-N at S13 are explained by the very low level of DO at that point, impeding the oxidation of NH_3-N to NO_3-N. In zone D, we again see relatively low NO_3-N with the exception of the peak loading at S15 because of untreated wastewater discharge from the abattoir. Denitrification is expected because of anoxic condi-

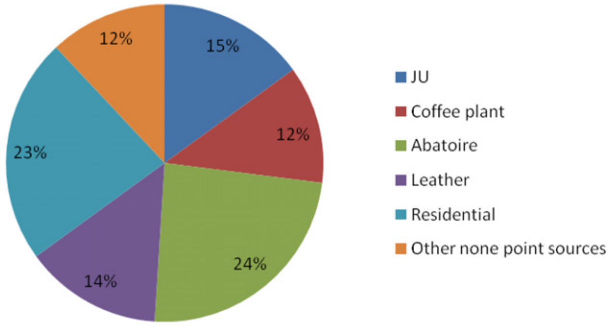

Fig. 9. Percent contribution of BOD_5 loading on Awetu-Kito rivers by main sources of pollution in Jimma town, SW Ethiopia, March 2010.

tions in this region. In addition, the presence of abundant aquatic plants can be responsible for nutrient uptake for growth. On the other hand, the increase of NH_3-N at S18 could be attributed to organic nitrogen decay.

The EPA has set the maximum contaminant level of nitrate as nitrogen (NO_3-N) at 10 mg/L for the safety of drinking water (EPA 1989). Nitrates at/or above this level have been known to cause a potentially fatal blood disorder in infants under 6 months of age called methaemoglobinaemia or *blue-baby* syndrome. Thus far, nitrate levels in this basin are below this guideline value.

In the case of NO_2-N, the concentrations remained relatively consistent throughout the system with the highest value being observed at S16 (0.21 mg/L) and the lowest at S17 (0.021 mg/L). The increase of nitrite concentration coincides with the region where there is not enough oxygen to (fully) oxidize NH_3-N to NO_3-N (S13–S14). EPA adopts 1 mg/L NO_2-N for regulated public water systems. Hence, also nitrite levels are within the permissible limit.

No national or state criteria have been established for the concentrations of phosphorus compounds in water. However, to control eutrophication, the EPA makes the following recommendations: total phosphate should not exceed 0.05 mg/L (as phosphorus) in a stream at a point where it enters a lake or reservoir and should not exceed 0.1 mg/L in streams that do not discharge directly into lakes or reservoirs. The phosphorus levels are, hence, too high to prevent eutrophication, witnessed by the state of the receiving Boye pond (which is in fact not a pond anymore at this moment).

The above observations are corroborated by other surveys in the Horn of Africa. For example, BOD_5 levels along the Nairobi River in Kenya ranged from 30 mg/L at Fourteen Falls to 204 mg/L at Chiromo. Phosphates ranged from 2 to 3.3 mg/L. The Nairobi River was also found to have a nitrate level as high as 520.6 mg/L. The major sources of pollution in this river basin were identified to come from industrial effluent, effluent from petrol stations and motor vehicle garages, surface run-off from factories and other business premises, raw sewage from broken or overloaded sewers as well as raw sewage from informal settlements (Budambula & Mwachiro 2006).

Turning back to the Awetu River, the increase in chloride concentration after S7 can be explained by the local level hide and skin processing (pickling) practiced by many retailers at different spots and is further magnified by the presence of the abattoir that also preserves hide and skins on-site. Agricultural activities that use potassium-based fertilizers and solid waste dump sites found in the area could be the reasons for increase in chloride levels in S14–S16. The decline at S17 and beyond is because of dilution from nearby streams that contribute for the increase of the water volume. The EPA secondary drinking water regulations recommend a maximum concentration of 250 mg/L. The reported values remain within the safe range.

The trend of the conductivity and TDS is very similar. The conductivity of natural waters varies between 50 and 1500 μS/cm. (Bartram & Ballance 1996; Reeve 2002). TDS values for fresh waters usually range from 0 to 1000 mg/L. The conductivity and TDS values of the sampled river water lie within the reported ranges.

From the survey, it can be concluded that the standards for BOD_5 (and corresponding DO values) and phosphorus are not met, while the values of the nitrogen components stay (just) below their limits. Because the highest values are always recorded in the vicinity of an industrial or institutional activity, it is clear that, at this moment, their impact on the water quality is much higher than that of the household wastewater.

