Environmental Management (2016) 58:694–706
DOI 10.1007/s00267-016-0734-y

River Water Pollution Status and Water Policy Scenario in Ethiopia: Raising Awareness for Better Implementation in Developing Countries

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Received: 9 June 2015 / Accepted: 19 June 2016 / Published online: 30 June 2016

Abstract Despite the increasing levels of pollution in many tropical African countries, not much is known about the strength and weaknesses of policy and institutional frameworks to tackle pollution and ecological status of rivers and their impacts on the biota. We investigated the ecological status of four large river basins using physicochemical water quality parameters and bioindicators by collecting samples from forest, agriculture, and urban landscapes of the Nile, Omo-Gibe, Tekeze, and Awash River basins in Ethiopia. We also assessed the water policy scenario to evaluate its appropriateness to prevent and control pollution. To investigate the level of understanding and implementation of regulatory frameworks and policies related to water resources, we reviewed the policy documents and conducted in-depth interviews of the stakeholders. Physicochemical and biological data revealed that there is significant water quality deterioration at the impacted sites (agriculture, coffee processing, and urban landscapes) compared to reference sites (forested landscapes) in all four basins. The analysis of legal, policy, and institutional framework showed a lack of cooperation between stakeholders, lack of knowledge of the policy documents, absence of enforcement strategies, unavailability of appropriate working guidelines, and disconnected institutional setup at the grass root level to implement the set strategies as the major problems. In conclusion, river water pollution is a growing challenge and needs urgent action to implement intersectoral collaboration for water resource management that will eventually lead toward integrated watershed management. Revision of policy and increasing the awareness and participation of implementers are vital to improve ecological quality of rivers.

Keywords Water policy · River pollution · Ecological water quality · Ethiopia

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Introduction

Among the most critical challenges facing global society is the failure to maintain and improve environmental quality to achieve sustainable development. Although developing countries have established policies, laws, and formal governmental structures to monitor and control environmental pollution, they fail to implement and enforce them to protect the environment (Bell and Russell 2002). Most of these environmental policies and laws of developing countries are based on those developed in North America and Europe with slight modification or as a carbon copy without considering the availability of local technologies and resources. This might be one of the impediments to their implementation (Tedla and Lemma 1998). Governments in developing countries are expected to design and implement policies to increase economic growth and at the same time to protect the environment. As resources are scarce, the activities related to the economic development often get political priority regardless of their impact on the environment (de Oliveira 2002). Thus, the reluctance of most developing nations to address environmental issues in favor of economic development is in danger of becoming an insurmountable obstacle to implement the environmental policies and to achieve sustainable development. Water resources protection and conservation remain understudied and extremely challenging in developing countries (Oki and Kanae 2006) even though the use of aquatic ecosystems and surrounding landscapes is intensifying as a result of accelerated population growth (Gross 1986; Dietz et al. 2007; Kareiva et al. 2007).

Inadequate and poor quality of water supply, as well as a decline in equitable distribution of freshwater, are being reported from developing countries that are experiencing water pollution (Postel 2000). Consequently, developing countries are increasingly using polluted water supplies. In addition to rapidly increasing consumption of freshwater by people, their livestock, agriculture, and industries, the often unregulated discharge of untreated wastewater tends to decrease the available safe water supplies (Gadgil 1998). This complex environmental problem is often contributing to increased incidence of infectious and noninfectious diseases in developing countries (Pandey 2006). Water shortages and pollution of water resources are also impacting the natural environment in freshwater ecosystems by causing damage to natural vegetation and crops and loss of terrestrial and aquatic species. There is growing consensus that human health and wellbeing are inextricably related to the health of the natural environment (Kareiva et al. 2007) and that water resource management should integrate environmental, economic, and social values of water resources development. Similarly, a basic precept of the new science of environmental economics is that provision of adequate safe water for environmental protection should be cost-effective in the longer term (Kloos and Legesse 2010).

The integration of environmental, economic, and social values of water resources development and use has not been practically considered in environmental policies in Ethiopia (EEPA 2004). Hence, the adoption, implementation, and valuation of water for ecosystems conservation and livelihood sustainability are considered to be still in their infancy (Kloos and Legesse 2010). Protection of water resources and other natural resources traditionally received inadequate attention at all levels in Ethiopia. This has been manifested in the gross pollution of many rivers as a result of rapidly increasing urban populations and intensified agricultural and industrial activities (Hailu and Legesse 1997; Haddis and Devi 2008; Beyene et al. 2009a, 2009b; Beyene et al. 2012). Several studies also reported that untreated waste from traditional and modern processing industries is threatening surface waters worldwide and is severe in developing countries like Ethiopia (Joshi and Sukumaran 1991; Ho and Hui 2001; Arimoro 2009; Beyene et al. 2009b).

In the two faces of competition for water supplies between the growing industrial, agricultural, domestic, and other human needs and for conservation of aquatic life in the natural ecosystems, there is a real danger of environmental collapse and ever worsening poverty, unless effective and feasible water policy with appropriate institutional framework is designed and implemented (Meinzen-Dick and Appasamy 2002; Xue et al. 2015). It is also estimated that the problem of scarcity and equitable access can further be exacerbated due to projected impacts of climate change unless appropriate tools are built in the form of effective policy (Mukheibir 2010).

Ethiopia has begun to fully address the issues of meeting the water needs of its rapidly growing population, reducing poverty and boosting economic growth regardless of the severe environmental impacts. Such patterns of resource use that aim to meet the human and economic needs without protecting the environment can lead to a disastrous unsustainable development-pollution-poverty cycle. This environmental policy scenario has been described by several studies focusing on land management in the highlands of Ethiopia (Hoben 1995; Shiferaw and Holden 2000; Benin 2006). These reports indicated the risk water bodies are facing as a result of poor land management. Most studies of water resources focus on quantity and use of water for different purposes without adequately considering ecological impacts (Kamara et al. 2004; Benin 2006).

