IDENTIFYING COST EFFECTIVE MITIGATION MEASURES TO BRING DOWN CONCENTRATIONS OF POLLUTANTS THAT ENTER LAKE HAWASSA

A STUDY REPORT

Submitted to: SOS-Sahel - ETHIOPIA

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I. ACRONYMS

AMBP	Agricultural Management Best Practices
BGI-BF	BGI Brewery Factory
BOD	Biological Oxygen Demand
CBO	Community Based Organization
CEO	Chief Executive Officer
COD	Chemical Oxygen Demand
DDT	Dichlorodiphenyltrichloroethane
EC	European Commission
ECG	Environmental Concern Group
EEPA	Ethiopian Environmental Protection Authority
EIA	Environmental Impact Assessment
EMS	Environmental Management System
EPA	Environmental Protection Authority
ERVL	Ethiopian Rift Valley Lakes
ETAB-SF	Etab Soap Factory
ETSC	Ethiopian Tannery Share Company (Mojo)
FAO	Food and Agricultural Organization
HECG	Hawassa Environmental Concern Group
HTF	Hawassa Textile Factory
HURH	Hawassa University Referral Hospital
KTSC	Kombolcha Textile Share Company
MHSDF	Moha Hawassa Soft Drink Factory
MOH	Ministry of Health
MOJ	Ministry of Justice
MOWR	Ministry of Water Resources
MPI	Metal Pollution Index
MPL	Maximum Permissible Level
MSLWM	Municipal Solid and Liquid Waste Management
NGO	Non-Governmental Organization
PMM	Possible Mitigation Measures

POP	Persistent Organic Pollutant
RCMM	Recommended Cost Effective Measures
RT	Research Team
SNNPRS	Southern Nations and Nationality Peoples Regional State
SRP	Soluble Reactive Phosphorus
TCF	Tabor Ceramics Factory
TDS	Total Dissolved Solid
TEA	Toronto Environmental Alliance
TS	Total Solid
UNEP	United Nations Environment Program
USEPA	United State Environmental Protection Authority
WHO	World Health Organization

II. EXCUTIVE SUMMARY

Lake Hawassa, being an urban lake, is exposed to increased population pressure, and there are indications that the lake is going through degradation in its water quality. Such changes, unless immediate actions are taken, may eventually lead to irreversible ecosystem changes that will compromise the environmental, economic and cultural importance of the lake. Therefore, the need for possible management and conservation actions has been staged by: aquatic scientists, environmentalists, government agencies, NGOs and many other concerned groups. It is out of this concern for the lake that the SOS-Sahel – Ethiopia took the initiative to answer the urgent call with respect to the conservation and management of the lake and its valuable resources.

This report is on a study carried out on Lake Hawassa as part of a project that SOS-Sahel - Ethiopia envisages to undertake on "Enhancing Climate Resilience, Food and Nutrition Security in the Lake Hawassa ecosystem". In order to take one of the outputs - "Concentrations of pollutants in Lake Hawassa contained below the maximum permissible levels (MPL)" into account, a research team (RT) from the Biology Department of Hawassa University was commissioned to identify cost effective mitigation measures to bring down concentrations of pollutants that enter Lake Hawassa. This included: identification of sources of pollutants, their routes and inlets to the lake, assessment of potential adverse impacts of the pollutants, and identification of mitigation measures at the different target sites and intervention strategies. This is directly related to the third outcome "secured and sustainable use of key natural resources".

The RT generated primary data through a number of field observations, visits to factories and relevant government offices in Hawassa, and secondary data through library and Internet search. The information gathered has been analysed and put together in this report that covers:

- *background information on Lake Hawassa and its present status with respect to pollution;*
- *types, sources and routes of the pollutants and their possible effects on the lake ecosystem;*
- *practical aspects of mitigation measures, and the possible intervention strategies.*

The recommended mitigation methods and intervention strategies presented in the report are believed to be the most cost effective mechanisms for containing the concentrations of pollutants in Lake Hawassa below the maximum permissible levels in freshwater bodies. Therefore, the RT believes that the objectives of its assignment have been accomplished.

III. GENERAL INTRODUCTION

The Ethiopian rift valley lakes (ERVL) are a chain of very productive lakes that contain edible fish, and support a variety of aquatic and terrestrial wildlife. The lakes play a very important role in tourism, biodiversity conservation and in ameliorating the effects of drought and protein shortage of the population (Wood and Talling, 1988). Lake Hawassa is one of these ERVL which has a significant environmental, economic and cultural importance to the region. The lake has been used for commercial fisheries, irrigation, and recreation and for some domestic purposes (Zinabu Gebremariam, 2002; 2003a; 2003b). In spite of its importance to the livelihood of the population, there are indications that Lake Hawassa is going through changes that, unless immediate actions are taken, may lead to irreversible degradation in its water quality and fisheries (Zinabu Gebremariam & Elias Dadebo, 1989; Zinabu Gebremariam, 2002a; 2003b). Lake Hawassa, being an urban lake, is exposed to increased population pressure; therefore it is probably one of the most polluted of the ERVL. This calls for immediate management and conservation actions to protect the lake ecosystem.

The major short-fall in the conservation and management of Lake Hawassa, and the ERVL at large, had been lack of scientific information on the lake (Zinabu Gebremariam & Elias Dadebo, 1989; Zinabu Gebremariam, 2002, 2003a). However, in the last two decades several studies have been conducted on Lake Hawassa by a number of Doctoral and Masters Students and other researchers working on the limnology, fisheries, ecotoxicology, and other aspects of the lake. In spite of such encouraging developments with respect to research on this lake, we see very little effort being made with respect to the conservation and management of the lake and its valuable resources. **The present initiative by SOS- Sahel is therefore a very timely initiative to protect the lake from further degradation.**

This study is part of the project on ‘Enhancing Climate Resilience, Food and Nutrition Security in the Lake Hawassa ecosystem’. It is directly related to the third outcome “secured and sustainable use of key natural resources” and output 10 “concentrations of pollutants in Lake Hawassa contained below the maximum permissible levels (MPL)”.

The general objectives of our assignment are to identify cost effective mitigation measures to bring down concentrations of pollutants that enter Lake Hawassa and the possible mechanisms to reduce the inflow of wastes to the lake.

The specific objectives include:

- identification of sources of pollutants, their routes and inlets to the lake;
- assessment of potential adverse impacts of the pollutants;
- identification of mitigation measures at the different target sites and intervention strategies.

In order to accomplish this task the Research Team (RT) generated secondary data through library and Internet search, made a number of field observations through survey, and visited factories and relevant government offices in Hawassa. The outcomes of the different sites visited and the observations made have been used as additional source (to the secondary data) of information for the analyses of the results of this study.

This report has been organized in two parts comprising of two chapters each. In the first two chapters, background information on Lake Hawassa and its present status with respect to pollution is presented setting the contextual scene for types, sources and routes of the pollutants and possible effects on the lake ecosystem. The two chapters of the second part of the report deal with the practical aspects of mitigation measures and the possible intervention strategies. The report culminates with recommendations that have emanated from the study.

PART A

GENERAL BACKGROUND ON LAKE HAWASSA AND ASSESSMENT OF ITS PRESENT STATE

CHAPTER 1

1. BACKGROUND

In this section of the report, information from past and present studies is put together to shade light on the present status of Lake Hawassa and the future trends of its water quality. Data from recent studies (mostly from our own work) have been used to evaluate the main causes of unfavourable changes in the lake. The section is presented in such a way that it can be used as a prologue that will lead to the analyses in the subsequent sections.

1.1. General Descriptions of Lake Hawassa

Lake Hawassa is located in the main Ethiopian rift-valley at Latitude / Longitude: 6° 58' – 7° 8' N / 38° 22' - 38° 27' E. (Alemayehu Esiayas, et al. 2011)[1]. The lake is the smallest of the chain of rift valley lakes in southern Ethiopia (Fig. 1). In terms of its surface area, it had been mostly reported to be 88 - 90 km^2 (Elizabeth Kebede, 1994; Ayenew et al. 2007; – cited in Mulugeta Dadi, 2013). Ashenafi Madebo & De Smedt (2007) and Mulugeta Dadi (2013) have recently reported that the lake has a surface area of 95 and 96 km^2, respectively – findings that would await confirmation by other studies. The catchment of Lake Hawassa is located at Latitude/Longitude 6º 45' to 7º 15' N / 38º 15' to 38º 45' E (Mulugeta Dadi, 2013). According to Ashenafi Madebo & De Smedt (2007) and Mulugeta Dadi (2013), the total drainage area of the lake, including the lake, has been reported to be 1371.6 and 1436.5 km^2, respectively.

The lake has a maximum depth of about 22m[2] and a mean depth of 11m (Wood & Talling, 1988, Elizabeth Kebede et al., 1994). The major morphometric and physical features of Lake Hawassa are given in Table 1).

[1] The location of the lake has been variably shown in different sources including Google Earth. We have chosen to use this information partly because it indicates the ranges of the Latitude/Longitude.
[2] Maximum depths of 21 and 23m have been reported by different workers.

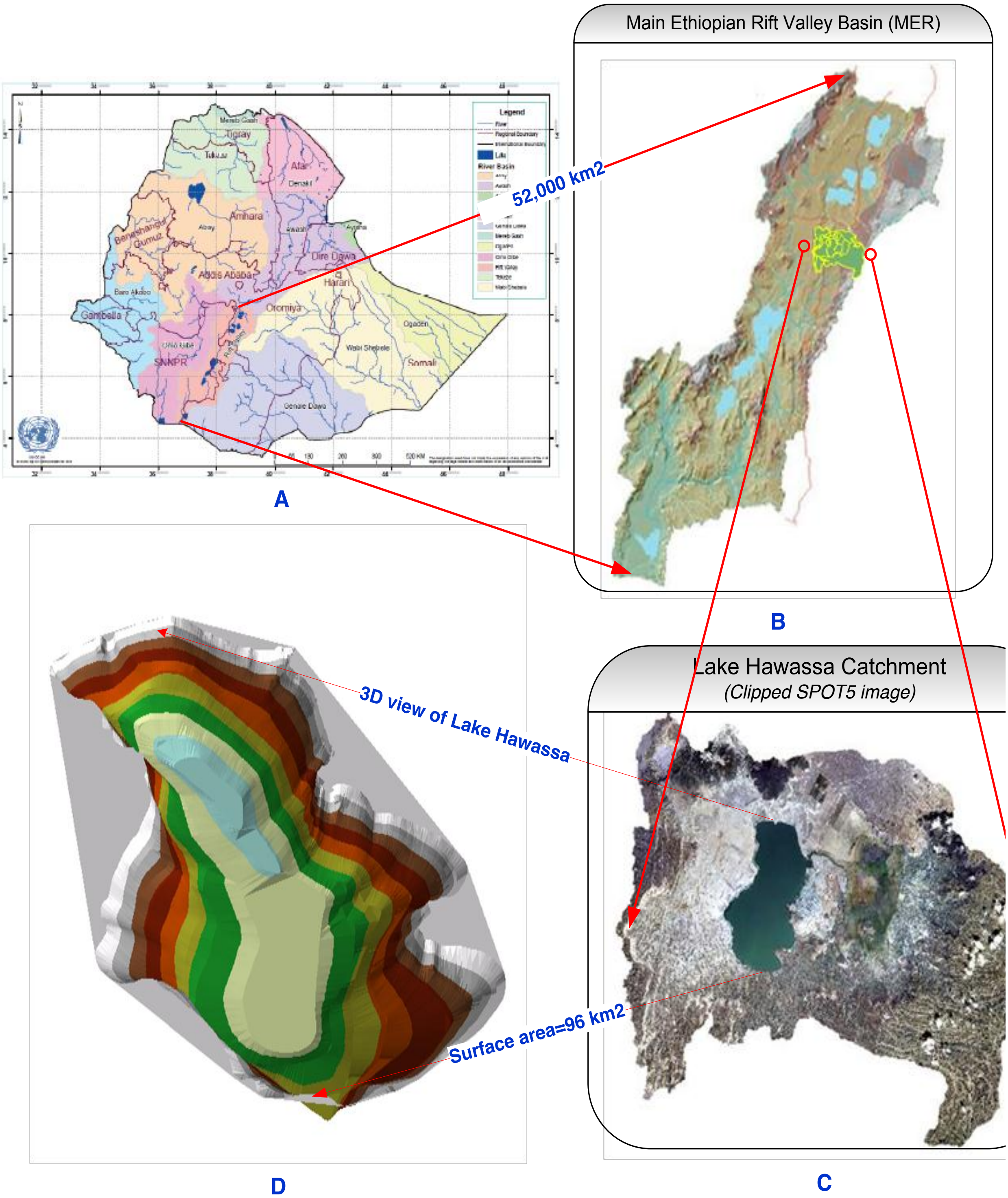

Figure 1. Maps of Lake Hawassa at different scales [Source: Mulugeta Dadi (2013)]

Table 1. The major morphometric and physical features of Lake Hawassa. Where references are not cited, data are from Elizabeth Kebede (1994).

Altitude (m.a.s.l.)	Surface area (km^2)	Max. depth (m)	Mean depth (m)	Catchment (km^2)	Volume (km^3)
1680	90	23	10.7	1250	1.34[c]
	95[a]	23.4 [b]	13.3 [b]	1436.5 [b]	1.36 [e]
	96[b]	22[c,d]			

[a] Ashenafi Madebo & De Smedt (2007); [b] Mulugeta Dadi (2013); [c] Wood & Talling (1988); [d] Grove et al. (1975), [e]Ayenew et al. (2007) – cited in Mulugeta Dadi (2013)

Lake Hawassa is a terminal lake completely enclosed by faulting with no visible surface outflow from the lake. It is fed by Tikur Wuha River which drains a swampy wetland - Shallo *(*locally known as *Cheffe* – the transliteration of which is swamp*)*. Although Lake Hawassa has no surface outlet, it is relatively dilute (Von Dam & Edmond, 1984) with a conductivity of about 780 - 965 uS cm^{-1} (Zinabu Gebremariam, et al. 2003). Like most African and Ethiopian rift-valley lakes, the dominant ions in this lake are sodium and bicarbonate (Elizabeth Kebede, et al. 1994, Zinabu Gebremariam et al., 2002, Zinabu Gebremariam, 2003, and references cited therein).

Levels of plant nutrients like phosphate, silica and the various forms of inorganic nitrogen (nitrite, nitrate and ammonia) are within world ranges and show large seasonal variations (Zinabu Gebremariam & Taylor, 1989; Elizabeth Kebede et al. 1994, Zinabu Gebremariam et al. 2002; Girma Tilahun, 2006). Some chemical and biological features of Lake Hawassa are given in Table 2.

The phytoplankton biomass and productivity of this lake is dominated by small blue green algae (cyanobacteria) and large Botryococcus (Elizabeth Kebede, 1987; Taylor and Zinabu Gebremariam, 1989; Girma Tilahun, 2006). The rate of primary production in the lake has been studied by various workers (Demeke Kifle, 1985; Zinabu Gebremariam, 1988; Girma Tilahun, 2006; Girma Tilahun and Ahlgren, 2010) and is reported to show a wide seasonal variability. Zinabu Gebremariam (1988) reported 131 – 371, and 211 – 511 mg C/m^2/hr. of net and gross photosynthesis, respectively. Girma Tilahun (2006) reported net photosynthesis of 123 - 437 mg C/m^2/hr. and 1.33 – 4.72 g C/m^2/day. The bacterioplankton density of the lake fluctuates between 3.88 - 8.33 million per millilitre of water (Zinabu Gebremariam, 1988; Zinabu Gebremariam and Taylor, 1989; 1990). The zooplankton fauna of Lake Hawassa is a mixture of several species of crustaceans dominated by cyclopods (Seyoum Mengistou, 1989; Seyoum Mengistou et al. 1991). All planktonic variables of Lake Hawassa show distinct seasonal variations mostly dictated by the rains and events of mixing of the lake (Elizabeth Kebede, 1987; Zinabu Gebremariam, 1988; Zinabu Gebremariam and Taylor, 1989; Seyoum Mengistou, 1989; Girma Tilahun, 2006). The littoral area of Lake Hawassa consists of large weed beds (emergent and submergent macrophytes) and a diverse invertebrate benthic community (Tilahun Kibret, 1985; Tilahun Kibret and Harrison, 1989; Tudorancea and Zullini 1989). The wildlife includes waterfowls, Nile monitor lizard (*Varanus niloticus*), otter (*Lutra lutra*), and hippopotamus (*Hippopotamus amphibious*), etc. (Tilahun Kibret, 1985). Most of the flora and fauna, except the fish, have not been adequately studied but the wealth of the biodiversity of the lake is remarkable.

Table 2. Some chemical and biological features of Lake Hawassa. The values in parentheses ( ) and square brackets [ ] indicate sample sizes and ranges, respectively. Data are from Zinabu Gebremariam et al. (2002b) and Zinabu Gebremariam (2003a)

Electrical conductivity (µS = µmho)	846 (22) [780 – 965]
Salinity (mg/L)	736 (4) [700 – 850]
Sum of cations (meq/L)	8.8 (5) [7.56 – 9.97]
Sum of anions (meq/L)	8.8 (5) [8.4 – 9.4]
pH	8.8 (22) [8.3 – 9.1]
$NO_3 \cdot N$ (nitrate-nitrogen, µg/L)	13.95 (26) [0 – 58.3]
NH_{4+}. N (ammonia-nitrogen, µg/L)	104.35 (26) [0 – 1328]
SRP (soluble reactive phosphorus, µg/L)	16.9 (22) [0 – 59]
SiO_2 (silicate, mg/L)	38.6 (19 - 65)
Chlorophyll-a (µg/L)	23.4 (26) [8.3 – 34]

Lake Hawassa supports at least six species of fish: the Nile tilapia (*Oreochromis niloticus)*, the African sharp-tooth catfish (*Clarias gariepinus*), the African big barb (*Barbus intermedius*), the small barb (*Barbus paludinosus*), the cyprinid minnow (*Garra quadrimaculata*), and the cyprinodont minnow (*Aplocheilichthyes antinorii*) (Zerihun Desta *et al*., 2006 and references cited therein). The Nile tilapia *Oreochromis niloticus* accounts for nearly 90% of the total landing, while the African sharptooth catfish *Clarias gariepinus*, and African big barb *Barbus intermedius* contribute only 7 and 3%, respectively, of the total commercial catch (Elias Dadebo 2000, and references cited therein). The other three small fish species, the small barb *Barbus paludinosus*, the cyprinid minnow *Garra quadrimaculata*, and the cyprinodont minnow *Aplocheilichthyes antinorii* have not been directly utilized by the local fishery, but have a vital ecological role as fish prey by some of the larger fish species (Demeke Admassu and Elias Dadebo, 1997).