It is legitimate to assume that in Jimma, 100% of the industrial wastewater is disposed of untreated. As indicated in the introduction, MoWR *et al*. (2004) reported that only 7.5% of the surveyed industries in Ethiopia have some kind of on-site wastewater treatment system. This is much lower than the UN-Water (2009) report, which indicated that in developing countries 30% of the industries treat their wastewater. Hence, a clear focus on the on-site treatment of the industrial wastewater, preferably with (feasible) treatment standards enforced by law and with a regular monitoring by the government, will alleviate a large part of the environmental burden. The wastewater of major (nonindustrial) activities such as university campuses must be treated with high priority. In addition, the run-off of fertilizer-based nutrients originating from agricultural activities must be prevented by adopting watershed management strategies. Furthermore, the high organic load of the wastewater of the coffee plant and abattoir could be turned into an advantage when anaerobic wastewater treatment with corresponding energy recovery is contemplated (the first results seem promising).

Evidently, this is only a part of the solution. While the impact of the population seems low at this moment, the population of the town has more than tripled during the past 30 years. Haile

(2004) reported that, in Ethiopia, while the national population growth rate is 2.46%, the urban centres grow at a rate of 5.1% (Fig. 10). Although Ethiopia has the lowest level of urbanization, the urban population growth rate is higher than in the rest of the world (CSA 2005; UNEP 2006). A retrospective analysis of the impact of urban population growth on surface water in Jimma, Ethiopia reveals that DO has been depleted nearly five times, and the BOD_5 load has been intensified 18 times in a span of 10 years at sampling point S8 (Table 2). Hence, the contribution of residential areas is likely to increase above the mentioned 23% in the near future.

Industrialization has been one of the major factors in the development of countries and has caused a population increase in cities, resulting in urban sprawl. Because industrialization and urbanization often advance in an uncontrolled or unorganized way in developing countries, they can have destructive effects on the environment, particularly on basic ecosystems, wildlife habitat and global biodiversity. Without proper on-site treatment and/or collection and centralized treatment of the household wastewater, the receiving water bodies will be threatened and even damaged beyond repair. While the technologies exist to treat this water, their costs, but predominantly also their management, will be the major bottleneck.

Most African countries have environmental policies. In Ethiopia, for example the Federal EPA has developed policies for water resources management and environmental protection in April 1997. The problem is that implementation lags behind policy and that the mechanisms of implementation and enforcement are not set properly (Haddis 2009; UNEP 2009). More details on strategies to overcome these treatment and management problems are presented in Haddis *et al*. (2012). Furthermore, the water supply and sanitation programmes that were initiated by development agencies for developing countries relied on on-site sanitation systems like septic tanks and pit latrines. This choice, which was logical at that time, proved to be insufficient as water supply coverage increases, hence demanding for low cost, community-based collection and treatment of water-borne sewage.

The conclusions that are drawn on the basis of this survey in Jimma are representative for numerous towns in Ethiopia (e.g. towns within the Awash river basin such as Debre Zeit, Mojo, Nazareth, Kombolcha and Dessie, to name but a few) and even for other mid-sized cities in Africa. Given the similarities in geographical location and climate zones and similar socio-economic indicator values (see Fig. 11), a common trend could be expected in other mid-sized cities south of the Sahel (Ethiopia and South Sudan) and the Serengeti ecosystem (from Tanzania to south-western Kenya), like, for example, towns in the Mara river basin in Kenya and Tanzania.

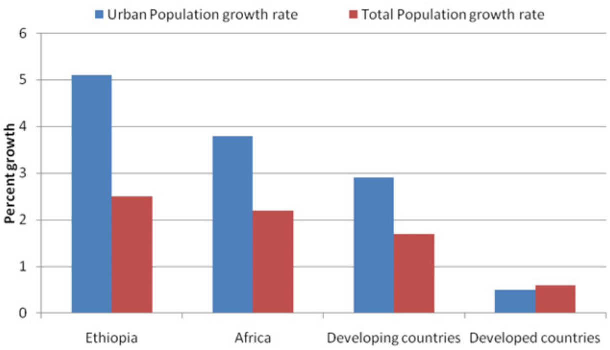

Fig. 10. Comparison of urban population growth in Ethiopia and different regions of the world.
Source: Situational analysis of SH in Ethiopia.

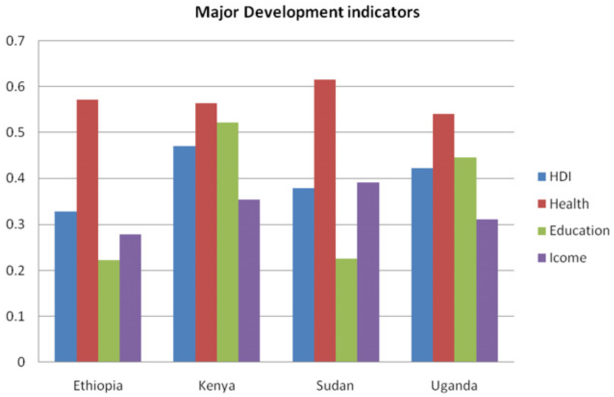

Fig. 11. Selected socio-economic indicators in some representative countries of Africa.
Source: UNDP 2010 report.