Ethiopia is often referred as a water tower of Africa as many large rivers originate in the Ethiopian highlands and flow to the surrounding countries. However, recent studies in Ethiopia indicated that surface water pollution is high especially around towns, in intensively cultivated agricultural areas, and in coffee producing areas (Alemayehu 2001; Devi et al. 2008; Beyene et al. 2009a, 2009b; Beyene et al. 2012). The Kebena and Akaki rivers flowing through Addis Ababa, the capital of Ethiopia, are examples of the world's most severely degraded ecosystems (Alemayehu 2001; Beyene et al. 2009a). Despite the increasing levels of pollution in Ethiopia and some other tropical African countries, there is little information about the current ecological status of their rivers and streams and impacts on the biota that may be used to influence the policy direction. This may be due to the lack or absence of regular monitoring programs. If the existing problems of poor ecological status of the rivers are not well studied and communicated to policy makers, it is highly likely that the policies and implementation activities overlook the issues (Hoben 1995; MoWIE 2001). While studying the ecological status of rivers to quantify the river pollution problem is mandatory, it is equally important to periodically evaluate the water policy scenario to determine its appropriateness to prevent pollution and to restore aquatic systems. Therefore, this study aimed to investigate both the physicochemical and biological water quality status of selected sites in four major Ethiopian river basins in severely impacted agricultural and urban landscapes and forested or minimally impacted localities to indicate the current status of pollution. The existing water policy, legal, and institutional arrangements are reviewed to investigate their appropriateness to prevent and control water pollution.

The results are relevant to frame the agendas and policies of Ethiopia to implement the sustainable development goals (SDGs). The results will also help to improve institutional arrangements toward optimum water resource management and the sustainability of aquatic ecosystems.

Methodology of Assessment and Evaluation

River Water Pollution Status

Study Area and River Basins

The study sites are located on the headwaters of the four major Ethiopian rivers in the central highlands around Addis Ababa, the southwestern highlands around Jimma Town, and the northern and northwestern highlands. Rivers and streams that receive untreated urban, coffee processing, and agricultural wastes and forested rivers with minimal impacts were included in this study. The Awash River is impacted mainly by urban pollution from Addis Ababa, the Tekeze river is impacted by agricultural pollution, and the Blue Nile and Omo-Gibe rivers are impacted by both agricultural and coffee waste. However, all types of impacts were observed in the four basins except the coffee waste impact, which was limited to the Omo-Gibe and Blue Nile sites (Fig. 1).

Sampling and Sample Processing

It is impossible to select aquatic sampling sites in the field that are similar in all aspects and that can be divided into control and experimental groups. But this problem can be solved by choosing adjacent sites on the same streams or rivers that permit upstream and downstream comparisons (Reynoldson et al. 1997). Based on this approach, an array of sampling sites comparatively free from urban, agricultural, and coffee waste impacts was selected in the upstream site of the rivers, hereafter called nonimpacted/minimally impacted or reference sites ($n = 28$). The second group which was affected by urban ($n = 44$), agricultural ($n = 59$), and coffee processing wastes ($n = 25$) is described as impacted sites. We selected a total of 156 sampling sites with a heterogeneous habitat for water, diatom, and macroinvertebrate sampling.

We conducted biological and water sampling immediately after the main rainy season (September to November) and during the dry season (February to April) from 2009 to 2012 to show the average level of pollution. Samples were taken once at each site during the dry and rainy seasons. Macroinvertebrates were collected and processed using a standardized method devised by Ostermiller and Hawkins (2004) and strictly followed as described by Beyene et al. (2009b). For the diatoms, three natural substrates (stones) were collected randomly at each sampling site within 10-m reach from the shore and a total surface area of about 75 cm^2 from these substrates scraped with a toothbrush and pooled to form a single sample, as recommended by Kelly et al. (1998). We followed similar procedures for diatom sample processing, identification, and counting as described in Beyene et al. (2009a).

We employed a composite sampling technique to take water samples at three sampling points across the width of the rivers for chemical analysis. Both the filtered and unfiltered water samples were kept in a chilled ice chest during transport and refrigerated in the laboratory of the School of Environmental Health Science and Technology, Jimma University, Ethiopia, and kept in a deep freezer until they were analyzed except for BOD which was immediately incubated. The concentrations of nitrate, 5 days biochemical oxygen demand (BOD_5), total phosphorous (TP), and total kjeldahl nitrogen were measured using cadmium reduction, azide modification of the Winkler's titrimetric method, ascorbic acid, and Kjeldahl methods, respectively, following American Public Health Association et al. (2005). In-situ measurements of dissolved oxygen (DO), water temperature, pH, and electrical conductivity were taken using multiparameter probe (Hach-Model-HQ30d multiparameter digital meter).

The data were analyzed and compared among different groups of impaired sampling sites (agriculture, coffee processing, and urban) versus reference sites (minimally or none-impacted forested sites). Standards for Ethiopian water bodies to protect aquatic life forms are not set yet to compare with, and therefore, we used the concern levels recommended by US-EPA and EU for comparisons to show the level of chemical pollution at the sampling sites.

Macroinvertebrate- and diatom-based biodiversity and pollution indices were computed and compared among the groups of sampling sites to determine the ecological quality profile of river basins in relation to anthropogenic impacts. Richness represents the total number of taxa in a sample or study site. Shannon-Weiner index is a measure of the proportional abundance of each species present at one location, and we determined the evenness by calculating