1.2. Past Records and Possible Changes in the Water Quality of Lake Hawassa

There has been a growing environmental concern among scientists that Lake Hawassa, like many freshwater bodies in the present era, may face some or all of the very common problems like: eutrophication, shoreline alteration, habitat change, change in biodiversity, toxic algal blooms, sedimentation, overfishing, introduction of alien species, extensive use of its catchments, user conflicts due to highly populated catchments, and all possible changes associated with climate change and eventually possible disappearance of the lake. Although not many of these undesirable changes have yet occurred in the lake ecosystem, some studies have shown that the Ethiopian rift-valley lakes, in general, and Lake Hawassa, in particular, are going through some water quality changes due to human factors (Zinabu Gebremariam & Elias Dadebo, 1989; Zinabu Gebremariam & Zerihun Desta, 2002; Zinabu Gebremariam et al. 2002a, and references cited therein, Girma Tilahun, 2013; Wilen et al., 2011: Zinabu Gebremariam 2013a-c). Such changes in the water quality of an aquatic system must be regularly monitored, evaluated, and the causes must be identified to take the appropriate environmental protection measures. **The present report deals with such measures that need to be taken before it is too late to make any interventions.** To undertake such mitigation measures, it is a requisite to scan the present state of the water quality of the lake. In this report, the present state of some water quality variables (indicators) of Lake Hawassa will be evaluated in light of past records. Possible causes for the changes that have taken place will be discussed in the subsequent sections in order to lay the foundation for the mitigation measures proposed in the document.

1.2.1. Ionic composition and salinity

A study on the long-term changes in seven Ethiopian rift-valley lakes (Zinabu Gebremariam et al., 2002b) has shown that the chemical concentrations of Lake Hawassa has decreased and the lake has become more dilute over the last 40 years. This study also revealed that, unlike the rest of the ERVL, (with the exception of Lake Langano) the salinity (and its correlates - conductivity, alkalinity and sodium concentrations) of the lake has decreased since the early 1960's. It is possible that the lake could have been saline at one point in time and then changes associated to water level may have diluted the lake. This suggests that the water level and the chemical concentrations of the lake may have fluctuated over the years. Although ions are variously concentrated or diluted depending on a number of biological and abiotic processes, a combination of natural factors like subterranean seepage-out of solutes, augmented by seepage-in of more dilute underground water, inflowing dilute surface waters, and precipitation of some minerals (Wood & Talling, 1988), may have played a role in counteracting the effects of evapo-transpiration in Lake Hawassa - making it less saline than it was in the past. Given the results from the most recent hydrological studies (Mulugeta Dadi, 2013) it is very likely that inflowing surface waters and seepage-in of underground water may have contributed to the changes in the salinity of the lake water.

1.2.2. Chlorophyll-a and nutrients

In the last three decades, concentration of soluble reactive phosphorus (SRP) and silicate have decreased in Lake Hawassa (Zinabu Gebremariam et al., 2002b; Girma Tilahun, 2006). In spite of the intensive human activity in the catchment (see section 1.3.) and the possible nutrient load carried into the lake by the effluents and domestic waste from different sources, it is interesting to see that the nutrient levels in this lake have decreased. The decline in the concentrations of SRP and silicate may be associated with macrophytes. **Macrophytes** are submerged water weeds, floating and emergent plants (Beadle, 1981) in the lake that have recently increased around the shore of the lake.

Chlorophyll-*a* levels measured during 1990–2000 in Lake Hawassa (Zinabu Gebremariam et al., 2002) were much lower than the values recorded during the 1960s and 80s. These values have further decreased in the 2005/2006 seasonal study of Girma Tilahun (2006). The decrease in the chlorophyll concentrations may be attributed to the decline in the fisheries of the lake, and the increase in the transparency of the lake may have resulted from the decline in the concentration of the chlorophyll-*a*.

Treating the changes that may have taken place in the concentrations of chlorophyll-a, phosphate and silicate in Lake Hawassa may shade a picture on whether or not there is a sign of the widely assumed eutrophication in the lake. Eutrophication is a process where increased growth of certain phytoplankton (algae) takes place in a lake due to high levels of nutrients deposited into it. Such events occur especially when a lake is subjected to increased depositions of nutrients due to human activities. However, the low chlorophyll-concentrations, in conjunction with results from SRP and silicate analyses, suggest that there is no sign of algal eutrophication in Lake Hawassa as yet. However, all the possible driving forces that lead to eutrophication are at work in and around the lake – suggesting that preventive measures have to be taken immediately to protect the lake from such environmental problems.

1.2.3. Toxic substances

Studies on toxic substances in Lake Hawassa had for a long time lagged behind most research themes leaving us with little information. But there has been ample information since the study of Zinabu Gebremariam and Pearce (2003) on heavy metals and related trace elements in some Ethiopia Rift-valley lakes and their inflows. These workers found that concentrations of heavy metals and other trace elements commonly known to impact the environment are not beyond the MPL level in Lake Hawassa. However, a recent study on the concentrations of mercury in one fish species - large big barb (*Barbus paludinosus*) - in Lake Hawassa has shown that this fish was associated with high mercury burden, mostly with concentrations that surpassed the international threshold for mercury in fish allowed for human consumption (Zerihun Desta et al., 2006). Given the situation where mercury was not detected in water from Lake Hawassa, the high concentration of the mercury in the fish could be a result of the natural processes like bioaccumulation and biomagnification. While natural causes could be the source of the mercury in Lake Hawassa, it is a well-established fact that toxic substances in lakes are mostly related to industrial point source pollution. The effluent from Hawassa textile factory (HTF) was reported to have contained high concentrations of heavy metals commonly known to be very toxic including: mercury, arsenic, cadmium, copper, and chromium (Zinabu Gebremariam & Zerihun Desta 2002). Most of the levels of these heavy metals in the treated effluent from the factory were much higher than the international average values for freshwaters. Solomon Aragie (2013) reported relatively high concentrations of Hg (0.12 μg/L) in effluent from Hawassa referral hospital. Higher mercury in water samples taken from Tikur Wuha, Amoara Gedel, Referral Hospital and Lokae compared with reference sites have been reported by Girma Tilahun and Tigist Ashagre (2011). It has therefore been concluded that anthropogenic causes (point & non-point sources) could be the sources of the mercury that was detected in the fish of Lake Hawassa (see Chapter 2). Therefore, there is an indication that the effect of chemicals from the various sources but most probably from the point sources is already at work. This issue is discussed in detail under Chapter 2 of this report.

1.3. Human Activity as a Cause of Water Quality Changes in Lake Hawassa

Water quality changes in lakes are mostly caused by different kinds of human activities, and the changes in Lake Hawassa that we have presented so far and those in Chapter 2 of this report may be due to pressures from a variety of interlinked human activities. The most critical impacts of human activities that have possibly caused and/or will continue to cause degradation of the water quality of Lake Hawassa are very briefly described hereunder.

1.3.1. Urbanization and industrialization

It has been recognized that urbanization and industrialization in close proximity to the Ethiopian rift-valley has exerted the greatest human impacts on water quality and quantity (Zinabu Gebremariam & Elias Dadebo, 1989; Zinabu Gebremariam, 2002a, 2003a*)*. Lake Hawassa is found adjacent to one of the fastest growing cities in Ethiopia (Hawassa), and the growing human population and intensive economic activities of the city have raised serious environmental concerns with respect to the water quality of the lake (Zinabu Gebremariam & Elias Dadebo, 1989; Zinabu Gebremariam, 2002, 2013a)

The high population growth in Hawassa coupled with the unprecedented increase in industrial activities has led to human impacts like uncontrolled discharge of industrial and domestic waste into the lake. This is the most serious effect on water quality related to urbanization -

its use for waste disposal. Garbage containing plastic bags and disposable bottles, mostly brought into the lake by the furious flood after the heavy rains, is among the emerging environmental problems of Lake Hawassa. All these situations may be considered as latent threats to future environmental problems in the lake and hence call immediate actions.

1.3.2. Deforestation and agricultural activities

Intensive agricultural and deforestation activities in the catchments are serious environmental problems in most Ethiopian rift-valley lakes (Zinabu Gebremariam and Elias Dadebo, 1989; Zinabu Gebremariam, et. al. 2002; Zinabu Gebremariam 2002a, 2003a). Human settlement and urbanization in the drainage basin of Lake Hawassa is concentrated mostly in the Eastern part of the catchment with the rest of it left to various agricultural activities. We have been able to verify that in the part of the catchment where there is agricultural activity; there is very little plant cover because of the increased tilling of the land and overgrazing of the vegetation. Therefore, the soil is exposed to erosion. This has been the trend for many years and will probably continue the same way. Such land use and degradation of catchments will certainly lead to increased input of sediment (sediment inundation) and nutrients which will eventually cause eutrophication of the lake.

One other aspect of increased agricultural activity in catchments of water bodies is chemical pollution from fertilizers and pesticides. The fertilizers and pesticide in the soil may reach the lake and eventually reach out the aquatic life including fish. The pioneering studies on persistent organic pollutants (POPs) in some ERVL including Lake Hawassa (Ermias Deribe et al., 2011, 2013a, b and Ermias Deribe, 2012) have shown that Dichlorodiphenyltrichloroethanes (DDTs), endosulfans, PCBs, chlordane, and chlorpyrifos were all POPs detected in fish from Lakes Koka, Ziway and Hawassa, and DDT was the predominant contaminant detected. Although the sum of DDTs found were lower than those found in most studies carried out in other African lakes, the presence of DDT in all muscle tissue samples collected from all fish species in the lakes indicates the magnitude of the incidence. While repeated studies have not been carried out with respect to POPs in Lake Hawassa, the results so far indicate that the ultimate impacts of such chemicals on the lake cannot be undermined.

1.3.3. Possible Long-Term Consequences of the Changes in the Water Quality of Lake Hawassa

From the sequence of events described in the preceding sections, one can deduce that the recent changes in water quality of Lake Hawassa are decrease in the salinity, decline in the nutrient and chlorophyll-a concentrations of the water, and higher level of toxic substances in fish. Moreover, domestic waste and industrial effluents associated with urbanization and industrialization seem to be the most notable threats to the water quality in Lake Hawassa. From the outset, none of these events may seem to be alarming. However, a closer look at the events sends a signal of warning. In the following section we will make an assessment of the future trends in the water quality of Lake Hawassa from the perspective of the events described in the foregoing sections.

1.3.4. Impaired water quality

Although the present quality of the water of Lake Hawassa is not yet impaired and it is suitable for both domestic purposes and irrigation (Zinabu Gebremariam, 2002a, 2003a), the future trends may not continue to be as optimistic as they are now. The effluents from the factories/industries and domestic/municipal wastes from the city pose a big threat to the lake. Such industrial effluents and domestic sewage will contribute large quantities of nutrients and toxic substances that have a number of adverse effects on the lake and the biota. The immediate response of the lake to the added nutrients will be increase in biomass of plankton - the major symptom of eutrophication, which will lead to reduced water clarity and oxygen levels. These natural processes will in turn bring about taste and odour problems of the water and loss of fisheries. Lake Hawassa, which at the moment is the main recreation centre of the public, will not be an attraction thereafter. Therefore, the environmental, economic and cultural impacts of such changes will be very damaging.

1.3.5. Habitat modification and biodiversity loss

The decrease in the salinity of Lake Hawassa over the last three decades may be considered less evil (with respect to water quality) than a possible increase as in the other Ethiopian rift-valley lakes (Elizabeth Kebede et al, 1994, Zinabu Gebremariam, 2002b; 2003b; Zinabu

Gebremariam, et al., 2002 b). However, this scenario may be rather unpleasant if the decline in the salinity of Lake Hawassa is due to macrophytes which can contribute to the decline in the salinity of the lake through direct uptake of ions (Talling, 1992). If this mechanism is the cause for the decrease in the salinity of the lake, it will probably continue for ever as the shores of Lake Hawassa are being invaded by macrophytes at an alarming speed (personal observation of the authors). Such situations will lead to a significant habitat modification that will affect the biodiversity of the lake.

The decrease in the concentrations of chlorophyll-a, phosphate and silicate in Lake Hawassa may also be considered as healthy, because it rules out eutrophication. However, if the decline in the chlorophyll-a is due to a decline in the fisheries of the lake, and if the decreases in the concentrations of SRP and silicate are associated with macrophytes (see above), the causes for the changes in these variables may not be optimistic. Such changes may lead to changes in phytoplankton species composition. Moreover, the decline in nutrient concentrations may limit algal production, ultimately affecting the fisheries production of the lake. Because the most consumed fish in Lake Hawassa, the Nile tilapia, gains its nutrition directly from the phytoplankton as an adult and relies on the littoral food-web in its juvenile stages, the decline in phytoplankton biomass, although good news with respect to water quality, is bad news with respect to the fisheries.

1.3.6. Health risk[3]

The public health hazard of the toxic substances (particularly the heavy metals) in the effluent from Hawassa textile factory (HTF) has not been established but its impact cannot be discounted. The study on the mercury concentration in large big barb (*Barbus paludinosus*) showed that its concentrations tended to increase with fish size which many people prefer to eat (Zerihun Desta, 2007). At the same time, large big barb is the least preferred fish by the public and hence not sold out but ends up being regularly consumed by the fishermen and their family members who probably cannot afford to buy other kind of food as alternate animal protein source. Regular consumption of fish with such large concentration of mercury is undoubtedly a serious public health issue. The human health risk assessment was determined in a study by Ermias Deribe (2012) and Ermias Deribe et al., (2014) where consumption of a certain amount of fish from the ERVL including Lake Hawassa, could pose

[3] This is discussed in more detail in Chapter 2 of this report.

a threat to health because of POPs and mercury present in the fish. According to this study, children and pregnant women of the local community, especially the subsistence fishermen and their families are the most vulnerable population sub-group.

Other issues related to water quality like pathogenic organisms have not been studied in Lake Hawassa. However, for a lake that, in one way or another, is linked to various sources of domestic sewage, hospital effluent, etc., problems related to water quality will continue to be concealed public health problems until identified and the proper measures are taken. This should be of a very serious importance to the neighbouring villages as the water from the lake is consumed by the people and their domestic animals (see chapter 2 of this report for further treatment of this issue).

In a nut-shell, if the present trend of human impacts, especially those related to the industrial effluents and domestic sewage as well as the agricultural activities and deforestation in the catchment continue unabated, the lake will unquestionably go through eutrohpication that will eventually lead to irreversible pollution and permanent loss of suitable habitats and the biodiversity. Therefore, the possibility that the lake may disappear in the long term – due to the possible chains of events portrayed above - will not be too imaginary.

Given all the facts brought about in this introductory section, it is very clear that the present initiative by SOS-S and hence the work of this RT is an issue that should have come at the forefront quite a long time ago. Very unfortunately, in Ethiopia, much attention has focused on losses of terrestrial systems, particularly the forests and soils, and the situation in freshwaters has tended to receive less attention. As portrayed in our discussion of the matter in this report, it is increasingly evident that this pending crisis is now setting the agenda regarding actions that need to be seriously considered.

CHAPTER 2

2. ASSESSEMENT OF THE PRESENT STATE OF LAKE HAWASSA WITH RESPECT TO POLLUTION

From the account given in the foregoing Chapter, there is enough reason to believe that Lake Hawassa is under increasing threat of pollution mainly due to anthropogenic activities in the catchment. A number of studies have shown that the major pollutants that reach the lake include: heavy metals, nutrients, organic materials and agrochemicals of different types. It is well documented that some of these pollutants reach the lake at a level higher than local and international standard limits and they can pose a real threat to water quality and consequently to living organisms in and around the lake. The most critical impact that is already observed and felt is industrial pollution. People in the neighbourhoods of factories complain about water quality problems, human and domestic animal health issues, loss setback in agricultural production, etc. due to the discharge of effluent from various sources to the environment.

All the circumstances mentioned and those elaborated in Chapter 1 of this report point to the fact that Lake Hawassa (and its environ) is under intense pressure of pollution, and thus mitigation measures have to be taken to alleviate the problem.

In this section of the report, available information from past and current studies is put together to show the types, potential sources and effects of pollutants, and their routes and inlet spots into the lake. See the Lake Hawassa Pollution Network in Figure 2.1.

Fig. 2. 1. Lake Hawassa Pollution Network

2.1. Sources and Routes of Pollutants to the Lake

It has been identified and reported by several researchers that Lake Hawassa and its wetland system including the Tikur Wuha River and Shallo swamp have been exposed to toxic substances due to anthropogenic activities in the watershed resulting in point and non-point source pollution (Zinabu Gebremariam and Zerihun Desta, 2002; Zerihun Desta, 2003; Zinabu Gebremariam and Pearce, 2003; Behailu Berehanu, et al. 2010; Yared Beyene et.al., 2013). According to different studies (Zinabu Gebremariam, 2002, 2003; Zerihun Desta 2003, and references cited there-in) the main causes of the pollution in Lake Hawassa were identified to be human activities associated, particularly, with poor agricultural practices; clearing of forest cover; use of fertilizers, herbicides and pesticides; rapid and unplanned urbanization; domestic waste and industrial effluent from within the watershed, etc.. It is important to identify the sources and routes of pollutants as a first step to mitigation measures and this section of the report presents the point and non-point sources of pollution to Lake Hawassa and the types of pollutants.

2.1.1. Point sources of pollution

The effects of industrial activities on the environment at large and aquatic systems in particular are becoming evident especially in water bodies in close proximity to the major cities of the country (Zinabu Gebremariam and Elias Dadebo, 1989; Zinabu Gebremariam and Zerihun Desta, 2002; Zinabu Gebremariam 2002a; 2003a). Hawassa city and its flourishing industrial zone are located very close to the Lake Hawassa. Previous studies and our current observations show that there are altogether six point sources - five factories and a referral hospital.

The factories that have been identified as point sources are: Moha Hawassa Soft Drinks Factory (MHSD), BGI Hawassa Brewery Factory (BGI-HBF), Hawassa Textile Factory (HTF), Tabor Ceramics (TCF), and Etab Soap Factory (Etab-SF). The Hawassa University Referral Hospital (HURH) that is located at a very close proximity (about 350 m) to the lake has been considered as one of the point sources of pollution. While the effluents from the industrial zone end up in Boga and Boeitch streams that flow into the Tikur Wuha River (the only visible inflow into the lake), the HURH discharges its effluent directly into Lake Hawassa.

A brief description of each of these sources is presented hereunder.

2.1.1.1. Hawassa Textile Factory (HTF)

Hawassa textile factory (HTF), located at the Eastern edge of Hawassa town, was established in 1989. The factory uses large amounts of ground water mainly as a solvent for processing chemicals and a washing-rinsing medium. According to Zerihun Desta (1997) the factory discharges about 1200 m^3 of liquid waste every day at a flow rate of 13.9 l/s. Effluent from HTF is the most studied industrial effluent in the city, and the effluents were analysed by different researchers at different occasions.

Previous studies (Zinabu Gebremariam and Zerihun Desta, 2002; Zerihun Desta, 2003; Zinabu Gebremariam and Pearce, 2003; Birenesh Abay, 2007; Behailu Berehanu, et al., 2010) indicated that waste water from the factory is treated, both chemically and biologically, before the effluent is discharged into the surrounding. The chemical treatment takes place within the compound of the factory and involves the use of sulphuric acid to neutralize the wastewater which has a very high pH. However, an investigation by Lijalem Hailu (2011) and our recent visit to the factory have revealed that the chemical treatment plant is non-functional. The biological treatment takes place in oxidation ponds located about 2 km away from the factory and it is very close to the neighbouring rural community.