Table 2 Urban population growth versus changes in water quality in Jimma town, south-west (SW) Ethiopia

Year	Population	DO (mg/L)	BOD (mg/L)	NH_3-N (mg/L)	Source
1984	60992	5.86	12.43	0.35	CSA 1985. lab practical reports
1989	71725	5,30	14.48	0.56	CSA 1990. lab practical records
1994	88867	4.71	28.63	2.17	Hailu and Legesse 1997, CSA 1995
1999	111674	4,85	19.67	4.47	Wacho 1999, CSA 2000
2004	157000	2.01	259	4.74	Abegaz *et al*. 2005. CSA 2005
2009	198000	1	360	5,48	Own data, CSA 2010

BOD, biochemical oxygen demand; CSA, central statistical abstract of Ethiopia; DO, dissolved oxygen.

They all suffer surface water pollution from the growing industrial activity and the growing population with overflows from pit latrines and septic tanks, as well as wastes from various institutions and domestic sources (MoWR *et al*. 2004; GLOWS & WWF 2007). According to a UNEP (2009) draft report, most of the cities in the western Indian Ocean in Africa do not have sufficient infrastructure for wastewater management. Accordingly, only 13% (the majority or 47% is for cities in South Africa) have central sewer systems. In Comoros Islands, for instance, a central sewerage system is available only for 0.3%, and cities in Mozambique and Madagascar have none. Open defecation is practised by 13% of the population in these urban centres, and 62% use some kind of a pit latrine. Most industries in Tanzania located in the municipal towns of Tanga, Unguja and Dar es Salaam lack infrastructures for adequate industrial wastewater collection and treatment and thus discharge untreated or partially treated wastewater into surface water bodies such as rivers and the ocean. Most of the major manufacturing industries (over 90 %) located along the Kenyan coastal area in the industrial areas of Mombasa and Mazeras and Mariakani area in the Kilifi District, do not pretreat their effluents before discharge, with the exception of a few which include the petroleum refinery (UNEP 2009).

A final remark is that no microbial (pathogen) loading or microbial community impact analysis has been included in this study because of a lack of resources. However, for the same region in Ethiopia but focusing on tannery wastewater discharge, the impact on the microbial community diversity and self-purification capacity of the river system, reference is made to E. Mengistie, A. Ambelu, T. Van Gerven and I. Smets, unpublished data.

Conclusions

The following major conclusions can be drawn from this study.

(1) Surface water pollution in the urban centre that has been considered was mainly as a result of a too high load in BOD_5 (with corresponding low DO values), phosphorus and nitrogen; the former three well above and the latter only just below the recommended limits. Because the extreme values were always recorded in the vicinity of industrial or other institutional activities, the impact of those activities is, at the moment, more significant than the more diffuse pollution imparted by the households. However, with the exponentially increasing population, timely action is required to prevent the rivers from becoming even more loaded than they are already.

(2) Similarities in socio-economic factors, in the patterns of urbanization and industrialization, in the trends of population growth and in environmental policy implementation in many mid-sized African cities in Kenya, Tanzania, Sudan and Ethiopia, suggest that the water quality deterioration in Jimma is a reflection of what happens to most (sub-Sahel and Serengeti region-related) African surface waters. Comparison with the higher population cities was out of the scope of this paper but might be an interesting research avenue.

(3) The discharge of untreated wastewater into rivers in many African cities indicates a lack of environmental management policies and a low level of enforcement when present. The use of stringent regulations integrated with awareness creation and sensitization of the industry and the general public should urgently be adopted by most rapidly growing cities in Africa.

(4) A huge contribution to surface water pollution in mid-sized African cities comes from on-site sources like industries and institutions. It is suggested that wastewater management policies should give priority to treating major point sources of pollution like effluents of industries and institutions with on-site wastewater treatment systems while at the same time developing strategies to cope up with growing municipal wastewater treatment demand.

(5) Cities in developing countries should use the advantage of the high-organic content of wastewater especially from abattoirs and coffee plants to generate energy.

(6) River quality assessment and monitoring systems are lacking. There is an urgent need to put this system in place to ensure sustainability of water resources. Assessment programmes should also consider microbial contamination and microbial diversity-related analyses.

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