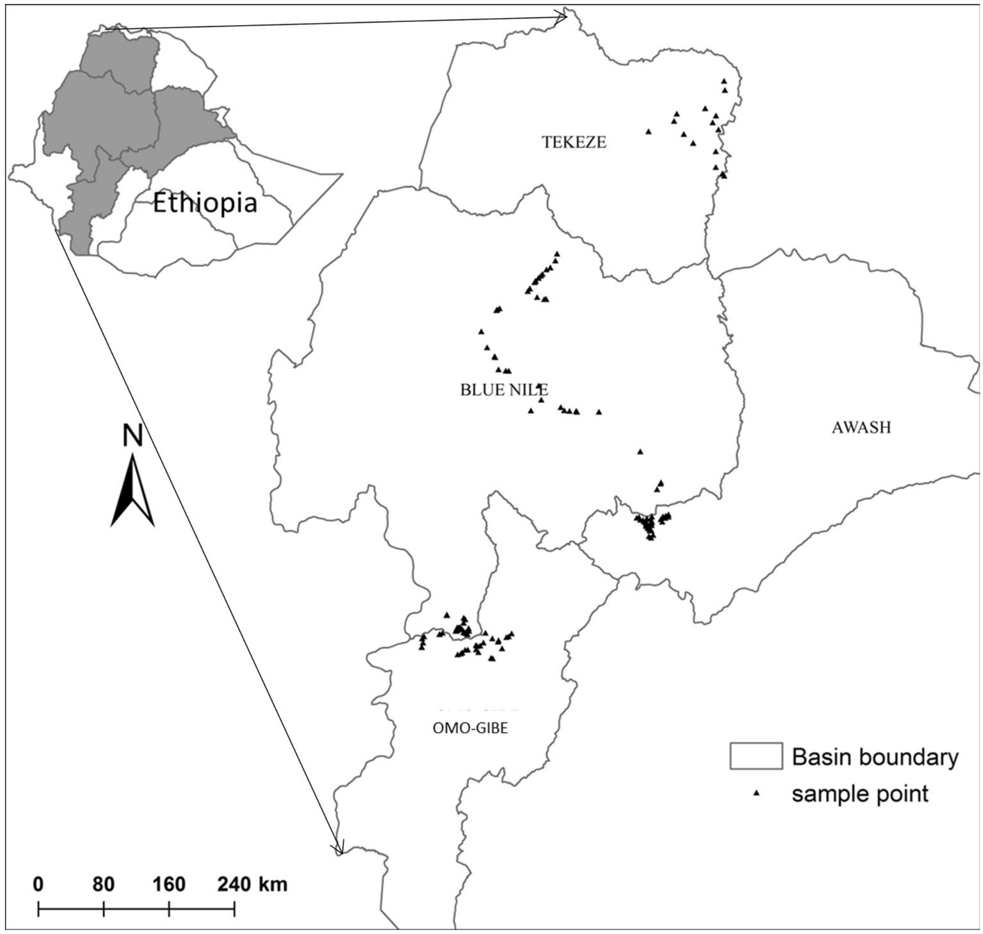

Fig. 1 The study area with four river basins and sampling points

the ratio of the calculated Shannon's diversity with the maximum possible diversity of the number of species found (Shannon and Weaver 1963). We used Simpson's index (D) to measure dominance and the probability that two randomly selected individuals from a community will belong to the same species (Simpson, 1949). Alpha index was calculated using the equation given in McAleece et al. (1997). All these indices were calculated with the help of Paleontological Statistics Software package (PAST) Version 2.17 (Hammer et al. 2001).

We also computed the percentage of pollution tolerant taxa (%PT) in the bioindicator communities by taking the ratio of pollution tolerant taxa in the total taxa. The biotic indices, Family Biotic Index (FBI) for macroinvertebrates and Indice de Polluosensibilité Spécifique (IPS) and Indice Biologique Diatomées (IBD) for diatom communities, were also calculated. The biotic indices for diatoms (IBD and IPS) were calculated for using the OMNIDIA software version 5.2 (Lecointe et al. 1993).

Family biotic index (FBI) that indicates organic as well as nutrient pollution and provides an estimate of water quality using established pollution tolerance values for each taxon was calculated for the macroinvertebrate community. The score on a scale of 0–10, higher scores indicating poorer water quality class in terms of organic pollution (Hilsenhoff 1988), was used to compare the water quality class among the reference and impacted sites.

Policy Scenario Review

In order to assess the regulations and policies related to water resources development and use and the effectiveness of institutional arrangements to enforce them, we reviewed all available and documented Ethiopian policies, legislations, proclamations, and strategic plans.

We also conducted stakeholder analysis of the knowledge of the major stakeholders about the main policies and the status of water pollution, to identify the gaps they experienced during the implementation of the policies and tasks planned for their respective institutions. In-depth interviews were conducted for 31 separate participants using a questionnaire that the participants were asked to fill in and supported by follow-up discussion with the investigator to supplement this information. The participants were drawn from stakeholders at different institutions dealing with water resources management within the study area. They are working in the Ministry of Water, Irrigation and Energy (MoWIE), Ministry of Agriculture (MoA), and Ethiopian Environmental Protection Agency (EEPA). The regional and local offices of these institutions in the Oromiya, Amhara, and Tigray regional water offices and the Addis Ababa EPA and Addis Ababa Water and Sewerage Authority were also visited. Four officials of the Basin Management Authority (BMA) and four local-level water committee members (who are representatives of the local communities that are users of river water) were also interviewed about how well they know and practice the water policies and understand the problems they encounter in implementing the policy objectives to safeguard the ecological quality of water bodies.

Results and Discussion

Extent of River Pollution in the Study Area (Part 1)

Results

Physicochemical Water Quality Features of the Rivers The mean, median, and 1st and 3rd quartiles of pollution in the rivers studied for urban, traditional coffee processing, and agricultural impacts are presented in Table 1. Although the organic pollution load expressed as biochemical oxygen demand (BOD_5) was high for all pollution sources, it was extremely high in the untreated coffee effluents and urban wastes that were directly disposed into nearby rivers. In all the basins, the BOD_5 level is significantly higher (at P value < 0.05) in impacted sites than reference sites (Table 1). Dissolved oxygen (DO) was depleted to an average level of 2.6 mg/L in the urban impacted river sites of the Awash River basin in Addis Ababa. All the other basins (Blue Nile = 4.9, Omo-Gibe = 5.7, and Tekezie = 4.9 mg/L of average DO concentration) also exhibited significantly lower levels of DO in the urban impacted sites. As shown in Table 1, the total nitrogen (TN) and the total phosphorus (TP) are significantly higher in impacted sites compared to reference sites in all basins. The TN and TP values in the impacted sites are also 100-fold and 1000-fold higher, respectively, than the concern concentrations pinpointed by either European WFD or US-EPA as concern levels to protect aquatic life in rivers (Chave 2001; US-EPA 1986). The pH value recorded was not significantly different between the reference and impacted sites. However, a slight decrease was observed in urban impacted sites of the Tekeze basin. The electrical conductivity was observed to be significantly higher in agricultural and urban impacted sites of all basins and coffee waste groups of the Omo-Gibe basin compared to the respective reference sites (Table 1).