Our recent observation of the factory's discharge route confirmed that the raw waste water from the production process is released into four treatment oxidation ponds and then the "treated" effluent is discharged through underground concrete tube into an open ditch. Another separate discharge, considered to be from washing and sewage system of the factory, joins the effluent from the ponds at the open ditch and all of the waste streams ahead to Tikur Wuha River through Boeitcha stream. Previously, it was reported (Zerihun Desta, 1997; Birenesh Abay, 2007) that the factory effluent is discharged into the nearby Shallo swamp/ wetland. However, the present observation on the route of the discharge revealed that the effluent intercepts the wetland only at the edge and joins Boeitcha stream flowing through a ditch towards Tikur Wuha River that ends up in Lake Hawassa.

There is no regular environmental audit system and no legal body has ever monitored the factory for the type of effluent discharged, manner of disposal or compliance to environmental laws and principles of the EEPA.

Effluent from textile factories is known to contain complex mixtures of chemicals that vary in composition from factory to factory as well as on a temporal basis at individual factory based on material used in wet processing (Wynne et al. 2001). Studies on HTF by several researchers (Zinabu Gebremariam and Zerihun Desta, 2002; Zinabu Gebremariam and Pearce, 2003; Birenesh Abay, 2007; Yadessa Chibsa, 2011) have clearly shown the presence of toxic substance in the effluent that is discharged from the treatment plants (both chemical and biological treatment ponds). Accordingly, effluent discharged from the factory after treatment contains high concentrations of organic and inorganic chemicals and it is loaded with different toxic substances, some of which are much higher than the MPL. This suggests that the waste treatment methods used by the factory are inefficient. Therefore, the effluent from the factory that contains pollutants reaches the nearby water bodies (Boeitcha stream, Tikur Wuha and then Lake Hawassa) and the immediate environment. This could pose a serious threat to the biota and disrupt the ecological integrity of the environment to which they are linked.

Brinesh Abay (2007) and more recently Yadessa Chibsa (2011) studied the phsico-chemical parameters and heavy metal concentrations of the effluent flowing down the water course (Boeitcha stream) to Tikur Wuha River at different points. The concentrations of some of the physico-chemical parameters reported by Yadessa Chibsa (2011), such as pH, phosphate, total dissolved solid (TDS) and electrical conductivity in the effluent were much higher than in the raw wastewater and above the provisional waste discharge limit set by the EEPA (2003) and WHO (2002). Although the measured pollution parameters downstream along Tikur Wuha River were highly reduced compared to the raw wastewater, concentrations of most of the pollutants entering the lake were still higher to meet the provisional discharge limits set by the EEPA (EEPA, 2003).

Yadessa Chibssa (2011) determined the concentrations of some heavy metals in different aquatic media along the waste stream and found that the concentrations followed in descending order in: sediments > macrophytes > wastewater. It is possible that the concentrations of the chemicals may be much higher in the sediments than the wastewater itself due to the accumulation effect, and hence creating an extended effect on the water body and the biota.

Birnesh Abay (2007) and Yadessa Chibssa (2011) reported four heavy metals (namely Cu, Mn, Zn & Cr) in treated effluent and two more (Hg and As) were reported previously by Zinabu G/Mariam and Pearce (2003) and recently by Behailu Berehanu, et al (2010). According to Yadessa (2011), the heavy metals concentration in wastewater samples was found in the order of Cu>Mn>Zn>Cr. The concentrations of heavy metals in sediment and in macrophytes also followed almost the same order, i.e. Mn > Zn > Cu> Cr.

Given that trace metals are not usually eliminated from aquatic systems by any known means (Forstner and Wittmann, 1983 cited in Zinabu Gebremariam and Pearce, 2003), it is evident that the lake is facing a very serious threat of heavy metal contamination. Therefore, the effluent from HTF can be considered as the major gateway of toxic substances and nutrients into Lake Hawassa.

In a nut-shell, even though the concentrations of most of the heavy metals detected in wastewater from HTF were low and within acceptable ranges of the provisional discharge limits of industrial waste (EEPA, 2003), their accumulation over time should be emphasized as potential threat to the ecological integrity of the environment.

2.1.1.2. Moha Hawassa Soft Drinks Factory (MHSDF)

This factory was established in 2007. The RT has confirmed that the raw wastewater from the factory is treated chemically, mainly by neutralization processes, using acids in a treatment plant located within its premises. The chemically treated effluent from the factory goes through underground tunnel (for only some distance from the factory) then flows through an open ditch around a residential area of a nearby rural community. According to our observation, the effluent from the factory is channelled through PVC pipes buried under the earth and is released into an open concrete ditch. There are two ponds right where the effluent is released into the open ditch from the PVC pipes. The ponds were presumably constructed to serve as storage ponds. But they were too small to hold the large volume of the effluent even for a few hours (according to local informants) and are not used at the moment. Instead, an alternative open ditch that leads into the open has been constructed. The effluent is finally collected through a metal pipe and discharged into the open at the edge of the Shallo swamp. The effluent then eventually reaches a stream (named as “Boga” by the local people) flowing down and joins another stream named as “Boietcha” that flows in to Tikur Wuha river. The rate of effluent discharge from this factory is not yet determined by the factory, but according to Behailu Berehanu *et.al*. (2010) it was estimated to be 3 litres per second (l/s). It has been observed by the RT that as the effluent from MHSDF runs through the ditch, the people in the neighbourhood use it for irrigation and for other domestic purposes. We have been able to learn that no environmental protection institution monitors the factory.

Behailu Berehanu *et.al*. (2010) studied the composition of the effluent from this factory and detected some nutrients, organic materials and heavy metals. However, this has not been confirmed by other studies and it is very difficult to be certain at this moment.

2.1.1.3. BGI Hawassa Brewery Factory (BGI-BF)

Like other sectors of industries, breweries in Ethiopia have also got attention in terms of their pollution contribution to the environment (Yared Shumate, 2008).Brewery plants have been known to cause pollution by discharging effluent into receiving stream, ground water and soil (Olajumoke , *et.al*., 2010). It has been estimated that approximately 3 to 10 litres of wastewaters are generated per litre of beer produced in breweries (Kenatu Angassa, 2011)

The BGI Hawassa brewery factory started production in 2010. It is a relatively recently constructed factory, and is located at the Eastern part of Hawassa city in the industrial zone between Moha soft drink factory and Hawassa textile factory. The Factory uses modernized technology for treatment of the ground water used for production and waste water. The treatment system includes chemical treatment using neutralization method and biological treatment using oxidation ponds in the compound of the factory. The treated effluent from the factory joins the waste stream from Moha soft drink factory at an open ditch of Boga stream and then flow to Tikur Wuha and finally Lake Hawassa.

Because it is recently operational factory, the chemical composition of the effluent discharged has not been studied. Although we do not have data on the chemical composition, it will not be out of place to mention the possible composition from other studies.

According to Fillaudeau (2006), the physical parameters of brewery wastewater include colour, door, temperature, turbidity. Brewery plants produce large quantities of highly polluting wastewater rich in organic substances. Generally, the wastewater is the combined effluent comprising discharges from various sources of unit operation in the plant and is usually characterized by wide variation both in the discharge volume and the strength of pollutants such as biological oxygen demand $(BOD)_5$, carbon oxygen demand (COD) , total solid (TS) and pH. Considering the continuous variation in the discharge of wastewaters (both in quantity and quality) due to the nature of the factory's operation, a brewery effluent can generally be characterized as medium to high strength waste.

2.1.1.4. Tabor Ceramics Factory (TCF)

Tabor ceramics factory was established in 1996. According to the information available, the liquid wastewater from the factory is collected in a kind of storage pond located inside the compound of the factory for long periods of time. According to the people living in the area, the effluent from the factory is discharged directly into Lake Hawassa through storm drainage lines along Shashamanne-Hawassa road side near the Tikur Wuha bridge. Behailu Berehanu, et al (2010) indicated that the effluent was monitored once or twice by EEPA. However, the factory has no regular environmental audit system and no legal documented reports concerning compliance to environmental laws and principles of EEPA.

Behailu Berehanu *et.al*. (2010) reported higher levels of nutrients (especially $S^{2,}$ SO_4 and PO_4) and heavy metals such as Zn and Hg exceeding MPLs of industrial waste. Massive growth of plants in the biological lagoon in the ceramic factory compound may be associated with high nutrients concentration in the effluent. Therefore, the presence of high nutrient load and toxic metals like Hg in the effluent could affect the aquatic life as the effluent is directly discharged into the lake.

2.1.1.5. Etab Soap Factory (ETAB-SF)

Etab soap factory, located near HTF, is founded in 2005. According to the factory officials, the factory is not discharging the waste out into the environment. The overall liquid waste generated by the factory is collected in the septic tank and when filled disposed by city municipality liquid waste disposal transport service. The by-product of the raw material is used as source of energy for the boiler. Therefore, there is no way the factory effluent reaches the lake and thus not potential source of pollution to the lake.

The only effluent analysis result of the soap factory was that of Behailu *et.al*. (2010). For analysis, the sample was taken from the storage container of effluent and it is very difficult to confirm the credibility and reliability of the data. However, among the measured parameters, the effluent contained higher concentrations of nutrients (NO_3 and PO_4), SO_4 and Pb that is above the general limit (EPA, 2003). The concentration of SO_4, NO_3 and PO_4 were about twenty, sixty seven and fifteen times, respectively, the general limit. Currently the factory is not discharging the liquid waste to the environment and thus not directly contributing to the pollution of the lake in particular and the surrounding in general.

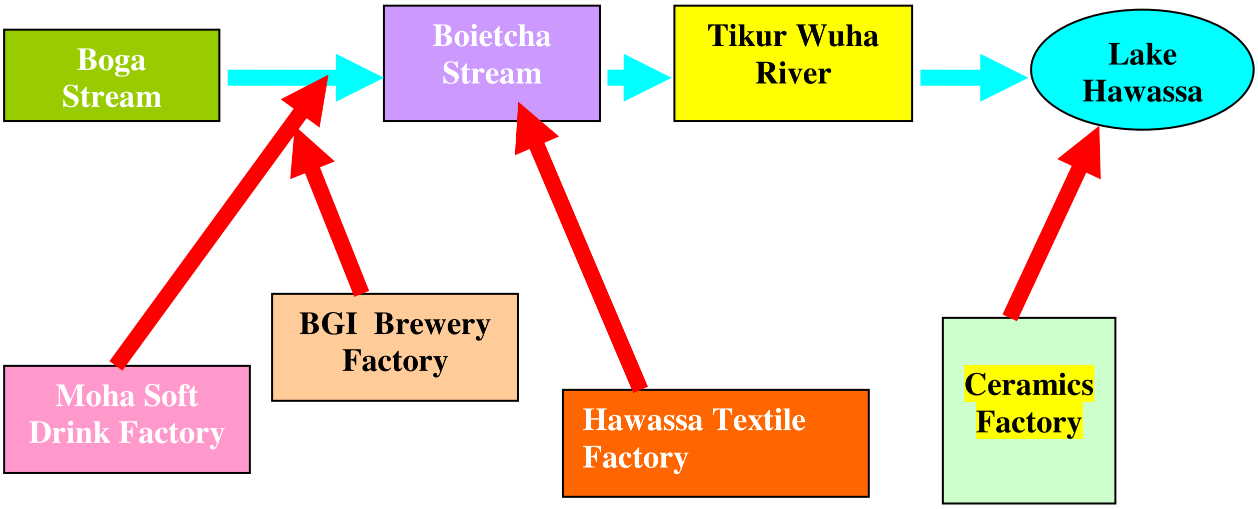

Figure 2.2. Route of effluents from factories into the Lake Hawassa

2.1.1.6. Hawassa University Referral Hospital (HURH)

The HURH, located at south-eastern edge of Hawassa city, started operation in 2006. The hospital and the waste stabilization/ oxidation ponds, which treat the wastewater of the hospital, are constructed in close proximity to Lake Hawassa, about 200 m to north of the hospital and about 150 m from Hawassa Lake.

The wastewater generated from the hospital (including that from students' dormitory, toilets, laboratories and cafeterias) flow directly to the ponds for treatment and finally the treated effluent is directly discharged into the Lake. According to Simachew Dires (2008), the estimated volume of wastewater that enters in to the ponds from the hospital was about 47 m^3 per day and the effluent is released at flow rate of 2 l/s (or 172.8 m^3 per day) from the treatment ponds.

Studies (Dana *et al*., 2005; Rezaee *et al*., 2005) indicated that hospitals discharge contains considerable amounts of chemicals and microbial agents in their wastewaters. Even though the hospital uses treatment ponds, the study results of Simache Dires (2008) and Hunachew Beyene and Getachew Redaie (2011) clearly showed inefficiency of the hospital treatment system and it is highly likely that some of the pollutants would reach the lake.

Concerning physico-chemical characteristic, Simachew Dires (2008) reported mean dissolved oxygen (DO) concentration of the treated wastewater far less than the value recommended for fish to respire and perform metabolic activities. Both Simache Dires (2008) and Hunachew Beyene and Getachew Redaie (2011) reported the effluent BOD, COD and total suspended solid (TSS) concentrations higher than that set by the U.S. federal standards (USEPA, 2001) for effluent quality discharged in to the lake and the European Commission or EC) for Environmental Protection minimum effluent standards.

Concerning heavy metals, the concentration of the Cu, Ni and Zn in the treated effluent of the hospital reported by Simache Dires (2008) was below the standard limits (USEPA, 2001). But Cd, Pb and Ag were not detected in the effluent. However, according to Hunachew Beyene and Getachew Redaie (2011), the concentration of Ni and Zn in the effluent was higher than the values recommended by Food and Agriculture organization (FAO) for agriculture reuse (Pescod, 1992).

Simache Dires (2008) reported a microbial contamination due to faecal coliforms in the treated hospital effluent that exceeded standard levels of 1000 cfu/100 ml. Therefore, the effluent of the hospital discharged in to Lake Hawassa may have a probability to contain photogenic and drug resistant microorganisms. Thus, the chance of multi drug resistant bacteria to leave the treatment plant is also high (Hunachew Beyene and Getachew Redaie, 2011). In summary, the available information mentioned above indicates that due to inefficient treatment of the waste water from the hospital, the lake receives considerable amount of pollutants including nutrients, heavy metals and pathogenic bacteria, the values of most exceeding the standard limits.

2.1.2. Non-point sources of pollution

Very little research work has been done to assess the non-point source pollutants in Lake Hawassa watershed; even though report of Demelash Amare (2008) indicated they often are the major contributors to onsite degradation of agricultural lands and offsite pollution of Lake Hawassa. In addition, there is little information on sources, impacts and possible management options of non-point source pollution. A brief description of each of the run-off from urban settings (mainly from Hawassa city and Tikur Wuha town) and rural areas (agricultural fields) in the catchment are presented hereunder.

2.1.2.1. Run-off from urban settings

Hawassa city can be considered as one of the rapidly growing cities in Ethiopia. The growth of the city across different economic sectors, the noticeable migration from rural areas in the region and the increased number of higher learning institutions (both private and government) in the city has made Hawassa a major population center. As a result of this, the city has undergone a substantial physical expansion and urbanization is visible with enormous urban sprawls in almost every corners of the city in general (i.e. especially in the South and South East part of the city).

With the expansion of urban infrastructures, the urbanization process resulted in major changes in the natural conditions of the Hawassa city watershed. With construction of residential and other buildings to accommodate the increasing population (both private and governmental), road rehabilitation and upgrading works, etc.; the main features of the natural areas are modified in Hawassa. Generally the urbanization process influences the natural surface detention, the infiltration characteristics and the drainage pattern formed by the natural flow paths.

Lake Hawassa is located at 1680m above sea level (a.s.l.) while the city of Hawassa is located at 1685m a.s.l. and the caldera rim rises to 2700m a.s.l (Behailu Berehanu, et al, 2010). Therefore, the surface and subsurface drainage from the immediate watershed, including Hawassa city, is towards the lake and hence, the lake is the main destination for any type of pollutants generated from anthropogenic activities in the city and its surroundings. The same is true for Tikur Wuha town located at Northern part of the lake near Tikur Wuha River.

The runoff containing pollutants from the city, particularly at the eastern and south-eastern shoreline of the lake, channelled through ditches into the lake at different points (in the vicinity of Greenwood and unique Parks, Amoragedel, Referral hospital; etc.). Similarly, the runoff from Tikur Wuha town is channelled into Tikur Wuha River near the bridge through two big constructed and directed ditches. Therefore, the runoff from these areas is expected to contain different kinds of pollutants that would eventually reach the lake.

Even though, runoff in the water shade of Lake Hawassa has not been studied, it is useful to see the potential pollutants in the urban runoff from other studies. According to Tenagne Addisu (2009), trace metals, suspended solids, nutrients, pesticides, petroleum products, and pathogenic bacteria (faecal coliform) are generally found in higher concentrations in urbanized and urbanizing areas than in natural systems, due to increased numbers of people, vehicles, roads, and building materials introduced into the landscape. These constituents that storm water runoff carries through drainage canals is found to be a major source of pollution to surface water quality and groundwater resources. Though the actual composition of wastewater may differ from community to community, as described by Hussain, *et.al* (2002), all municipal wastewater contains organic matter; nutrients (Nitrogen, Phosphorus, and Potassium); inorganic matter (dissolved minerals); toxic chemicals and Pathogens. Therefore, runoffs entering the lake from Hawassa city and Tikur Wuha town are anticipated to contain some of these pollutants.

2.1.2.2 Runoff from rural areas

Intensive agricultural and deforestation activities in the catchments are serious environmental problems in most Ethiopian rift-valley lakes (Zinabu Gebremariam and Elias Dadebo, 1989; Zinabu Gebremariam 2002). Human settlement and urbanization in the drainage basin of Lake Hawassa is concentrated mostly in the eastern part of the catchment with the rest of it left to various agricultural activities.

Our visit to the catchment area of Lake Hawassa revealed that agricultural production is a major activity of local farmers residing at the northern, western and southern part of the catchment. Also there are state and private farms at the northern catchment area and these include Wondotika state farm, the seed multiplication plots of the seed corporation, the ELFORA farm, the G-farm located near ELFORA, etc. Furthermore, the RT observed intensive shoreline agriculture at south and south-eastern part of the lake. According to Susanne (1995), however, agriculture is generally regarded as one of the largest contributor of pollutants of all the categories and the pollutants are usually discharged as a component of natural runoff into surface waters and the underlying groundwater.

Through current observation, we have been able to verify that in the part of the catchment where there is agricultural activity; there is very little plant cover because of the increased tilling of the land and overgrazing of the vegetation. Therefore, the soil is exposed to erosion. This has been the trend for many years and will probably continue the same way. Such land use and degradation of catchments will certainly lead to runoff with increased input of sediment (sediment inundation) and nutrients which will eventually cause eutrophication of the lake.