Biological water quality features of the rivers and their ecological quality Both macroinvertebrate and diatom indices showed poor river water quality due to pollution resulting from urban sprawl, traditional coffee processing, and poor agricultural practices as compared to reference sites. Diversity was significantly depreciated in the impacted sites as compared to the reference sites. The urban impacted sites were also dominated by the pollution tolerant (PT) taxa, i.e., 99.9 and 85.9 % for macroinvertebrates and diatoms, respectively (Table 2). Based on Family Biotic Index (FBI), water quality class is determined on a scale of 0–10, where higher values indicate poor water quality class. According to this FBI, all the impacted sites were within the range of bad water quality (FBI > 5.0).

Diatom indices, both Biological Diatom Index (IBD) and Specific Pollution Sensitivity Index (IPS), which are interpreted on a scale of 1 to 20 (low scores indicating poor class), also indicated poor water quality (IPS and IBD < 9.0) for the impacted sites (Table 2).

Discussion

Physicochemical Stressors Most measured physicochemical parameters that indicate water pollution are significantly higher in impacted sites when compared to reference sites. Biological oxygen demand (BOD_5) levels were extremely high in urban and coffee waste impacted sites, while DO was significantly lower in those groups compared to reference sites. In some of the rivers in the Awash basin, DO values were lower than 1.0 mg/L. Other case studies in Ethiopian rivers also reported high organic pollution in streams transversing towns or cities (e.g., Beyene et al. 2009a, 2009b; Van der Bruggen et al. 2009) and release of untreated coffee waste (e.g., Beyene et al. 2012) that significantly depleted oxygen to almost zero. This stress that the rivers receive from the organic loads due to the discharge of untreated coffee processing wastes, industrial effluents, or domestic wastes from urban settlements has severe ramifications to the aquatic life forms in the rivers, especially the pollution-sensitive ones.

Very high levels of nutrients (TN and TP) which are causes for eutrophication in water bodies were also observed. Eutrophication of surface water in Ethiopia and other countries in Sub-Saharan Africa due to siltation and nutrient enrichment was also reported by several other case studies (Devi et al. 2008; Nyenje et al. 2010). Electrical conductivity was observed to be significantly higher in agricultural and urban impacted sites compared to reference sites. This indicates that the inorganic dissolved solids such as chlorides, nitrates, and other ions are high in the impacted sites due to their exposure to the pollution sources.

Table 1 The physicochemical measurements summarized in mean, median, and interquartile range for the impacted sites of the Blue Nile, Omo-Gibe, Awash, and Tekeze river basins compared to the reference sites and the concern level (CL)

Parameters, mean (median, IQR)	CL	Reference forest	Impact type		
			Agriculture	Urban	Coffee waste
Blue Nile					
TN(mg/L)	<0.3	0.9 (0.2, 0.1–1.2)	**7.3** (8.0,1.5–10.5)	**11.1** (5.9,4.4–18.0)	**9.3** (8.2, 5.4–10.5)
TP(mg/L)	<0.015	0.02 (0.08,0.06–0.15)	**0.4** (0.2, 0.1–0.4)	**1.0** (0.2,0.1–2.0)	**1.3** (0.4, 0.1–1.4)
DO(mg/L)	>7	6.9 (7.0,6.5–7.2)	6.2 (6.6, 5.8–6.8)	**4.9** (5.2, 2.9–6.8)	5.9 (6.2, 5.7–6.6)
BOD5(mg/L)	<3	1.8 (0.7, 0.3–1.0)	**12.2** (1.2, 0.7–21.4)	**18.4** (15.3,8.1–28.6)	**17.6** (3.3,1–22.7)
pH	6.5–9	7.0 (7.0,6.9–7.2)	7.4 (7.4, 7.0–7.6)	7.2 (7.4,6.7–7.7)	7.1 (7.2, 7–7.3)
EC (µS/cm)	–	76 (66, 65–95)	**122** (76, 66–156)	92 (86,79–105)	95 (76,64–96)
Omo-Gibe					
TN(mg/L)	<0.3	1.5 (2.7, 1.9–3.4)	**20.3** (21.1, 16.7–23.4)	**17** (16.4, 14.8–19)	**22** (23, 18–26)
TP(mg/L)	<0.015	0.08 (0.08, 0.08–0.1)	**0.3** (0.1,0.1–0.4)	**0.2** (0.2, 0.1–0.3)	**0.3** (0.1, 0.1–0.3)
DO(mg/L)	>7	7.0 (6.9, 6.5–7.3)	6.1 (6.2,5.6–6.5)	**5.7** (6.3, 5.7–6.5)	**4.7** (4.8,4.3–5.6)
BOD5(mg/L)	<3	2.3 (2.4, 2.2–2.6)	2.7 (2.1,1.5–2.5)	**108** (130, 90–150)	**64** (57, 24–102)
pH	6.5–9	7.3 (7.3, 6.8–7.8)	7.2 (7.3, 6.7–7.6)	7.3 (7.3, 7.2–7.3)	6.8 (6.8,6.4–7.2)
EC (µS/cm)	–	95 (99, 94–103)	**117** (102, 95–130)	**140** (140, 120–160)	101 (99, 89–110)
Awash		Minimal impact	Agriculture	Urban	
TN(mg/L)	<0.3	0.2 (0.1, 0.1–0.2)	**2.6** (2.2, 1.6–2.7)	**30.8** (26, 18–46)	
TP(mg/L)	<0.015	0.08 (0.08, 0.05–0.12)	**0.9** (0.3, 0.1–1.1)	**12.5** (11.2, 6–15)	
DO(mg/L)	>7	7.1 (7.1, 7–7.2)	6.8 (7.0, 6.2–7.5)	**2.6** (1.9, 0.9–3.8)	
BOD5(mg/L)	<3	3.2 (2.5, 2–4)	**6.9** (5.9, 4.3–7.9)	**508** (413, 98–864)	
pH	6.5–9	7.3 (7.3, 7.2–7.4)	7.8 (8.0, 7.2–8.3)	7.2 (7.4, 7.0–7.8)	
EC (µS/cm)	–	93 (92, 81–102)	**192** (195, 105–250)	**580** (608, 220–800)	
Tekeze					
TN(mg/L)	<0.3	0.7 (0.4, 0.2–0.8)	**1.5** (1.0, 0.9–1.6)	**3.1** (3.1, 2.2–3.9)	
TP(mg/L)	<0.015	0.13 (0.06, 0.04–0.09)	0.2 (0.1, 0.1–0.2)	**2.0** (2.0, 1.3–2.6)	
DO(mg/L)	>7	7.6 (7.5, 7.3–8.1)	6.8 (6.2, 6.1–7.8)	**4.9** (5.2, 3.9–6)	
BOD5(mg/L)	<3	6.5 (5.5, 5.2–6.2)	**11.3** (10, 7.8–14.5)	**29** (30, 21–37)	
pH	6.5–9	7.5 (7.4, 7.2–8.1)	7.6 (7.6, 7.4–7.7)	6.3 (6.6, 6–6.7)	
EC (µS/cm)	–	381 (350, 325–430)	**560** (551, 403–573)	**514** (456, 403–624)	

The concern level (CL) to protect aquatic life in rivers were compiled from recommended values by European WFD (Chave, 2001) and US-EPA (1986)

Mean values in bold fonts are those significantly different from the reference sites at $p < 0.05$

The physicochemical results in general revealed that there is gross pollution in the study sites in the Awash, Omo-Gibe, Blue Nile, and Tekeze river basins. In Ethiopia, like many other African nations where environmental legislation is weak, it is not surprising that water pollution is rampant. Other studies, which had been conducted in Ethiopian rivers also indicated the severe organic pollution and depletion of dissolved oxygen (Alemayehu 2001; Haddis and Devi 2008; Beyene et al. 2009a, 2009b; Van der Bruggen et al. 2009).

Agriculture and urbanization are intensifying in Africa, increasing pressure on the environment. Agriculture is a large contributor of nonpoint source pollution to aquatic systems. The interaction between agricultural malpractices and the environment in Ethiopia results in relentless pollution of freshwater (Taddese 2001; Devi et al. 2008). Agriculture in Ethiopia is the main economic activity, contributing about 50 % of GDP, and 85 % of the population are making a livelihood in this sector (CSA 2007) but agriculture-induced pollution contributes significantly to damaging aquatic ecosystem health in the country. Agricultural malpractices have not only worsened environmental quality but also substantially reduced the productivity of the soil (Taddese 2001). The findings of this study are in agreement with studies conducted elsewhere in Africa where rivers have allotted for years as sinks for

Table 2 Macroinvertebrate and diatom indices for the impacted sites as compared to the reference sites: %PT percentage of Pollution Tolerant group; FBI Family Biotic Index; IBD Biological Diatom Index; and IPS Specific Pollution Sensitivity Index

Indices	Impacted river sites			Reference sites
	Urban pollution	Coffee processing pollution	Agricultural pollution	
Macroinvertebrate families				
Richness	4.0	5.0	10.0	30.0
Evenness	0.3	0.2	0.7	2.0
Simpson diversity (D)	0.1	0.3	0.5	0.6
Alpha	0.1	1.0	1.1	1.6
% PT	99.8	74.4	88.8	13.4
FBI	10.0	9.6	8.8	4.5
Diatom species				
Richness	4.0	10.0	90.0	250.0
Evenness	0.3	0.3	0.5	0.9
Simpson diversity (D)	0.6	1.0	1.0	1.6
Alpha	0.6	1.3	3.3	8.5
% PT	85.9	52.2	34.8	19.5
IBD	5.4	4.5	9.6	14.1
IPS	1.3	8.8	11.8	15.0

waste materials. Most of Africa's rivers flowing through agricultural landscapes, cities, and towns are heavily polluted as a result of agricultural malpractices and open dumping of wastes without adequate treatment (Alin et al. 2002; Ndiritu et al. 2003; Mati et al. 2008).

Water pollution has a major ecological impact on aquatic systems in coffee producing countries (Joshi and Sukumaran 1991; Mwaura and Mburu 1998) and this also appears to be the case in Ethiopia (Damodaran 2002; Haddis and Devi 2008). Although traditional coffee shedding systems, which have social and economic value (Vergara and Badano 2009) with minimal impact on biodiversity and environment (Perfecto et al. 1996; Damodaran 2002; Gordon et al. 2007; López-Gómez et al. 2008) prevail in most parts of Ethiopia, untreated waste materials from the increasing coffee processing activity is routinely discharged into local streams and rivers. Coffee processing has been criticized for the production of byproducts such as parchment husks, coffee pulp, and coffee husks, all of which contribute to environmental pollution unless treated or recycled (Mburu and Mwaura 1996). Coffee processing discharge therefore should be considered as one of the point source pollution causes that needs attention for its prohibition.

Biological Indications on the Study Sites The biological indicators, both diatoms and macroinvertebrates, are key indicators of water quality and widely used worldwide for water quality monitoring and assessment (Metcalfe 1989; Triest et al. 2001; Beyene et al. 2009a, 2009b). The indices of macroinvertebrates and diatoms revealed significant ecological quality deterioration at impacted sites but the most extreme impacts were recorded at the urban and coffee processing river sites as indicated by the individual biochemical parameters and the FBI, IBD, and IPS metrics. These findings are in agreement with other studies on Ethiopian rivers (Beyene et al. 2009a, 2009b; Beyene et al. 2012).