In this regard, the only available study on Lake Hawassa catchment is that of Demelash Amare (2008) carried out to identify primary sources of the non-point pollution in the watershed and assessed the relative contribution of each source. Results of the researcher indicated the presence of strong association of land use/land cover, run-off water yield, non-point sources and pollutants. The major pollutants identified were sediment/siltation and nutrient loading.

One other aspect of increased agricultural activity in catchments of water bodies is chemical pollution from agro-chemicals (fertilizers and pesticides). We have no information on how much agro-chemicals are being used in the catchments of Lake Hawassa. However, we are sure that the state and private farms, and south-eastern shoreline vegetable farms, even some local farmers, etc., which are in the catchment of the lake may use some kind of agro-chemicals that end up in the lake.

One of the indications that the lake is polluted with Persistent Organic pollutants (POPs) of pesticide origin is the findings of a more recent study by Yared Beyene *et.al*. (2013). these researchers detected organochlorine pesticide (predominantly DDTs) in the muscle and liver of fish in Lake Hawassa. Therefore, the runoff from those agricultural fields in the catchment area is expected to carry the pollutants into the lake through storm water ditches or water courses.

2.1.3 Pollutants in Lake Hawassa

As described in the above sections, Lake Hawassa receives wastewater containing complex mixture of pollutants from factories, referral hospital, storm water (urban run-off) from Hawassa city as well as Tikur Wuha town and from agricultural fields. Usually, the level of pollutants in the aquatic environment is determined by measuring the concentration in water, sediment and living organisms. In this section attempts will be made to present the pollutants in different media of the lake (water, sediment and fish) giving special attention to concentrations of toxic substances (heavy metals) and nutrients.

2.1.3.1 Pollutants in the lake water

A study on the long-term changes of Lake Hawassa (Zinabu Gebremariam et al., 2002) has shown that the chemical concentrations of the lake have decreased and it has become more dilute over the last 40 years. This study also revealed that, unlike the rest of the ERVL (with the exception of Lake Langano) the salinity (and its correlates -conductivity, alkalinity and sodium concentrations) of the lake has decreased since the early 1960s. Behailu Berehanu, *et.al*. (2010) also reported the absence of appreciable variation in EC in the Lake water over the years except for the change from 1961 to 1964. Zinabu Gebremariam *et al*., 2002) reasoned out the possibility that the lake could have been saline at one point in time and then changes associated to water level may have diluted the lake, and they suggested that the water level and the chemical concentrations of the lake may have fluctuated over the years.

However, a more recent study (Behailu Berehanu, *et.al*., 2010) indicated that pH showed little variation within four decade; the concentration of nutrients (NO_3^-, NH_4^+ and PO_4^{3-}) were slightly increasing over the years; and sodium concentration is by far greater than other metal ions in the Lake. Alemayehu (2008) described that the dominance of Na could be due to weathering of acidic rocks. During our visit to southern shoreline of the lake, the RT observed extensive stone mining sites, a short distance from the shoreline. Therefore, weathering of rocks as result of mining activity and entering into the lake in the run-off from these sites may be responsible for increased Na.

More recently, Andualem Gezahagn (2013) investigated water of the lake for a total of eight heavy metals (Cu, Zn, Mn, Cr, Ni, Cd, Co and Pb) and only three were detected (namely Cu, Cr and Ni). A similar result was reported by Simachew Dires (2008) but, Mesfin Mengesha (2009) reported additional four heavy metals, Hg, As, Pb and Se.

According to Andualem Gezahagn (2013), concentration of heavy metals detected in the water of the lake generally followed the order of Ni > Cr > Cu. The concentration of Ni and Cr determined in the water (Andualem Gezahagn, 2013) were greater than the standard of WHO (1993) and USEPA (2006). But, the recorded concentration of Cu is far below the standards (WHO, 1993 and USEPA, 2006).

Zenebe Yirga (2011) and Andualem Gezahagn (2013) investigated the concentration of heavy metals in water of Lake Hawassa sampled from different sites (Tikur Wuha, Dorie Bafana and Hospital) selected based on potential sources of pollution. The Tikur Wuha site contained significantly higher concentration of Cr and Ni compared to the other sampling sites. Furthermore, the Metal Pollution Index (MPI) values calculated were highest for Tikur Wuha (0.088) followed by Dore Baffena (0.075) and Hospital sites (0.071). This result revealed that Tikur Wuha site had highest metal pollution (Andualem Gezahagn, 2013).

The three heavy metals (Cu, Cr and Ni) were also detected in samples taken from hospital site (Andualem Gezahagn, 2013). Simachew Dires (2008) detected three additional heavy metals (Cd, Pb, and Zn) at the same site with Zn concentration being the highest and only Cd exceeded the standard limit (0.01 mg/L) set for lake water (EC, 1998 and USEPA, 2002).

2.1.3.2 Pollutants in the sediment

The only available information about sediment constituent of Lake Hawassa is that of Girma Tilahun and Tigist Amare (2011). They assess the potential accumulation of heavy metals in the sediment and detected a total of five (namely, Hg, Cr, Zn, Cd and Pb). The average concentration of each of the detected heavy metals was higher than that of the reference site, indicating potential accumulation in the sediment. Among the metals, Zn concentration was the highest. The concentration in the sediment followed the order of Zn > Cr > Pb > Hg > Cd.

2.1.3.3 Pollutants in fish

Fish occupies the highest trophic level in aquatic systems. According to Zhou *et a*l. (2008), fish attracted a lot of attention as bio-indicators for monitoring aquatic pollution, due to their relatively large body size, long life cycle, position in the aquatic food chain and their use for human consumption. Furthermore, Ahmed and Shubami-Othman, (2010) pointed out that fish is a good bio-indicator of water quality because it has a potential to accumulate heavy metals and other organic pollutants of water. Moreover, Pourang *et al.,* (2005) reasoned out that exposure of fish to elevated metal levels in an aquatic environment may cause them to take up metals from their direct environment.

It is well known that fish in polluted water could accumulate heavy metals in their organs (e.g. liver, muscle, gills, etc.) and muscle is considered in the discussion below from consumers' safety point of view because it is the principal edible fish section and can directly affect human health.

Lake Hawassa supports at least six fish species (Elias Dadebo, 2000 and Zerihun Desta, 2003), three of which are commercially important (the Nile tilapia or *Oreochromis niloticus*; the African sharptooth catfish or *Clarias gariepinus;* and African big barb or *Labeobarbus intermedius*); the other three species, although not directly utilized by the fisheries, have an important ecological significance.

Different researchers (Abayneh Ataro et al., 2003; Zerihun Desta, 2007; Asrat Fekadu, 2013; and Andualem Gezahagn (2013) have reported the presence of various metals in organs (muscle, liver, gills, etc) common fish species in Lake Hawassa. But the reliability of these data needs to be verified by further studies. Previous studies (Abyneh Ataro, *et.al*., 2003 and Zerihun Desta, 2007) revealed the presence of less number of heavy metals in muscle of only two species (*O. Niloticus* and *C. gariepinus*), most of which were below the limit. The detection of large number of heavy metals with majority of them higher than the limit in recent studies (Zenebe Yirgu, 2011; Asrat Fekadu 2013 and Andualem Gezahagn, 2013) is an indication of increased pollution danger of Lake Hawassa if and only if confirmed by further studies. This also has implications in terms of consumers safety point of view; survival of the fish and other aquatic life; and biodiversity of aquatic life.

2.2. Possible Adverse Effects of Pollution

As described in section 2.1 above, Lake Hawassa is under a serious pollution threat due to anthropogenic activities from the Hawassa city and its surroundings. Although the effects of pollution on Lake Hawassa are not noticeable at the moment, the long term effects are inevitable unless mitigation measures are taken as early as possible.

There is no comprehensive study conducted in Hawassa to see the overall picture of environmental impact caused by all kinds of pollution in general and the effluents discharged from factories into the immediate vicinity of Lake Hawassa that eventually reach the lake. We present here the potential effects of pollution on Lake Hawassa based on available information.

2.2.1. Effects of pollution on water quality

The quality of water is central to all of the roles that water plays in our lives and good water quality is fundamental to the network of life and livelihood that water supports.

Water from the Boga and Boeitcha streams, near the residential area of rural community and water of the Tikur Wuha River; have been used by the people for different purposes for a long period of time. However, the waste water discharged from the factories into the stream has radically altered the physical, biological and chemical quality of the stream water and its receiver, the Tikur Wuha River.

According to the residents in the area, since the establishment of HTF, the waste water released and mixed with the streams is turbid and this gave a bad appearance and foul odour. Due to the altered physico-chemical parameters and high concentrations of some heavy metals in the waste water, the water quality of Boga and Boeitcha streams and Tikur Wuha River are poor and not safe for human and animal consumption. People in the area use the effluent for irrigation and, according to Michel *et.al*. (2007), the use of wastewater for irrigation also leads to risk of ground water pollution through leaching and sorption of heavy metals.

Polluted water that cannot be used (for drinking, bathing, industry, or agriculture, etc) effectively reduces the amount of water available in a given area. Therefore, the water quality of the streams and the river has been severely affected since the establishment of HTF. Thus, people in the area are in short supply of safe water primarily because of industrial pollution.

Although eutrophication in Lake Hawassa has not yet observed and not a problem now, with continuous input of the pollutants, particularly with loading of nutrients and organic matter, eutrophication may be a challenge in the future.

Even though, Lake Hawassa receives different kinds of pollutants from different sources, including the factories, studies showed that its water quality has not been severely affected and seriously disturbed in the past years apparently due to dilution of the pollutants. Therefore, the present quality of the water of Lake Hawassa is suitable for both domestic purposes and irrigation (Zinabu Gebremariam 2003). However, the future trends of the lake may not continue to be as optimistic as they are now, as pollutants loading to the lake have still continued with no pollution mitigation measures.

2.2.2. Effects on aquatic life

Anthropogenic source of pollution, such as industrial discharges and urban run-off containing domestic wastes and agricultural storm run-off have adverse effects on Lake Biota, in particular when it contains pollutants and released into the system in partially treated or untreated form. The threats imposed on aquatic life can be direct, affecting survival, growth and reproduction of the organisms and/or indirect by making them unusable to humans.

Results of early experimental studies on aquatic biota (Zinabu Gebremariam and Zerihun Desta, 2002) has shown that the effluent from HTF kills fish of different species (probably due to the toxicity from the heavy metals in the effluent). Similarly, a recent toxicity study on fish revealed that effluent from HTF caused highest mortality on fry of Nile tilapia, followed by effluents from ceramics and soft drink factories (Behailu Berehanu, *et.al*. 2010). A more recent study by Kssaye Balkew (2013) also confirmed the toxicity of the HTF effluent to Nile tilapia. The findings of these studies strongly suggest that the effluent from factories is potentially hazardous to the survival of fish. Therefore, the adverse effects of the effluent, from HTF and other factories in the area, on the biota of the lake are the ultimate environmental concern.

Experimental studies (Zinabu Gebremariam and Zerihun Desta, 2002; and Behailu Berehanu Berehanu *et.al*, 2010) to investigate the effect of effluents from factories on aquatic plants (algae) revealed highest rate of algal growth compared to the control group at low concentrations of effluent. According to Behailu Berehanu *et.al*. (2010), high concentrations of plant nutrients (particularly phosphate and nitrate) present in the effluents of factories might be responsible for the observed excessive algal growth. This boost of algal (phytoplankton) growth is an indication of the likely-hood of eutrophication in the lake.

On the other hand, Behailu Berehanu *et.al*. (2010) demonstrated reduction in the rate of algal growth with increasing concentration of the effluent and this may be explained by the toxic effects of the effluent when the concentration reaches a considerable level.

Several studies (Zenebe Yirgu, 2011; Asrat Fekadu, 2013 and Andualem Gezahagn, 2013) demonstrated accumulation of different heavy metals in organs (muscle, liver, gill, etc) of commonly edible species of fish (***O.*** *Niloticus, C.gariepinus* and *L.intermedius*) in Lake Hawassa. This is an indication that heavy metals are accumulating in aquatic biota. With continuous input of pollutants into the lake, the level of heavy metal concentration is expected to rise to levels that would affect the physiology of aquatic organisms that may lead to reduction in the fitness of the natural population. As described by Farkas ***et al.*** (2002), the progressive and irreversible accumulation of heavy metals in the various organs of aquatic life in Lake Hawassa would ultimately leads to metal-related problems in the long run because of their toxicity, thereby endangering the aquatic biota including fish.

2.2.3. Effect on domestic and wild life

According to Kumar *et al*. (2006), aquatic macrophytes can accumulate large amounts of heavy metals in their tissues from polluted water. Birenesh Abay (2009) and Yadessa Chibsa (2011) reported that macrophytes are growing along the waste stream discharge way of factories and analysis showed that they accumulated heavy metals in concentrations more than that in effluent. Observations revealed that domestic animals graze macrophytes and other species of grasses grown near the wastewater discharge point and also drink out of the effluent. Therefore, the heavy metals in aquatic macrophytes can be transferred through food chain and bioaccumulation in livestock. Thus, this is a potential of health risk to livestock grazing these macrophytes and drinking the effluent.

Wild animals, particularly birds, are observed feeding and swimming in treatment ponds of the HTF and in the discharged waste, and also there are reports of other wild animals such as hyena drinking out of the effluent. Although the effect of effluent from the factories to the immediate surrounding has not been investigated, the birds and other wild animals in contact with effluent (feeding and drinking) also may be in danger of harmful effects.

Yadessa Chibsa (2011) surveyed households in the industrial neighbourhood to find out if there is any health problem of livestock. According to the result, the most serious health problems encountered by livestock were decrease in productivity, abortion, sickness and weight loss, and even death. This is indicative of the effect of industrial pollution on domestic animals.

2.2.4. Effects on humans

As described in the previous sections, the factories located at the eastern edge of Hawassa city discharge untreated or partially treated effluent into the immediate surroundings of the rural residential areas. Observations made by Birenesh Abay (2007), Yadessa Chibsa (2011) and currently by RT revealed that due to scarcity of tap water or other safe fresh water sources, people in the area have no alternative but to use contaminated waste water from the factories for different purposes. They use it for bathing, washing clothes, irrigation, etc. This suggests that people in the area are directly or indirectly exposed to pollutants in the effluent, which some of them may be at toxic levels. Exposure of the people in the area to pollutants in the effluent may involve direct contact, consuming contaminated agricultural products (crops, vegetables, fruits, etc), and livestock (milk, meat, etc), as well as fish in polluted water. These exposures may have effects on human health and livelihood.

2.2.4.1. Human health risk

A range of pollutants in the environment are known to have direct and indirect impacts on human health, including inorganic and organic contaminants. Among the pollutants, extended exposure or exposure to high concentrations of metals can have serious consequences for humans as these metals tend to bioaccumulate in tissues (UNEP GEMS 2007).

Some heavy metals detected in water of Lake Hawassa tend to accumulate in the tissues of important fish species. Therefore, in the long run, humans regularly consuming these fish can receive high concentration of the toxic metals exceeding the maximum permissible (MPL) level in the diets, depending on the amount consumed.

The human health risk assessment was determined in a study by Ermias Deribe (2012) where consumption of a certain amount of fish from ERVLs including Lake Hawassa, could pose a threat to health because of POPs and mercury present in fish. According to this study, children and pregnant women of the local community, especially the subsistence fishermen and their families are the most vulnerable population sub-group. Thus, the people in the area are at risk of health problems related to environmental pollution.

The effluent from the factories is also used for irrigation to produce crops, vegetables and fruits and the effluent has been reported to contain toxic heavy metals that contaminate soil. According to Dudka and Chlopecka (1990), plants are known to accumulate heavy metals in their edible portion as a result of cropping on contaminates fields. Moreover, there are reports that consumption of metal contaminated crops may lead to many kinds of diseases in humans (Oluwatosin *et.al*., 2005; Zheng *et.al*., 2007; Bosso and Enzweiler, 2008; Fu et al., 2008; Lim et al., 2008; Agbenin et al., 2009). For example, high prevalence of upper gastrointestinal tract cancer in Turkey has been linked to heavy metal pollution of soil, fruits and vegetable (Turkdogan *et.al*. 2003). Therefore, introducing heavy metals into the food chain through waste water irrigation may have potential health risk for producers and consumers in and around Hawassa city.

Although there is very little information about the magnitude of human health impact due to effluent pollution in Lake Hawassa, a survey conducted by Yadessa Chibsa (2011) showed that people living in neighbourhoods of factories encountered different health problems as a result of direct or indirect exposure to the effluent. The health problems reported includes skin allergy, breathing problem, vomiting, loss of appetite, fatigue, headache and diarrhoea. Some of these symptoms are typical to heavy metal toxicity to humans reported by several researchers (Jordao et al., 2002; ATSDR, 2004 and 2008; Rai & Tripathi, 2009; Rehman and Sohail Anjum, 2010).

As clearly indicated in the previous sections, effluents from factories and Hawassa referral hospital, urban and agricultural storm run-off that enter Lake Hawassa contain pathogenic organisms originating from human and animal wastes. These can contaminate Boga and Boeitcha streams; Tikur Wuha River and finally Lake Hawassa and highly affect quality of the waters. Because of the absence of adequate tap water in the area, many people in and around Hawassa city use these contaminated streams, river and lake waters. It is obvious that using this water contaminated with pathogenic organisms would have likelihood to cause water-borne diseases. Although this has not been studied, it should be very seriously considered as the water from streams, the river and Lake Hawassa is consumed by the people and their domestic animals.

2.2.4.2. Effects on livelihoods

Clean water and healthy freshwater ecosystems provide the basic goods and services upon which many livelihoods depend, including irrigation water, fertile floodplains for agriculture and grazing, and habitat for fish that may be eaten or sold. According to Husain, et al. (2010), industrial wastewater and the resulting environmental pollution deteriorates the quality of water, soil, crop and environment. And polluted water can reduce or eliminate the viability of many livelihoods (Palaniappan, *et al*. 2010).

Farmers at the shoreline use Lake Hawassa and those near the factories use effluent in irrigation agriculture. Using water of Lake Hawassa for irrigation may not be of great concern as most of the pollutants detected were below the standard limit of irrigation agriculture. But using effluent is a big concern because it contains several kinds of pollutants, especially, heavy metals, some of which are above discharge limits.

Soil and water pollutants that adversely affect agriculture include sediment, out of place nutrients, inorganic minerals, organic wastes, infectious agents, industrial and agricultural chemicals, etc. Most of these pollutants were present in effluents from the factories.

According to Reddy and Behera (2006), contamination of soils from polluted irrigation water is responsible for loss of cultivable land. And water and soil pollution affects the economic productivity of agriculture by destroying crops, reducing food crop quality, and/ or diminishing yields. A good example to show how much industries effluent irrigation affects agricultural yield and livelihood is the yield loss projected by Kurnia *et al*. (2000) in India.

According to this researcher, after 20 years of textile industrial effluent contamination, the average rice yield will be decreased by about 80% due to pollutions.

A survey by Yadessa Chibsa (2011) indicated that those people who used factories effluent for irrigation reported reduced fruits and vegetable productivity, changes in their color and burning of their leaves. This suggests that farmers that use effluent in agricultural production may loss yield and this would greatly affect their livelihood.

As describe in the section related to the effect of pollution on domestic animals above, livestock were forced to depend on polluted drinking water due to inadequate supplies of safe water to the people around the industrial area in Hawassa city. According to Yadessa Chibsa (2011) drinking this effluent from the factories caused sickened livestock resulting in loss of reproductive capacity and production of poorer quality milk and even it may result death. There are people who depend on products of their livestock for income and the industrial pollution could greatly affect livelihood of the people in the area.

Commercially important and edible fish species of Lake Hawassa were exposed to pollutants and some of them accumulated heavy metals in their muscle in higher concentration than the water. Some of these heavy metals are known to be toxic to fish and can affect their survival and reproduction.

Water pollution and associated accumulation in the organs of fish can cause a decrease in fish production either by reducing or eliminating fish populations or by making fish unsafe or undesirable for consumption. On top of the existing overfishing and faulty fishing observed in Lake Hawassa, continued pollution of the lake would be a major threat to fishery in the future. If mitigation measures are not taken, this would clearly affect the livelihood of fishermen that depend on it.

PART B

MITIGATION MEASURES AND INTERVENTION STRATEGIES

As clearly portrayed in Part A of this report, Lake Hawassa has become one of the most vulnerable Ethiopian rift valley lakes to pollution and other ecological degradation processes that arise from intensive anthropogenic activities in the catchment area (refer to Part A of this report for details). In this part of a study report, cost effective mitigation measures and intervention strategies to bring down concentrations of pollutants that enter Lake Hawassa are proposed. The proposed mitigation measures and intervention strategies are believed to reduce adverse impacts of industrial and medical wastes from point sources as well as municipal and agricultural wastes from non-point sources reaching the lake.

Before embarking on to the details of the mitigation measures and intervention strategies, it is appropriate to present a brief overview of the processes we went through in identifying the RCMM and RCIS. Figure 3.1. illustrates these processes that consist of a series of actions or step-wise undertakings.

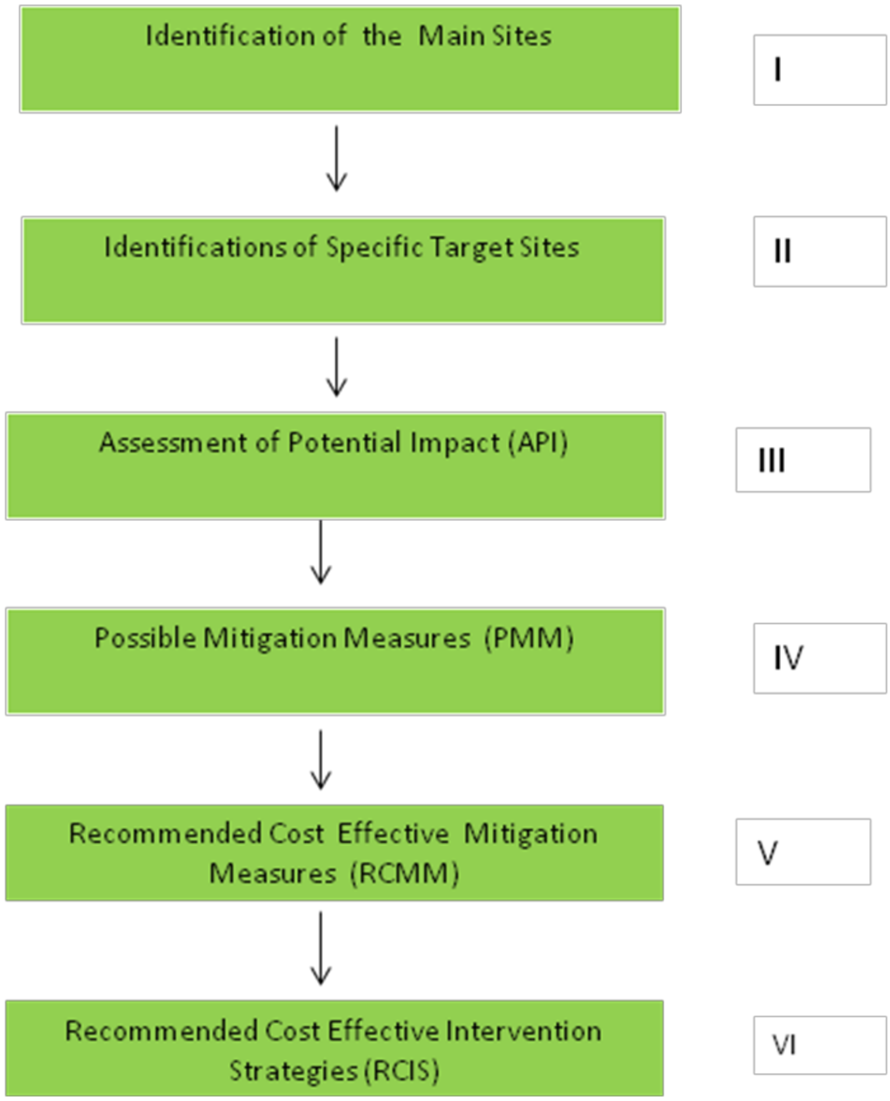

Fig 3.1. A flow chart of processes involved in the Cost Effective Mitigation Measures and Intervention Strategies recommended in this study report.

CHAPTER 3

3. MITIGATION MEASURES

Mitigation measure is a measure designed to reduce the undesirable effects of a proposed action on the environment. Different types of mitigation measures act in different ways to reduce adverse impacts:

i. *Prevention and control measures:* fully or partially prevent an impact or reduce a risk by changing means or technique, changing the site and specifying operating practices;
ii. *Remediation measures:* involve repairing, rehabilitating or restoring the affected environment after damage is done;
iii. *Compensatory measures:* involves compensating for an impact by replacing or providing substitute resources or environments, e.g., offset adverse impacts in one area with improvements elsewhere;

3.1. Possible Mitigation Measures (PMM) at the Point Sources

Based on previous studies and our current observations, the factories in Hawassa city and a referral hospital that operate at close proximity to Lake Hawassa and that release their liquid waste directly or indirectly into the lake are considered as point sources of pollution. These sources include major factories in the industrial zone of Hawassa city (such as HTF, MHSDF, BGI-BF, and ETAB-SF), a factory outside the industrial zone of Hawassa city (TCF), and HURH.

There are three ways to mitigate pollution at these point sources - factories and hospitals. (a) use of new, less polluting technologies (b) effective treatment of effluent so that it conforms to specified discharge requirements, and (c) recycling waste several times over before discharge, which is considered as the most practical solution. Figure 3.2. illustrates how wastes can be minimized at the point sources, i.e. in the factory (in-house management), and can be reused or recycled or treated before being released into the environment. Prevention and control measures (EIA-follow up, minimize chemical use, and minimize solid and liquid wastes) and, remediation measures are the possible mitigation measures proposed at the point sources.

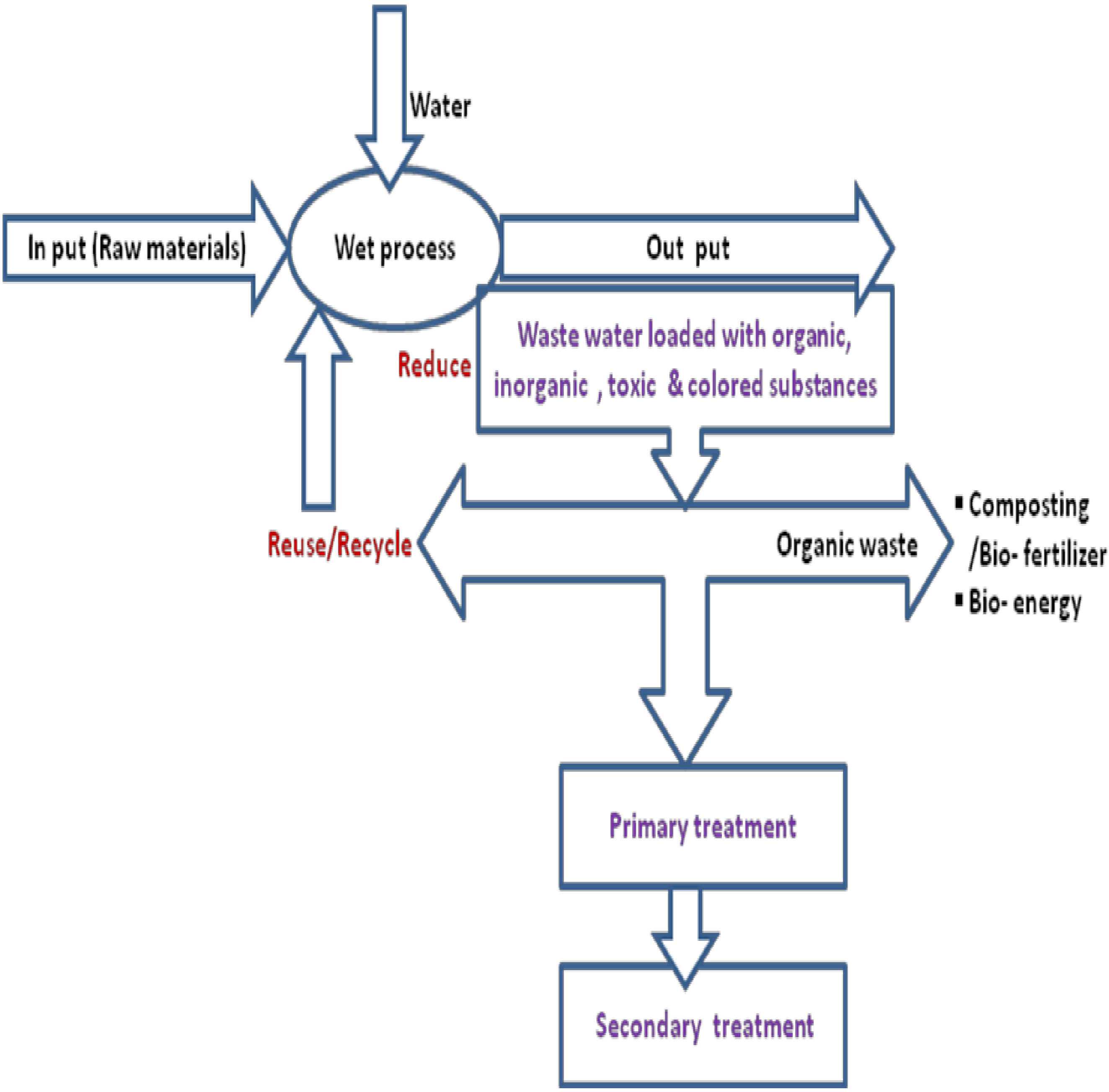

Fig. 3.2. Industrial waste management at the source

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3.1.1. Prevention and control measures

3.1.1.1. EIA-Follow up

Environmental impact assessment (EIA) is assessment of the beneficial and adverse changes in environmental resources or values resulting from a proposed project. Essential elements of EIA include: identification of possible positive or negative impacts of the project, quantifying impacts with respect to common base, and preparation of mitigation plan to offset the negative impacts. EIA generates huge benefits in selection of project location, process, design, development actions, and decision-making. The outcome of EIA (EIA report) acts as a "reference" guide to the implementation, for use of mitigation strategies and monitoring schemes. It may form a basis for management plan to assist project implementation and environmental management practice.

Considering this, the government of Ethiopia promulgated EIA Proclamation No. 299/2002 in December 2002. The primary objectives of this proclamation were to make EIA mandatory for defined categories of activities undertaken either by the public or private sector. Despite the presence of this proclamation, the RT has been able to learn that some of the factories in Hawassa were allowed to establish and function in areas that were not designated as "Industrial Zone" e.g. TCF. Therefore, they lack the proper infrastructure to handle their waste products. The sewage infrastructure in the industry zone has not also been expanded or improved for decades. There is no enforcement of the existing environmental regulations regarding use of chemicals and their disposal. Absence of monitoring practices and lack of proper knowledge has led to the use of inappropriate or old technologies to the detriment of the environment. There is a lack of monitoring and enforcement of the existing environmental regulations and legislations, and, in most cases, lack of resources and good will on the part of the policy implementers to mitigate the environmental problems. The RT has been able to learn that there is no regular monitoring of the factories by environmental protection institutions. Therefore, EIA follow-up is one of the mitigation measures proposed for the factories currently working**, and these include** monitoring, evaluation, management, and communication. We provide hereunder a brief description on each of them:

i) Monitoring: is one the steps in EIA follow-up and it involves comparing data that has been collected in the assessment if the project in the point source is working in compliance with environmental standards and the guidelines set as well as the predictions and expectations outlined prior to the commencement of the project. These include:

- National/local standards and regulations for the discharge of industrial wastewater to sewers and streams and rivers
- National water quality standards and controls
- Workplace health and safety regulations
- Regulations on the storage, handling, use, and disposal of toxic chemicals

Monitoring and systematic gathering of information on pollutant levels in the effluent released to the environment, and pollution prevention practices in the factories are essential components of any pollution control system. Although pertinent regional and federal government agencies (like the EPAs,) have already been established, they lack the experience of monitoring and reinforcement of environmental laws and regulations. There are no sufficient technical and manpower resources to maintain effective monitoring and pollution-control. Considering the fact that governments are the major sources of funding for most activities, the participation of government agencies is essential in the successful execution of any scheme of environmental monitoring. Thus, the first step in any such program is to establish and/or strengthen the relevant agency to carry out these activities.

ii) Evaluation: involves assessment of the findings based on the information from the monitoring step in relation to standards, pre-project predictions and expectations. It often includes scientific and technical procedures.

iii) Management: involves responding to the issues which may arise from the monitoring and evaluation processes. All EIA reports should include an impact management plan and this may include environmental management within the factories and/or outside in the environmental components. The role of management is undertaken by the parties including the proponent and the regulator.

iv) Communication: Experience of EIA, globally, has shown that stakeholder involvement and, increasingly, participation is an important contributor to the overall utility of EIA reports in decision-making.

3.1.1.2. Minimize chemical use

Minimizing chemical use is one of the key control and prevention methods to mitigate adverse environmental effects in factories. Minimizing chemical use can be achieved by:

- Following certain standard processing methods that increase the efficient use of Chemicals (e.g. higher bath temperatures, good measuring equipment, etc.).

Improving chemical application techniques like spot apply solvents instead of pouring - this helps to avoid spills and stops excessive chemical use

- Using correct measurements to reduce waste or spoilage
- Using less dangerous or hazardous chemicals
- Replacing potentially carcinogenic chemical inks with vegetable based inks
- Using lower-foaming detergents or solvents with less isopropyl alcohol to reduce pollution by reuse certain chemicals
- Investigating which chemicals can be reused or recycled: caustic soda, for example, can be recaptured from the mercerizing process (an intermediate step in textile refinishing) through evaporation, and
- Having good storage and handling to reduce waste and spills (e.g. sturdy and easily secured containers.

3.1.1.3. Minimize solid and liquid wastes

Likewise, minimizing solid and liquid wastes is a prevention and control measure that helps to fully or partially prevent an impact/reduce a risk. The following list of prevention and control measures can also help, in one way or another, to minimize solid and liquid waste:.

- Operate the project in the point source within its design capacity
- Primary and secondary treatment of waste waters: primary treatment is physical and chemical process that often precedes secondary, or biological, waste water treatment processes
- Separate liquid from solid waste
- Screen liquids to remove coarse solids
- Drain liquid wastes into a settling tank
- Air dry sludge and dispose as solid waste
- Separate and sell uncontaminated wastes to farmers as fertilizer
- Avoid dumping solid waste

- Use a proper landfill or bury it in a pit (away from water sources)
- Collect, dry and dispose of as solid waste

However, implementation of this mitigation method depends on the willingness of the company and the enforcement of the environmental safety regulations treated under Chapter 4 of this report.

3.1.2. Remediation measures

Environmental remediation would be one of the recommended mitigation measures at the point sources identified in this study. It is an environmental clean-up practice with the aim of recovering ("healing" so to say) the contaminated site in the point sources into acceptable conditions. In a more broad sense any type of recovery of the contaminated site is considered as a remediation. To remediate the contaminated site in the point sources, one or more of the following physical, chemical and/or biological remediation techniques can be considered.

3.1.2.1. Physical remediation

On-site containment and reconstruction of the treatment facilities (biological lagoons/oxidation ponds located outside the factory compound and the treatment ponds located inside the factory compound) may be among the physical remediation measures that need to be considered here. These may involve the construction of a complete isolation of the hazards materials that can be achieved by covering/capping, inserting low permeability and concrete wall, and solidification of wastes in the contaminated sites. This is widely applicable for contaminated sites with high level heavy metal wastes (Wright and Welbourn, 2002). Reconstruction of the site is also an alternative physical remediation measure that overlaps with on-site containment. It involves physical and biological construction that includes physical diversion of flow of surface or ground water, installation of barriers, placement of impermeable clay cover to shade surface water and prevent its infiltration through the soil. Such engineering constructions of course perturb the ecosystem and need to be carried out with caution (Wright and Welbourn, 2002).

3.1.2.2. Biological remediation

An alternative or a complementary method to the above physical remediation is using natural processes called biological remediation (bioremediation and phytoremediation). Bioremediation is a process of degradation of contaminants using microorganisms. Microorganisms bring degradation of organic matter either through oxidation or reduction processes. Microorganisms can naturally bring degradation but such a natural process is unexpectedly slow in many cases. Therefore, the remediation process is facilitated by creating favorable conditions to the organisms. According to (Rockne and Reddy, 2003), bioremediation of contaminated sites can be achieved by:

(i) Complete oxidation of organic contaminants into carbon dioxide and water,
(ii) Biotransformation of organic chemicals into smaller less toxic metabolites, or
(iii) Reduction of halogenated compounds like PCBs using an electron donor

The success of bioremediation in the field relies mainly on the presence of adequate microorganisms, the physical access of the contaminants to the microorganisms and supply of electron donor/acceptor. Adequate microorganism flora can be achieved either by stimulating indigenous microorganisms in the site by the process called biostimulation or by adding an enriched culture of microorganisms by the process called bioaugmentation. The physical access of the contaminants can be achieved by chemical or physical treatment of the contaminants through the process of diffusion, desorption and /or dissolution (Frazar, 2000).

3.2. PMM at the Non-point Sources

Unlike pollution from industrial and sewage treatment plants, non-point source pollution comes from many diffused sources. Non-point source pollution is caused by rainfall moving over and through the ground. As the runoff moves, it picks up and carries away natural and human made pollutants, finally disposing them into the lake. Run-off from urban settings, mainly from Hawassa city and Tikur Wuha town, and rural areas (agricultural fields) in the catchment are the main non-point sources that bring pollutants to the lake.

The RT has identified Integrated solid waste management (ISWM) and reduce, reuse and recycle (3Rs), and Agricultural best management practices (ABMPs) as the possible mitigation measures at the non-point sources.