Both the physicochemical and biological results indicate that there is high river pollution in the study area due to urbanization, intensive agriculture, and untreated wastes from coffee processing. This implies that both point source and nonpoint source pollutions are contributing to the ecological degradation of rivers in Ethiopia. The point source pollutions like the coffee processing wastes can be prevented by emission control regulations and stricter application. The prevailing nonpoint source pollution from urbanization and agricultural activities calls for remedies through strong policies that aim to apply good agricultural practices, consider the rapid urbanization and its pressure on aquatic systems, and promote integrated watershed management through intersectoral collaboration. We reviewed the existing water policy and the level of implementation by stake holders in Ethiopia and the results are discussed in part two of this paper below.

Water Policy Review and Assessment of the Implementer's Knowledge (Part 2)

Legal, Policy, and Institutional Framework

There are different documented water resources related legal, policies, and institutional arrangements issued by the Ethiopian government for water pollution prevention and control. These include the national conservation strategy, environmental policy, water resource management policy, and water sector strategy and development program.

The National Conservation Strategy The Conservation Strategy of Ethiopia (CSE) was initiated by the government and approved by the Council of Ministers in 1994 (MoNRDEP 1994). The document is the first attempt to achieve sustainable development in Ethiopia. It provides an umbrella of strategic frameworks, detailing principles, guidelines, and strategies for the effective management of the environment. It also elaborates the state of the natural resources bases of the country and the institutional arrangements and action plans for the realization of the strategy, as well as the environmental challenges of the country. Thus, it identifies policy gaps and recommends short- and long-term interventions to mitigate the environmental challenges, including pollution. Although comprehensive and inclusive, the policy cannot be implemented as intended due to the shortage of skilled manpower, resources, and infrastructure. Moreover, this policy focused merely on water usage (MoNRDEP 1994) without considering the issues of aquatic resources conservation and pollution prevention via systematic monitoring.

The Environmental Policy of Ethiopia The Environmental Policy of Ethiopia, approved in April 1997, constitutes 22 spectral and cross-sectoral policy elements (EEPA 2004). Its overall objective is to improve and enhance the health and quality of life of all Ethiopians by promoting sustainable development (i.e., to meet current needs without compromising the ability of future generations to meet their own needs) (Lélé 1991). The articles in this policy theoretically address land degradation, soil conservation and sustainable agriculture, forest conservation and afforestation, genetic and ecosystem biodiversity, and protection of water and mineral resources. Section five indicates the need for the protection of water bodies but provides very limited details on its implementation. For instance, the objectives in section five, "preventing the pollution of soil, air and water" is not underpinned by specific enforcing legislations and strategies as well as appropriate institutional structures to ensure its implementation.

The EEPA has been given the authority in this policy to issue the first Environmental Pollution Control Proclamation in the country. This proclamation, which emanated from the environmental policy, was approved by Parliament as Proclamation No. 300/2002 (FDRE 2002). The proclamation set the goal to prohibit the release of pollutants into the environment, including water bodies. The proclamation advocates for the "polluters pay" principle to be implemented. In order to meet this goal, the EEPA is further empowered to issue environmental standards and guidelines based on scientific and environmental principles (EEPA 2004). Nevertheless, the EEPA issued standards and guidelines for only a limited number of pollutants in wastewater effluent discharged from selected industries (EEPA 2008). The guidelines also allowed very high concentrations as maximum levels that cannot protect aquatic life forms. Even for those elevated standards, despite advocating the polluters pay principle in the policy, there is no enforcing strong law or regulation stipulating how to penalize entities which exceed the standards. Moreover, the need for systematic monitoring of rivers and evaluation of environmental risks of pollution is not mentioned in any of the documents. Thus, it is not clear by whom and how such monitoring should be conducted within the context of the guidelines and proclamations, prohibiting the assessment of impacts on the ecological quality of water bodies. This situation appears to be due mainly to the lack of scientific evidence and lack of cooperation between policy makers and researchers on how to monitor and mitigate water pollution, as is often the case in developing countries.

Ethiopian Water Policy The Ethiopian Water Sector Policy, also known as Federal Water Resource Management Policy (MoWIE 2001), was issued in 1998. The objectives of this policy are sustainable use, protection, and efficient use of water resources (MoWRE 1998). The policy was legalized by the Ethiopian Water Resource Proclamation No. 197/2000, which is intended to be a more comprehensive and stronger version of the earlier Water Resources Utilization Proclamation No. 92/1994 (FDRE 2000).

The Ethiopian Water Sector Policy focuses primarily on river basins as the fundamental planning unit and water resources management domain. Thus, the policy gives direction for the establishment of basin institutions which are directly responsible for the integrated management of the respective basin systems of the country. Guidelines were issued only for two basins (Blue Nile and Awash). Although the future plan is to establish basin management authorities for all basins, currently efforts are being made to accommodate the management of the remaining ten basins by these two established basin authorities due to shortage of man power and resources and the absence of institutional arrangements. It is clear that river management based on continuous monitoring by two basin management authorities established only at the central level will not be feasible.

More specifically, Article 2.1.3 of the Water Sector Policy states the need to establish and adapt water quality standards and proper assessment procedures. However, the policy does not provide clear direction for the establishment of these standards and monitoring methods. Besides this infrastructural problem, the lack of scientifically proven tools impedes regular monitoring, considered to be essential for the effective prevention and control of water pollution (Chapman 1996).

The Environmental Policy states that the Ethiopian Quality Control Authority (EQCA) is authorized to set standards for water quality (EEPA 2004). Nonadherence to these standards by the EEPA, as stated above, and lack of coordination of efforts by the EEPA and other institutions, including the MoWIE, and the Ministry of Agriculture, render the standards ineffective. The EEPA focused only on maximum contaminant levels for industrial effluents while preparing the standards without considering the maximum possible concentration levels to safeguard aquatic life forms (EEPA (Ethiopian Environmental Protection Authority) 2008). Such overlap in responsibilities coupled with lack of coordination among EQLA, Ethiopian-EPA, and the MoWIE can be a key cause for failure to effectively protect water resources.