3.2.1. Integrated solid waste management (ISWM) and reduce, reuse and recycle (3Rs)

Integrated Solid Waste Management (ISWM) and Reduce, Reuse and Recycle (also known as the 3Rs) are a comprehensive waste prevention, recycling, composting, and disposal approaches that manage solid waste in ways that most effectively protect human health and the environment. This method involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions. As a consequence of conventional waste management practices, many cities in developing countries are facing environmental and health risks as well as losing economic opportunities in terms of the resource value of the waste.

ISWM and 3Rs have been given highest priority on waste prevention, waste reduction, and waste recycling instead of just trying to cope with ever-increasing amounts of waste through treatment and disposal. Therefore, a paradigm shift from conventional waste management practices to ISWM and 3Rs is essential for a city like Hawassa in order to effectively manage the waste stream.

City Mayors and administrators should try to encourage a fundamental change in mindsets and attitudes of the public toward waste. Public information and campaigns need to encourage urban populations to help reduce the waste stream and to turn what used to be considered as "waste" into "resources" i.e. resources can be recovered from waste if they are separated at the source, and are treated properly. This paves the way towards "Zero" disposal of solid waste management integrated with production of transformed resources (see Chapter 4, Section 4.2.1.2. of this report).

3.2.2. Agricultural best management practices (ABMPs)

Agricultural BMPs are procedures and practices designed to reduce the level of pollutants in runoff from farming activities to an environmentally acceptable level, while simultaneously maintaining an economically viable farming operation for the grower. Indigenous farmers have traditionally used and still use an array of traditional slope, water, soil, pest, and vegetation management techniques, including composting, crop rotation, polycultures, agroforestry, and watershed management systems. Some of these practices can be selected and used to reduce pollution that reaches Lake Hawassa from agricultural fields. Source controls are often the most effective ABMPs for reducing some types of pollution. Examples of source controls include the following:

- Reducing or eliminating the introduction of pollutants to a land area. An example is minimizing the application rates for chemical pesticides, herbicides, and fertilizers.

- Preventing potential pollutants from leaving a site during land-disturbing activities. Examples include conservation tillage and limited land clearing.
- Preventing interaction between precipitation and a potential pollutant. An example is timing chemical applications according to weather forecasts or seasonal weather patterns.
- Protecting riparian habitat and other sensitive areas. Examples include protection of shorelines and highly erosive slopes.
- Protecting natural hydrology. An example is proper water management (USEPA, 1993).

These mitigation measures could be grouped as non-structural or structural practices. The nonstructural BMPs are modifications in agricultural practices that do not require some type of construction. They focus on source reduction (pollution prevention) and programs and procedures for controlling agricultural nonpoint source pollution. These may include educating at various levels; water management practices; proper land use; erosion and sediment control; etc.

Structural BMPs are practices related to something constructed or built. There are a variety of structural BMPs and most require some level of routine maintenance to continue working effectively. The physical structures are primarily concerned with changing slope characteristics to reduce the amount and velocity of runoff. Slope management, based on a combination of simple and inexpensive cropping practices, can be highly effective in maintaining or improving crop productivity with minimal erosion risk (Manrique, 1993). Physical structures are also used to trap sediment and pollutants before they enter surface waters.

3.3. PMM at the routes

A route is a river/stream or drainage canal/surface storm by which the effluents from point and non-point sources reach the hot inlet spots that ends up in the lake. *Wetland vegetation along the catchment* of the river/stream, *constructing filtering racks* (municipal waste trash trap) with different mesh size along municipal drainage canals, *cover vegetation* for reducing flow of storm water, *diverting effluents* and *digging ditches* can be the PMM at the routes.

3.3.1. Wetland vegetation along the catchment

Wetland vegetation using, for instance vetiver system along the catchment of the river/stream, would be a possible measure to mitigate downstream pollution in Lake Hawassa. The system is based on the unique plant vetiver, *Chrysopogon zizanioides*. The hedge is a dense barrier above and below ground, the plant is sturdy and stiff and the root is deep and strong (Fig. 3.3.)

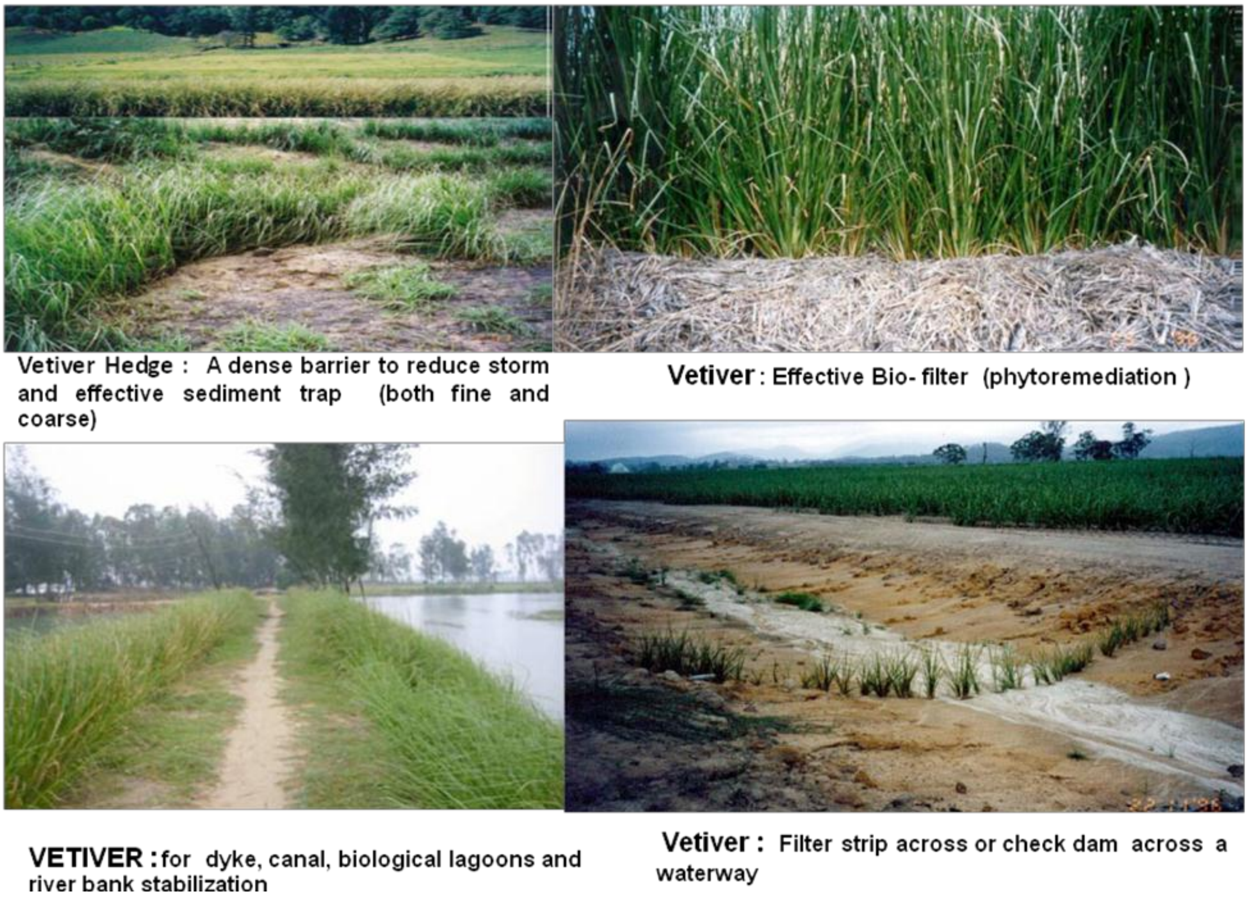

Fig. 3.3. The vetiver system (Adapted from "http://www.vetiver.org/")

The Vetiver grass has special characteristics that are tolerant to extreme environmental conditions, suitable for bio-filter and wastewater treatment, and tolerant to pollutants (agrochemicals and heavy metals) (Table 3.1).

Table 3.1: Special characteristics of the plant - vetiver (Adapted from "http://www.vetiver.org/")

Special characteristics	**Descriptions**
Tolerate extreme and wide range of conditions	– Grows under extreme and wide range of conditions – Long living perennial grass – Air temperatures: -15 $^{\circ}$ C to >55° C – Soil pH from <3 to >10 – Annual Rainfall <300 mm to > 5,000 mm. Tolerant to extreme drought – Tolerates at high levels all heavy metals – Saline tolerant (salinity threshold ECse = 8 dSm-1) – Fire tolerant – Tolerant to long and total submergence in water – Resistant to most pests and diseases – Powerful (average 75 MPa) root strength and deep root system – Noncompetitive and noninvasive. According to the PIER level of invasiveness criteria, non-fertile vetiver cultivars are rated - 8. *(An acceptable level for plant importation)*
Suitable for Bio-filter	– Strips Stiff and erect stems which can withstand fast flow. – Forming a thick living barrier which slows and spreads runoff and traps both fine and coarse sediment. – Deep root system binding the soil against erosion. – Highly tolerant to adverse growing conditions such as acidity, alkalinity, salinity, drought, water logging and extreme temperature. – Highly tolerant to pollutants, agrochemicals and heavy

	metals *by the most strict countries is +1)*
Suitable for wastewater treatment	– Very high capacity for N and P uptake under Dry-land, Wetland or Hydroponics conditions – Very fast growth with very high water consumption under wet conditions – Biomass up to 132t/ha – Tolerant high levels of herbicides and pesticides – Highly tolerant to heavy metal toxicities – A hospital sewage farm on Lake Awassa – This sewage effluent is being discharged into the Lake. The effluent needs further treatment, a Vetiver wetland would be a low cost and effective solution.

3.3.2. Construction of filtering racks along drainage Canals

Drainage canals collect trash and silt that build up and finally reach to treatment ponds or open shoreline. Constructing filtering racks (municipal waste trash trap) with appropriate distance along the drainage canal holds trash/solid wastes and help to retain the trash and silt before reaching the hot inlet spots. This decreases the burden on storm water treatment ponds under construction along lake shoreline. The trash trapped along the drainage canal can be easily removed before reaching the hot inlet spots

3.3.3. Cover vegetation for reducing flow of storm water

Absence of cover vegetation in open spaces and areas reserved for park will increase the flow of storm water loaded with waste and silt. Therefore, cities should be green with public open spaces covered by dense grass. This will trap sediments and increase filtration of toxic substances on the route before reaching the storm treatment ponds and inlet spots.

3.3.4. Diverting effluents

The effluents from the factories (particularly those from HTF, MHSDF and BGIBF) that enter the streams (especially into Boeitcha, Daka, etc.,) that flow adjacent to the Shallo wetland need to be thwarted from entering the streams that end up in the lake. Diverting the effluents into the wetland so that they do not reach the routes (the streams) and/or into a series of storage/stabilization/oxidation ponds within the wetland can be an alternative or complementary mitigation measure. A kind of a simple Waste Stabilization Pond (WSP) a modified version of oxidation ponds/lagoons in which stabilization occurs through sunlight, air and microorganisms can be constructed as depicted in Figure 3.4. Given that the Shallo wetland is not being used for any agricultural purposes it can provide a long detention time for sedimentation and biological treatment.

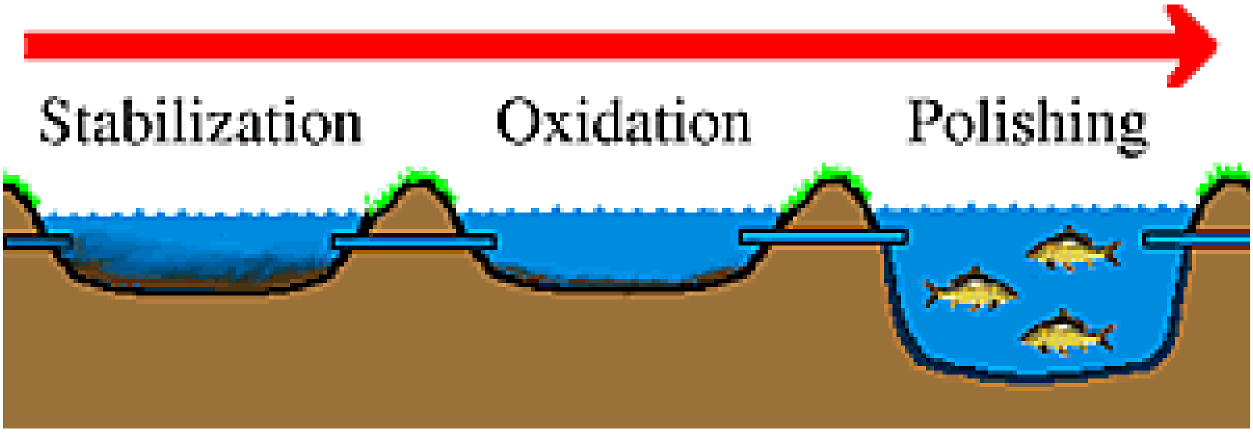

Fig. 3.4. A modified version of oxidation pond that can be constructed in Shallo Wetland .
Source: http://www.oilgae.com/ref/glos/waste_stabilization_pond.html

3.3.5. Digging ditches

During one of its field visits, the RT, was able to observe that the local farmers (adjacent to the point where the effluent from MHSDF is released into the streams) have dug a series of rows of ditches to slowdown and restrain the backflow of the effluent from the stream during the rainy seasons. Such ditches that serve the same purpose can be constructed in a modified form down the Boeitcha stream. The ditches resemble the "ridge-tie- method" used to arrest water along the hill side. A rectangular ditch at certain distance along water course, besides reducing the speed, temporarily holds/stores the waste water as it flows downstream. This will allow the soil to filter the waste water. The dense herbs grown around such ditches will also help in bio-filtering the wastewater. This can be duplicated and scaled-up as one mitigation method.

3.4. PMM at the Hot Inlet Spots and Shorelines

Inlet spots are effluent entry points to the lake from point and non-point sources via the routes. Although, effluent enters Lake Hawassa through different entry points (Tikur Wuha, Amora Gedel, Hawassa University Referral Hospital (HURH), Loke-Bete mangiest, Green wood, Oasis, Unique park etc…), the three most important hot inlet spots identified by the RT are Tikur Wuha, Amora Gedel, and HURH.

It will not be out of place to indicate here why the later three spots are considered as the most important hot inlet spots. Tikur Wuha receives the effluent from the factories and the Shallo wetland. Moreover, there is an increasing trend in settlement around the shore, shoreline agriculture by the local community, private horticultural farm in the immediate vicinity of the river, grazing, etc. Amora Gedel is the major entry point for municipal waste and surface storm water from the city. The inlet spots at the Hawassa University Referral Hospital receive medical wastes from the hospital and municipal waste from the city that enters the south eastern side of the lake. Major emphasis should therefore be given to these three hot inlet spots and some recommendations should be suggested for the others.

The interrelationship between a lake and its shoreline is also of a paramount importance since shoreline zone is the last line of defense against challenges that may otherwise threaten the health of the lake. Development within the catchment, particularly along the immediate shoreline of the lake increases the amount of pollutants that reach the lake. A lot of activities are taking place along the shoreline of Lake Hawassa. The presence of hotels, villages, recreation centers, and hospital are some of the development activities that have taken place adjacent to the nearby shoreline. Medical wastes from the hospital and municipal wastes from the hotels and the households pose danger to the lake ecosystem. Shoreline farms are also the main agricultural activities that may release agrochemicals sequestrated in the soil and reach the lake through runoff. On-site observation of the shoreline revealed that there are mining activities at the SW part of lake that may aggravate the siltation problem.

In summary, waste water loaded with pollutants reach Lake Hawassa along the shore facing Hawassa City. Industrial wastes enter the lake through Tikur Wuha, and Municipal/Urban wastes via drainage channels. Surface storm enters at different entry points (Green Wood, Unique park, Amora Gedel), Hospital waste at the HURU, and Agro- Chemicals from the shore line agriculture extending from Loke up to Bete Mangiest. Phytoremediation and establishment of buffer zone (i.e. a strip of natural vegetation along shoreline/restoration and enhancement of the associated wetland) as well as storm waste management (SWM) pond can be the PMM at the hot inlet spots and the shoreline.

3.4.1. Phytoremediation

Some plants like vetiver (see section 3.3.1. above) have a remarkable ability to tolerate exposure and accumulation of high dose (x200 the normal dose) of contaminants and such plants are referred to as hyper accumulators. Phytoremediation is thus an *in situ* treatment of contaminated sites using various plant species (Anderson et al., 1993 ; Pulford and Watson, 2003). Other types of plants that appear promising for this form of remediation include the mustard plant, alpine pennycress, broccoli and cabbage (Arthur and Coats, 1998). However, we do not recommend the use to these edible plant species for phytoremediation due to the possible accumulation of toxic substances in the plants that can, intentionally or accidentally, be consumed by humans and/or domestic animals.

Plants achieve the recovery of contaminated site by effectively reducing the bioavailability of the harmful contaminants through the following processes:

1. Phytotransformation: the transformation of organic contaminants into less toxic, less mobile or more stable form (Frazar, 2000),
2. Phytodegradation: the metabolization of the organic contaminant by the plant enzymes or by microbial assisted degradation (Burken and Schnoor, 1996)
3. Phytovolatilization: the volatilization of organic contaminants as they pass through the plant leaves (Brusseau et al., 1997)
4. Phytostabilization: the stabilization and reduction of the mobility and the migration of contaminants through the soil by absorbing and binding leachable constituents to the plant structure (Salt et al., 1998)

The process of phytoremediation is affected by various factors like chemical and physical properties of the contaminants (Briggs et al., 1982) and other environmental factors like soil matrix, chemical speciation and climate. Although phytoremediation is an emerging technology that promises effective and inexpensive cleanup of certain contaminated sites, it has the following limitations:

- It is limited to Shallo soils: the depth of the treatment zone is determined by the plant root depth in the soil
- It can transfer contamination across media, e.g., from soil to air.
- Contaminants may enter the food chain through grazing / browsing animals

3.4.2. Storm water management (SWM)

Storm water is of concern for three main reasons: its large volume and short timing of flooding, its huge potential to carry contaminants, and the misconception that people assume that water dilutes the pollutants and hence use storm water to dispose domestic wastes - this is the extension of the old unwarranted thinking that "dilution is the solution to pollution". Thus, storm water management (SWM) should consider technical, institutional and social aspects including:

- control of flooding and erosion
- control of hazardous materials to prevent release of pollutants into the environment (source control)
- construction of storm water retention or detention ponds as a treatment system so contaminants are removed before they pollute water bodies
- planning in advance to create solutions before problems become too great
- Educating the community to change the mind set on how improper waste disposal can affect water quality and what the public can do about SWM.

3.4.3. Establishment of buffer zone

As discussed in 3.4.1. above, it is possible to restore and enhance the associated wetland and then ecological functions of the lake shore by restoring the shoreline with native plants. Moreover, such a buffer zone can play a key role in limiting negative potential impacts from developed shore land activities that leads the pollution of the lake from medical, municipal and agricultural waste by filtering and retaining the wastes. The vegetation buffer zone in general helps also to prevent the siltation problem by retaining the sediments.