Ethiopian Water Sector Strategy The Ethiopian Water Sector Strategy was developed by the MoWIE to be used to operationalize the Water Sector Policy. A major problem with the strategic plan is the lack of specificity in terms of the methods for activities/actions with clear indications of what should be done and by whom it would be done in order to achieve the intended objectives. The strategic plan states that the MoWIE should undertake proper assessment, preservation, and enrichment of aquatic resources in rivers and lakes (MoWIE 2005). However, the responsibility was not delegated to a specific institution. Thus, Objective No. 5 of the Water Sector Policy aimed at "conserving, protecting and enhancing water resources and the overall aquatic environment on sustainable basis" is not addressed (MoWIE 2001; MoWIE 2005). The Water Sector Development Program was developed based on this strategy. The strong side of the Water Sector Development Program is that it makes an effort to involve sectors who will later assume responsibility for the implementation of the programs (MoWE 2002).

Summary of Water Related Policies A critical review of the documents of Ethiopian Water Sector Policy, the Ethiopian Water Sector Strategy, and the various water sector development programs vividly reveal what is missing from the policies, especially in terms of safeguarding the ecological quality of rivers and other water bodies. Most importantly, there is no clear goal to achieve within a certain period in terms of ecological quality status and the means and the tools to achieve the set goals and measure the progresses toward it. A good lesson in terms of this can be learned from the European Water Frame Work Directive (WFD). The Water Framework Directive (WFD 2000/60/EC) established a new regime for the prevention and control of chemical pollution of surface and groundwater. According to the provisions of the WFD, the member states should aim to achieve the objective of at least good water status by defining and implementing the necessary measures within integrated programs, taking into account existing livelihood requirements. These measures include environmental quality standards (EQSs), defined as the concentration of a particular pollutant or group of pollutants in water, sediment, or biota which should not be exceeded in order to protect human health and the environment. The scope of water protection covers all bodies of groundwater and surface waters, with the aim of achieving "good status" by 2015 (Chave 2001). Therefore, there is a clear goal to achieve and tools for assessing the progresses are provided in the WFD (Dworak et al. 2005), unlike in the Ethiopian water policies. Ethiopia does not need to carbon copy the WFD as the settings are clearly different, but in terms of planning clear objectives and identifying appropriate tools it could be a good example to learn from. In Ethiopian policy documents, lack of clarity and specificity is one of the major weaknesses. This weakness is leading to ad hoc development practices without having coherent objectives, monitoring, evaluation, and continuity in activities. Ethiopian water policies do not provide the necessary legal framework for penalties proportionate to the violations. This may be due to the use of policies and frameworks developed in developed nations that cannot be easily implemented with local technologies and resources in developing countries and the lack of locally adapted water quality assessment methods and guidelines. These aberrations render the policies and frameworks unrealistic and impractical. The water framework of Ethiopia has not set proper water quality standards and assessment procedures that enhance preservation and enhancement of aquatic resources. In the absence of an effective monitoring and control program, practically all rivers that cross cities and towns serve as dumping sites of liquid and solid waste from domestic, industrial, and commercial sources. Therefore, comprehensive legislation that is supported and enforced by effective institutional mechanisms is urgently required in Ethiopia to implement multisectoral water protection and conservation programs. Recently, upper catchment and lower catchment countries with transboundary rivers signed several agreements on the utilization of these rivers. It should be noted that these rivers can be utilized optimally only if they are not degraded. Therefore, those agreements should scale up toward integrated watershed management which is the long-term and sustainable solution.

Knowledge and Practices of Stakeholders

A total of 31 officials working in the water sector, 6 females and 25 males aged 24–51 years, participated in the interviews completely among the total of 38 invited individuals (7 individuals could not participate). The interviews aimed to assess the knowledge and perceptions of the stakeholders toward the policies related to water resource management and to identify the problems faced during implementation and practicing of ecological monitoring of freshwater systems. In a first set of questions the respondents were asked if they are familiar with the four major policy and proclamation documents related to water resources described above. Only about 5 % of the respondents were familiar with all four documents. The responses of the respondents indicate that the Water Sector Policy seems better known than the other three documents by the stake holders. As the water development program in the documents claim to involve stakeholders from all layers of the sector during preparation, one expects this document to be well known and positively perceived by stakeholders.

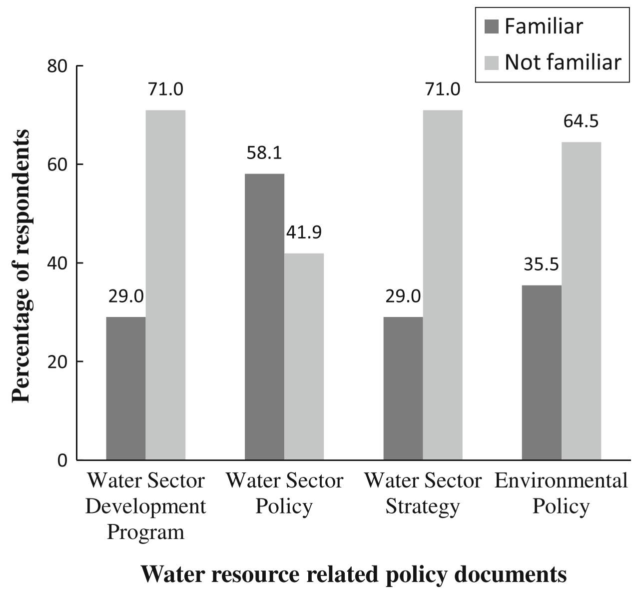

Fig. 2 Participants' responses indicating their level of knowledge about four common policy documents mentioned to them grouped as familiar and not familiar

Table 3 The relationship between the sociodemographic variables of the stake holders and the level of knowledge related to water resource policy documents

Variables	N	Mean rank	Kruskal–Wallis Test
Gender			
Male	25 (80.6)	16.26	$\chi^2 = 0.108$;
Female	6 (19.4)	14.92	df = 1; P value = 0.742
Age in years			
< 30 years	23 (74.2)	16.92	$\chi^2 = 3.569$
30–40 years	8 (25.8)	17.68	df = 2
>40 years		9.10	P value = 0.168
Educational level			
Lower grade	4 (12.9)	4.00	
BSc	9 (29.0)	10.50	$\chi^2 = 17.092$
MSc	13 (41.9)	21.54	df = 3
PhD	5 (16.1)	21.10	P value = 0.001*
Work experience			
1–2 Year	9 (29.0 %)	17.06	$\chi^2 = 0.963$
3–5 Years	15 (48.4 %)	14.65	df = 2
More than 5 Years	7 (22.6)	18.70	P value = 0.618
Working level			
Federal	16 (51.6)	20.22	$\chi^2 = 22.553$
Regional	4 (12.9)	26.25	df = 3
Basin	6 (19.4)	7.92	P Value = 0.000**
Local	5 (16.1)	4.00	

* The post hoc comparison with rank sum test indicates the lower grade was different from BSc (P value = 0.043), MSc (P value = 0.003), and PhD (P value 0.010). There was also difference between the BSc and MSc (P value = 0.002), and PhD (P value = 0.025). The difference was not significant between MSc and PhD level education. ** The post hoc comparison with rank sum test indicates the federal was different from basin (P value = 0.000) and local levels (P value = 0.001). The difference between the federal and regional was marginal (P value = 0.06). Regional was different from basin (P value = 0.009) and local (P value = 0.009). Moreover, basin was different from local (P value = 0.03)

However, more than 70 % of the participants were unfamiliar with it (Fig. 2). This may be due partly to the fact that the officials involved in the preparation are different persons than the ones who are responsible to implement it or they are working in different departments that are not related to implementation of water resource management.

The respondents were also asked to rank their knowledge of the four major policy and program documents related to water resource listed in Fig. 2. Responses were scored from "familiar" (2), to "heard about it" (1) and to "don't have any awareness" (0). A summed score was calculated for each respondent ranging from 0 to 8, where the higher scores indicate higher knowledge levels. As the sample size was small and the summated scores created were not normally distributed, the nonparametric Kruskal–Wallis test was applied. The mean ranks were compared as the groups exhibited varying distribution patterns. To determine statistically significant differences among the groups, we ran a post hoc test for "educational level" and "work level," which were found significant in affecting the knowledge of the participants for the omnibus test. Other background variables (like gender, age, work, and experience) did not show significant differences (Table 3).

The study participants working at federal level were more aware of national policy and program documents related to water resources management than at the basin and local levels (Table 3). This may be due to their proximity to the authorities responsible for policy making and greater accessibility of the documents. The lower knowledge levels of these documents among participants working at regional, basin, and local level may hinder the implementation of the policies and programs as stakeholders working at close proximity of water projects are expected to play a major role in implementation. Strikingly, although the policy documents are better known by the higher level (federal and regional) implementers, the river water pollution status of the country is better recognized by the lower (local) level workers. When respondents were asked to give their opinion on the issue of river water pollution status of the rivers, 82 % of the local-level implementers stated that water pollution problem is a "current" issue, while 68 % of the federal-level workers indicated that it is an issue to be addressed in the future. In contrast, the results of this study "Extent of River Pollution in the Study Area (Part 1)" and other case studies conducted prior to this work (e.g., Beyene et al. 2009a, 2009b) revealed increasing ecological river water quality degradation resulting from increasing urbanization and intensive agriculture. This implies that to better address the problem, it is very important to improve the communication between researchers, policy makers, and implementers. In addition, existing policies need to be revised by considering the reports from different research activities about water resources and by incorporating the knowledge of lower level workers as well. Understanding how Ethiopians value their rivers and involving them in the planning and implementation of water resource management activities is a key for success.

The respondents were also asked to rate the problems encountered to achieve goals related to fresh water quality issues. Lack of technical knowledge (29.0 %), lack of tools and guidelines (25.8 %), and inadequate funding (25.8 %) and experience (19.4 %) were the most common challenges identified by the respondents to implement the planned activities. Therefore, any effort to improve the ecological water quality status of rivers in the study area needs to address those problems.

Conclusion

In this paper, combinations of approaches to investigate river water pollution status and the water policies to manage pollution were used in parallel. Both physicochemical and biological data revealed that water quality degradation is severe at the urban and coffee processing impacted river sites in the four major Ethiopian river basins. Macroinvertebrate- and diatom-based diversity and pollution indices showed low ecological quality classes at sites impacted by urban, agricultural, and coffee processing wastes. The review of legal, policy, and institutional framework revealed that the regulatory fabric is too weak to solve these growing water quality problems. The implementers of the existing policies are not fully aware of the policies and their inefficiency to avert the reported pollution status. The fact that the integration of environmental, economic, and social issues of water resources was not considered in Ethiopia plays a major role in this scenario. Hence, the adoption and implementation of monitoring of water quality for ecosystems conservation and livelihoods should be urgently addressed. Integrated water resources management (IWRM), which demands that all water uses be managed in an integrated fashion for optimum and sustainable benefits to all water users is a vital long-term sustainable solution. Until IWRM can be implemented at full scale, Ethiopia needs to strengthen intersectoral collaboration and integrated management among federal and regional authorities and stake holders. This calls for raising awareness and a judicious water resources management policy and framework that considers the resources of Ethiopia, including financial and implementation capacity. Recognition of the severity of the problem and development of appropriate water quality standards and monitoring programs are urgently required steps on the road to preserving the quality of water resources in Ethiopia and other African countries.

Acknowledgments The authors are grateful to Vlaamse Interuniversitaire Raad (VLIR) for funding the PhD scholarship of Aymere Awoke Assayie and the Vrije Universiteit Brussel (VUB, BAS42) and Jimma University, Ethiopia for financial and logistic support.

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