The primary purposes of vegetation buffer zones are therefore to:

- Remove nutrients from fertilizers, septic systems and storm water runoff. Vegetation reduces runoff by increasing storm water infiltration into soil. Less runoff means fewer nutrients and other pollutants entering the water. Needless to mention that excess nutrients are the primary cause of algal blooms and increased aquatic plant growth.

- Intercept and remove sediments in runoff
- Stabilize soils with plant root systems
- Reduce shoreline erosion due to wave action
- Purify water with aquatic vegetation
- Improve wildlife and fish habitat by providing food, shelter, and shade

In addition, a native plant buffer zone can create a more aesthetically pleasing shoreline for human.

Creating effective buffer zone requires understanding of local circumstances. Although the delineation of any width of the buffer zone has benefits, the delineation of buffer zone needs to follow a certain standard criteria. A different line of trees, shrubs and grasses from native/indigenous plants may create a multiple layers-just like in nature. What should we plant? We may need to look around at natural areas to see what plants are growing there and consult professionals. Buffer vegetation also should reflect local needs and conditions.

All the possible mitigation measures to reduce adverse impacts of Industrial and Medical Wastes from point sources and municipal and agricultural wastes from non-point sources on the lake are summarized in Table 3.2.

3.5. Recommended Cost Effective Mitigation Measures (RCMM) at the Specific Target Sites

It is not practical to mitigate every impact at a given time in order to address the pollution challenges faced by the lake and to effectively manage the lake resources within the catchment area. For mitigation to be effective, it must be:

- Realistic - achievable within time, resources and capabilities.
- Targeted - correspond to impacts
- Considering early - preventive mitigation is usually the cheapest and most effective especially when built-in at the design stage

- Adequately Funded - over the life of the activity; if funding/budget for mitigation measures are not programmed at the design stage, they are almost always inadequate

Therefore, there is a need of prioritizing the urgent impact at the target sites that can be mitigated at a given time and with the resources available. Recommendation of cost effective mitigation measures requires detailed cost benefit analysis; however such approach demands time and other resources. The RT has considered the following key points in line with the aforementioned criteria while selecting mitigation measures as cost effective:

i. Mitigation measures recommended by the RT are preventive and control actions - which are generally considered as cost effective;
ii. Integrated and joint efforts among concerned environmental bodies (NGO, GO and the public at large) will minimize cost by reducing duplication of efforts and insure synergistic benefits;
iii. Priority has been given to the critical sources that cause serious impact on the environment and human health. Such impacts are either irreversible or very costly to reverse.

Accordingly, the effluent from the factories released to the nearby stream ("Boeitcha" Stream) that reaches Tikur Wuha river and ends up in the lake should come at the forefront of the mitigation actions. By the same token, the HURH that operates at close proximity to Lake Hawassa and releases liquid waste, that may cause serious impacts, directly into the lake needs to be mitigated urgently.

While addressing the pollution challenges faced from the discharges of the industries and the referral hospital, the RT also realizes that development within the catchment, particularly along the immediate shoreline of the lake increases the amount of pollutants that reach the lake. Hence the RT has prioritized and recommended the following cost effective mitigation measures at the:

- Point sources - factories and hospitals
- Routes - the "Boeitcha" stream
- Hot inlet spots - Tikur Wuha River and the HURH
- Shorelines around the lake

In the following sections (3.5.1. to 3.5.5) the Recommended Cost-effective Mitigation Measures (RCMM) are described based on the rationale described under 3.5. above. Needless to point out again, that there is no single promising mitigation technique and hence each approach mentioned hereafter is not mutually exclusive from the others. Some combinations of these approaches are commonly used and have synergistic and/or additive effects.

3.5.1. RCMM at Specific Point Sources

3.5.1.1. Hawassa Textile Factory (HTF)

The Hawassa textile factory, like other textile industries utilizes large amount of water and produces proportional amount of wastewater from different steps in the dyeing and finishing processes. Wastewater from printing and dyeing units is often rich in color containing residues of reactive dyes and chemicals, and hence requires proper treatment before being released into the environment. Cotton provides an ecologically friendly textile, but more than 50% of its production volume is dyed with reactive dyes. Unfortunately, dyes are unfavorable from an ecological point of view, because the effluents generated are heavily colored, contain high concentrations of salts, and exhibit high biological oxygen demand/chemical oxygen demand (BOD/COD) values. In dyeing textiles, there is a need of following strict ecological standards throughout processing from raw material selection to the final product.

Previous studies on HTF (Zinabu Gebremariam and Zerihun Desta, 2002; Zerihun Desta, 2003; Zinabu Gebremariam and Pearce, 2003; Birenesh Abay, 2007; Behailu Berehanu, et al, 2010) indicate that waste water from the factory is treated both chemically (using sulphuric acid to neutralization in the system located within the compound of the factory) and biologically in a lagoons/oxidation ponds (located outside the factory compound) before the effluent is discharged into the surrounding. However, an investigation by Lijalem (2011) and our current visit to the factory revealed that the chemical treatment plant is non-functional. The study by Zinabu Gebremariam and Zerihun Desta (2002) has clearly shown that the biological treatment method is inefficient in that it does not remove the chemicals but rather concentrates the content of the "treated" effluent before it is discharged. According to their findings the concentrations of about 70% of the elements in the "treated effluent" were up to 10 to 100 times higher than in the raw effluent. In general, the effluent released from HTF after treatment and reaching Tikur Wuha River contains large nutrient load and heavy metals that can bring about harmful environmental impacts on the lake (see Sections 1.2.3. and

2.1.1.1. and 2.2. of Chapters 1 and 2, respectively). In order to preclude the deterioration and contamination of the lake and its biota from textile discharges and to contain the effluent at HTF, the RT recommends prevention and control measures (EIA-follow up, minimize chemical use, and minimize solid and liquid wastes) and, remediation measures as in section 3.1.1 and 3.1.2. as cost effective mitigation measures. In this regard the Environmental Management System (EMS) of Kombolcha Textile Share Company (KTSC) can be taken as bench mark for best practice (http://www.ethiomarket.com/KTSC/).

Fig 3.5. Biological lagoon outside the HTF: The effluent from the factory reaches the lagoon through underground channel by crossing the village. Note how damaged the ponds are. (Photo by RT)

3.5.1.2. Moha Hawassa Soft Drinks Factory (MHSDF) and BGI Hawassa Brewery Factory (BGIHBF)

As it has been described in Chapter 2, the MHSDF has no biological treatment system. The chemically treated effluent from the factory goes through underground tunnel (for only some distance from the factory) then flows through an open ditch around a residential area of a nearby rural community. According to our observations, the effluent from the factory is channeled through PVC pipes buried under the earth and is released into an open concrete ditch (see Fig. 3.1). There are two ponds right where the effluent is released into the open ditch from the PVC pipes. The ponds were presumably constructed to serve as storage ponds. But they were too small to hold the large volume of the effluent even for a few hours (according to local informants) and are not used at the moment. Instead, an alternative a concrete ditch that leads into the open has been constructed

As described in, Chapter 2, the effluent from BGI is released into the wetland through an open muddy channel (see Fig. 3.1). The effluent, in a large volume, flows fast with a lot of pressure, indicating that the slope has been properly drained to allow all the effluent to end up in the wetland. The effluent from BGI joins/mixes with the one from Moha and flows down to the Boeitch stream along the edge of the wetland and everything ends up in the River Tikur Wuha, and then eventually into lake. The RT recommends prevention and control measures (EIA-follow up, minimize chemical use and minimize solid and liquid wastes) and, remediation measures as in section 3.1.1 and 3.1.2. as cost effective mitigation measures at MHSDF and BGIHBF.

Fig.3.1. Concrete ditch (A) that takes the effluent from MHSDF into an open ditch that is directly discharged at the edge of the wetland (B) and flows down to the Boga stream. The effluent from BGIH-BF that flows to the edge of the wetland (C) confluents with the one from Moha and flows down to the Boeitch stream along the edge of the wetland (D). (Photo RT)

3.5.1.3. Tabor Ceramics Factory (TCF)

The factory is not located in the industrial zone designated by the city administration and according to the neighboring community, the effluent from TCF is discharged in a park (forested area) right at the North Eastern side of the lake (along the Shashamenne-Hawassa road side) that ends up to the lake. Behailu Berehanu, et al. (2010) indicated that the effluent was monitored once or twice by EEPA. However, the factory has no regular environmental audit system and no officially documented reports concerning compliance to environmental laws and principles of EEPA.

The RT recommends prevention and control measures (EIA-follow up, minimize chemical use and minimize solid and liquid wastes) and, remediation measures as in section 3.1.1 and 3.1.2. as cost effective mitigation measures at TCF.

3.5.1.4. ETAB- Soap Factory (ETAB-SF)

The overall liquid waste generated by the factory is collected in the septic tank and disposed by the city municipality services. The byproducts from the factory after the production process are re-used as source of energy for the boiler. The RT recommends prevention and control measures (EIA-follow up, minimize chemical use and minimize solid and liquid wastes) as in section 3.1.2. as cost effective mitigation measures at ETAB-SF.

3.5.1.5. Hawassa University Referral Hospital (HURH)

The effluent from HURH is carried to the oxidation pond right at the edge of the lake and part of the effluent escapes into the lake during the rainy season. Although the HURH has a set of oxidation ponds, they are not properly functioning and studies have shown that the treatment is inefficient. It requires renovation and strict follow- up to ensure that the pond is performing the intended purpose. Furthermore, modification of design of the ponds to produce treated effluents suitable for disposal into the environment is required (Simachew Direse, 2008). The RT recommends prevention and control measures (EIA-follow up, minimize chemical use and minimize solid and liquid wastes) and, remediation measures as indicated in 3.1.1 and 3.1.2. as cost effective mitigation measures at HURH.

Fig. 3.2. Hawassa University Hospital and its Oxidation ponds (Photo by RT). Note that the Hospital and the ponds are at very close proximity to the lake.

3.5.2. RCMM at non-point sources

3.5.2.1. Households, hotels, health centers and other public service rendering institutions

In many cases, municipal wastes are not well managed in Hawassa, as the city municipality cannot cope with the accelerated pace of waste production. Waste collection systems are inefficient and waste is often disposed of through uncontrolled landfilling and is processed through unsafe and informal recycling. Municipal wastes from urban settings are therefore, one of the non-point sources of pollution. The RT recommends Integrated Solid Waste Management (ISWM) and Reduce, Reuse and Recycle (3Rs) as in section 3.2.1. as cost effective mitigation measures at the house-holds and public service rendering institutions.

3.5.2.2. Agricultural fields

Agricultural fields are also one of the main non-point sources that may release agrochemicals (pesticides and fertilizers) sequestrated in the soil and reach the lake by runoff. Some banned pesticides grouped under persistent organic pollutants (POPs) are also used in the area (Ermias Deribe, 2013b). The RT recommends ABMPs as in section 3.2.2. as cost effective mitigation measures at agricultural fields.

3.5.3. RCMM at specific routes

3.5.3.1. Industrial effluent route

Our observations on the route of the discharge from the HTF, MHSDF, and BGI-BF revealed that “Boeitcha” stream (Cheffe Kotti Jebessa) is the main course for downstream pollution of the lake. It has for long been taken for granted that effluents from the factories are finally discharged into the open wetland. Therefore, it was anticipated that the effluent would have been naturally purified by the time it reaches Tikur Wuha River. Our present observations and the information from the community have unequivocally shown that the effluent from the factories intercepts the wetland only at the edge and joins the stream flowing through “Boeitcha” stream towards Tikur Wuha River that ends up in Lake Hawassa. The gravity of the pollution problem is therefore much higher than it could have been if the effluent had been discharged into the wetland. “Boeitcha” stream is therefore the main route that needs mitigation measures. The RT recommends wetland vegetation using vetiver system as cost effective mitigation measures as in section 3.3.1. along the catchment of “Boeitcha” stream, diverting the effluents as in section 3.3.4 and digging ditch as in section 3.3.5.

Fig 3.3. "Boeitcha'' stream: The main course to Tikur Wuha River and the main route for downstream pollution of Lake Hawassa (Photo by RT)

3.5.3.2. Drainage canal/surface storm

The drainage canals and the storm water directed to Lake Hawassa pile up trash materials on the lake shore. This will impair the function of treatment ponds constructed by the Hawassa Municipality and eventually will have a negative impact on the lake ecosystem. The RT recommends construction of filtering racks (see Fig.3.4.) and cover vegetation for reducing flow of storm water as indicated in 3.3.2 and 3.3.3 cost effective mitigation measure.

Fig. 3.4. Filtering racks (municipal waste trash trap) constructed along the drainage canal holds trash/solid wastes and helps to retain the trash and silt before reaching the hot inlet spots which also decreases the burden on storm water treatment ponds under construction along the lake shoreline by Hawassa Municipality (Photo by RT)

3.5.4. RCMM at specific inlet spots

3.5.4.1. Tikur Wuha Site

A study conducted by Zinabu Gebremariam and Pearce (2003) revealed that the Tikur Wuha River, which is a receiver of the effluent from point sources (factories) and that flows into Lake Hawassa, contains toxic metals like Cu, Cr, Ni, Pb, Cd, and Zn among others. Therefore, the high concentrations of Cu, Cr and Ni detected in the lake and the metals in Tikur Wuha were assumed to be due to downstream pollution from point sources. Moreover, Tikur Wuha and the associated wetland have suffered from degradation due to adverse human activities. The macrophyte vegetation has been greatly reduced. As a result, the capacity of the wetland to hold back storm water, remove pollutants and slow down erosive forces has reduced through time. Restoration of the wetland to its approximate status prior to degradation is critical. Enhancement of the wetland by introducing non- invasive or non-competitive grass species to increase its function of sediment trapping and bio- filtering toxic substances should be undertaken. In this regard the RT recommends biological remediation - specifically phytoremediation as in 3.4.1. using the plant - *Chysopogon zizanioides* - Vetiver Grass as a bio filter along the Tikur Wuha River and restoration and enhancement of the associated wetland by establishing a buffer zone: a strip of natural vegetation as in 3.4.3.

Fig. 3.5. Tikur Wuha River: Influent from the ''Boeitcha'' stream and municipal waste from both sides of the road are drained into Tikur Wuha River and end-up at Lake Hawassa (Photo by RT).

3.5.4.2. Amora Gedel Site

Amora Gedel is an important inlet and hot spot for urban waste. It receives waste water loaded with toxic substances and pathogens through drainage canals and surface storm water. Storm water treatment or sedimentation pond is on construction by the Hawassa city administration just near the shore at the Amora Gedel ("fish market"). The effectiveness of the pond will largely depend on measures that should be taken at the source and the route. In this regard the RT recommends: storm water management (SWM) as indicated in 3.4.2., biological remediation - specifically phytoremediation as in 3.4.1. using the plant - *Chysopogon zizanioides* - Vetiver Grass as a bio filter around Amora Gedel, and establishing a buffer zone as indicated in 3.4.3.

3.5.4.3. Referral Hospital Site

The Referral Hospital site is located very near to the HURH, a potential source of medical wastes including toxic substances and pathogens. The site is both source and hot inlet spot that poses a threat to Lake Hawassa. Moreover, this the site receives storm water loaded with urban waste and silt entering the South Western side of the lake. Therefore, considering these problems, the RT recommends SWM, construction of wetlands (with dense Vetiver) and establishment of buffer zone as indicated in, 3.2.1, 3.3.1 and 3.4.3, respectively. The Research Team has also observed that shore line agriculture is practiced in the narrow strip of land that occurs between the oxidation pond and the macrophyte at the littoral zone of Lake Hawassa. It is this narrow strip of land that should be used for constructing wetland.

3.5.4.4. Green Wood – Unique Park Site

This is an inlet for storm water coming from North Western side of the Hawassa city. The storm water is intercepted by the dyke constructed on the Eastern shoreline of Lake Hawassa. It has formed artificial wetland consisting of a band of dense macrophyte belt that reduces storm water, trap sediment and solid wastes. This vegetation has to be protected and established as biological mitigation measure.

Fig. 3.6. A band of dense macrophyte belt along the shoreline of Lake Hawassa forming "Artificial wetland" behind the dyke at Green Wood and Unique Park sites. (Photo by RT)

3.5.5. RCMM along the shoreline

As indicated earlier (section 3.4.) a lot of activities are taking place along the shoreline of Lake Hawassa (see Figs. 3.7. & 3.8.) For instance Loke – Bete Mangiest site is a site for intensive shoreline agriculture and a possible cause of pollution from agrochemicals. The RT recommends the establishment buffer zone for RCMM as indicated in 3.4.3.

Fig. 3.7. Pictures showing Intensive Shoreline Agriculture at Loke-Bete Mengiest site.

Fig. 3.8. Shoreline activities along the SW part of Lake Hawassa: Intensive shoreline agriculture and mining activities around the shoreline (Photo by RT)

The RT proposes establishment of buffer zone as in section 3.4.3. along shoreline of the lake. In this regard, the buffer zone proclamation by the Hawassa City Council (in process) and its implementation is a long lasting solution to reduce the concentration of toxic substances entering Lake Hawassa.

Finally, several mitigation measures to reduce the concentration and inflow of pollutants reaching Lake Hawassa have been identified in this study. The recommended cost effective mitigation measures at the different target sites of the lake are summarized in Table 3.3.

Table 3.3. Summary of recommended cost effective mitigation measures at the different target sites

	Main site	**Specific target sites**	**RCMM**
1	Point sources	HTF,MHSDF, BGIHBF, and TCF	1. EIA-follow up 2. Minimize chemical use 3. minimize liquid and solid wastes and 4. contained the effluent in the long run
		ETAB-SF	1. EIA-follow up 2. Minimize chemical use 3. minimize liquid and solid wastes
		HURH and the Oxidation pond at Hawassa University Main Campus	1. Regular monitoring 2. minimize liquid and solid wastes and 3. contained the waste in the oxidation pond in the long run
2	Non-point sources	State farm and Shoreline farms	• a buffer zone with a strip of natural vegetation along shoreline
		Municipal (households, hotels, garages	• a buffer zone with a strip of natural vegetation along shoreline
3	Routes	"Boeitcha" stream	• vetiver wetland along the catchment of the stream
4	Hot inlet Spots	Tikur Wuha R	• Phytoremediation

CHAPTER 4

4. INTERVENTION STRATEGIES

This chapter deals with the three important and interrelated intervention strategies: 1) Institutional Arrangements 2) Legal framework, and 3) Social arrangements. These strategies are critically needed for the realization of the proposed cost effective mitigation measures to reduce the inflow of wastes to Lake Hawassa and bring down concentrations of pollutants that enter the lake. The strategies are approached according to the conceptual framework represented by Figs. 4.1 & 4.2 with a view to point out constraints or shortcomings and show mitigation or corrective measures that are needed for effective and efficient environmental pollution control.

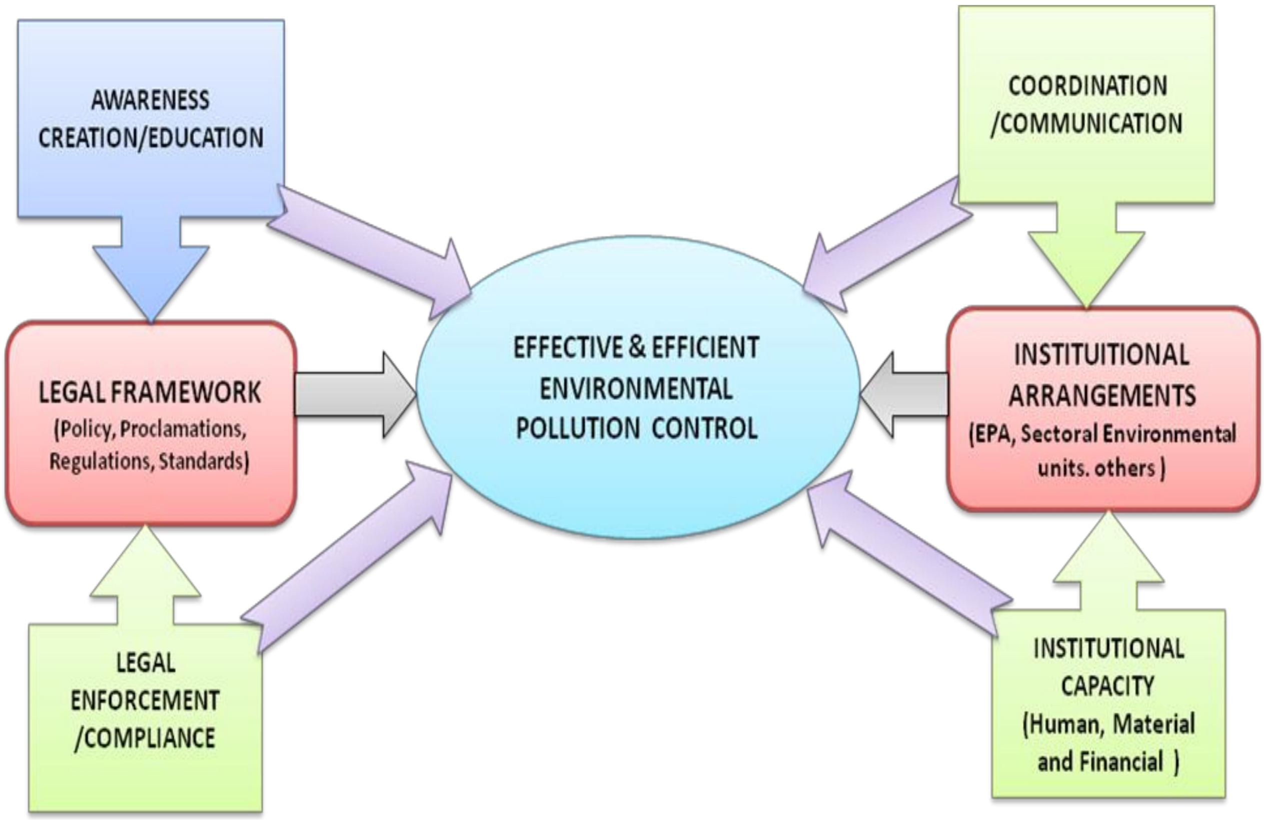

Fig. 4.1 Conceptual framework: Institutional arrangements & Legal frameworks for Effective & efficient environmental pollution control

As indicated in the conceptual framework (Fig 4.1.) effective and efficient environmental pollution control requires legal frameworks and institutional arrangements. However, the mere existence of these frameworks or arrangements is not sufficient for pollution control. The environmental pollution control, among others, specifically requires: 1) Institutional capacity 2) Institutional coordination and communication 3) Environmental awareness or

Education program, and 4) Legal Enforcement/ Compliance. These essential components are briefly assessed under institutional arrangements and legal frameworks.

4.1. Institutional Arrangements

The Environmental institutions or environmental organs of focus for this study include, the environmental protection agency of SNNPRS and its sectoral environmental units as well as the Hawassa city council with respect to their responsibilities and activities in protecting Lake Hawassa from anthropogenic sources of pollution. Their efficiency and effectiveness has been assessed in terms of institutional capacity, and coordination and communication capabilities.

4.1.1. Institutional capacities

The pollution threat on Lake Hawassa is huge, multifaceted and complex (see chapters I & II of this report) that requires multidisciplinary and integrated approaches to bring about meaningful interventions. This in turn demands strong institutional capacity with adequate number of qualified staff with proper professional mix, as well equitable financial and material support. In this respect, the Regional Environmental Protection Agency (REPA) that should play the leading and regulatory role in the control of environmental pollution suffers from all the aforementioned constraints. These limitations do not allow the agency to establish, coordinate and follow up the environmental units or waste management systems as expected in the Federal Environmental Pollution Control Proclamation and the Prevention and Control Regulations of the Industrial Pollution.

The agency, the environmental units, and the waste management systems in place as per the proclamations and regulations are briefly evaluated hereunder.

4.1.1.1. Sectoral environmental units

Article 14 of the Federal Proclamation No. 292/2002 requires of all government organs to establish environmental units to coordinate and follow-up sectoral activities to prevent pollution and comply with environmental laws. However, sectoral environmental units are either absent or weak in their capacity of implementing environmental laws. The support and follow-up of these sectoral units by the environmental protection agency is not to the level indicated in the proclamations and regulations. **It is essential that the regional environmental protection agency and the sectoral environmental units create a common forum for integrated action and effective implementation of pollution control**

proclamations and regulation. These sectoral environmental units that should come to a common forum to control pollution are those under the regional bureau of Agriculture & Rural Development, Bureau of Water Resource, and Bureau of Health.

4.1.1.2. Integrated waste management system in urban public administration

Management of municipal waste is key to pollution control. It is so important that the environmental agency of the SNNPRS should closely work with Hawassa city council and municipality to ensure the collection, transportation and, as appropriate, the recycling , treatment or safe disposal of solid waste and discharge of waste water towards Lake Hawassa. The establishment of Environmental protection unit under the city council is an exemplary measure for effective and efficient environmental pollution control and systematic approach to mobilize the community (public) at large using sub- cities and kebeles as grass root partners. However, the city council has to exert strong efforts to implement integrated waste management in proportion to the expansion of the city and huge amount of waste generated from different sources. It has to work towards “Zero” waste disposal strategy by introducing Bioprocess or converter technology where a by-product or organic waste of one system can be used as input for another system with the release of Biofertilizer and Bioenergy (Fig.4.2.)

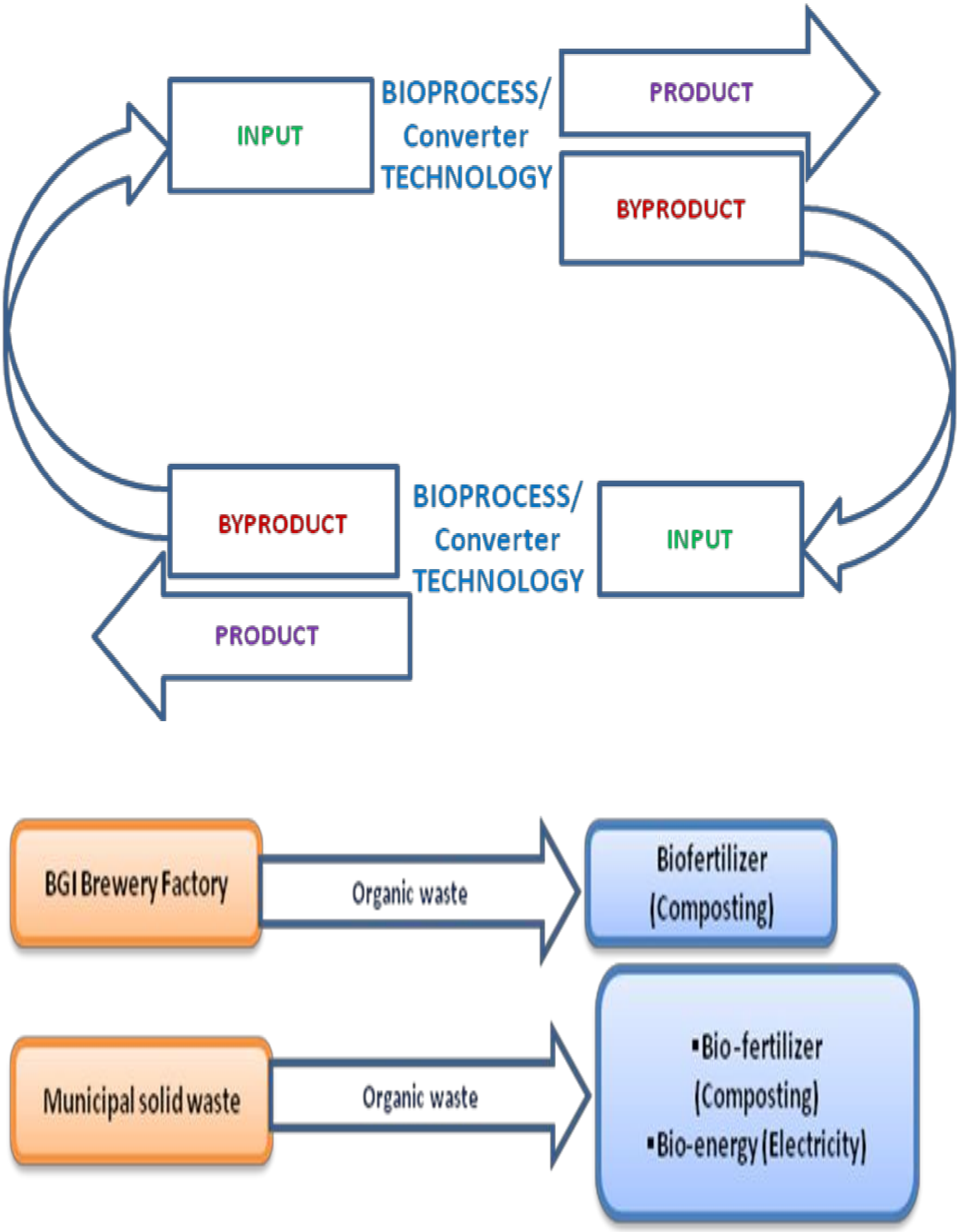

Fig. 4.2. Proposed Strategy towards Zero waste disposal

The zero waste disposal strategy is a necessity rather than a choice because environmental pressures and costs in incineration or land filling makes removal or disposal a difficult task in rapidly growing and urbanized cities like Hawassa. Moreover, using waste not only reduces cost but generates income and creates job opportunity.

4.1.1.3. Environmental management system (EMS) in industries

Article 9 of the National regulation No. 159/2008 for prevention of industrial pollution demands that every factory in compliance with the regulation should prepare and implement its own internal environmental monitoring system. Moreover, every existing factory should undertake environmental audit, and prepare and implement an environmental management plan. Such a plan is crucial as it is in–house pollution management system to minimize the release of pollutants or hazardous wastes to the environment. In this regard, the experience of **Ethiopian Tannery Share Company – ETSC (Mojo)** can be taken as a lesson for all factories in Hawassa (http**://www.pittards.com/news-page/34/Ethiopia**).

4.1.2. Institutional coordination and communication

The Ethiopian Environmental Protection Authority (EEPA) is a leading and regulatory organ for environmental pollution control. In addition to EEPA, relevant sectoral institutions such as ministry of water resources (MOWR), Ministry of Health (MOH), Ministry of Justice (MOJ), and Urban administrations (City council, Sub-cities and Kebeles) are directly and indirectly involved in the implementation of proclamations and regulations of environmental protection and pollution control. Institutional coordination and collaboration between EPA and the aforementioned sectoral units as well as inter – sectoral linkages and partnership are vital for efficient and effective pollution control. The coordination and linkage among these institutions play key role for integrated action, reducing cost, eliminating risk of gaps and duplication of efforts. Collaboration and partnership pave the way to build comparative advantages of each partner and ensure synergistic benefits to be achieved more than any of the actors working alone. The collaboration and partnership should involve stakeholders including NGOs, CBOs, Civic Societies and concerned groups working on environmental protection. This helps to synchronize and consolidate capacity, and permit direct and active participation of the public at large. The stronger the coordination, communication and partnership, the greater is the effectiveness of compliance with and enforcement of the pollution control system. However, all these essential elements are not developed and structured in the way they can foster effective implementation of the pollution control legislation. Thus it is so important that, the regional environmental protection agency should give priority and work hard to create a joint forum of the sectoral environmental units. The agency has to establish strong functional linkage and interactive regular communication among the environmental units working for the same goal. The Regional Environmental protection agency should also initiate the establishment of a consortium of NGOs, CBOs and Civic societies working on environmental protection and pollution control.

4.2. Legal Frameworks

The Ethiopian government has produced environmental policy and declared different proclamations that adequately state the power, duties and responsibilities of regulatory institutions for environmental pollution control. Regulations and penalties with regard to pollution discharge of hazardous wastes and toxic substance to air, soil and water as well as environmental protection and environmental impact assessment are clearly indicated in the proclamations. The major declarations that exist include:

- The 1997 Environmental policy
- Water Resource Management Proclamation (Proclamation No. 197/2000)
- Public Health Proclamation (Proclamation No.200/2000)
- The Environnemental Protection Organes Establishment Proclamation (proclamation No. 295/2002)
- The Environnemental Pollution Control Proclamation (Proclamation No. 300/2002)
- Solid waste management proclamation (Proclamation No. 513/2007)
- Industrial Pollution Regulation (Regulation No. 300/2002)
- The Environnemental Impact Assessment Proclamation (Proclamation No. 299/2002).

Although the aforementioned proclamations are declared and instituted, their implementation suffers from two directions: Lack of public awareness and little or no enforcement /compliance. In the following section, we will briefly discuss these two constraints and the intervention measures required for efficient and effective pollution control.

4.2.1. Environmental awareness or education program

In addition to institutional capacity and coordination, it is essential that all stakeholders involved in environmental protection and pollution control activities acquire full and equal understanding of the Ethiopian environmental policy proclamations and regulations declared for the control of pollution and discharge of hazardous wastes. There is still a lot of misunderstanding at different levels with regard to environmental issues. For instance, there is a lack of awareness and widespread misconceptions about EIA in Ethiopia; some even consider EIA as an obstacle to development activities. Moreover, there is little or no public awareness & participation in EIA processes.

Besides inadequate guidelines, people seldom receive enough information regarding the guidelines that have been developed for implementation. There is no sufficient information flowing within, between and among government and non-government organizations working on environment. Therefore, there is a pressing need for the establishment of environmental information system and data base as well as dissemination mechanisms to the public at large. This in turn demands creating environmental awareness and education program with multi-media approach and various tools of communication as illustrated in Fig. 4.3. The Environmental awareness and education program should be continuous and needs to adequately involve the different environmental actors. It should promote the empowerment of the community to assist the development of knowledge, skills, values and commitment necessary for successful integrated pollution and waste management. The following figure summarizes the different tools or channels for creating awareness and provides specific examples on how to reach decision makers and the public at large.

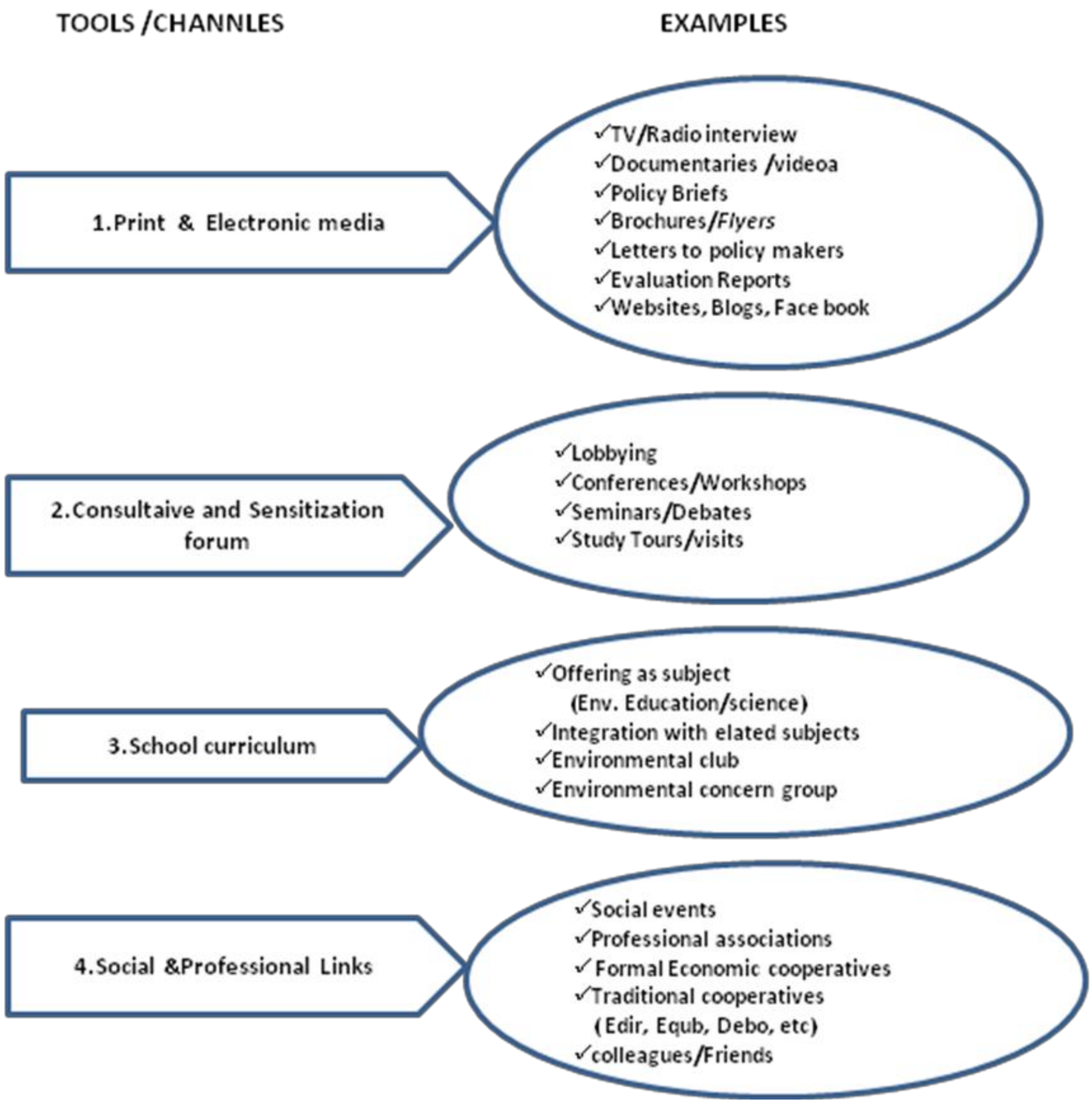

Fig. 4.3. Communication tools for creating awareness among policy makers and the public at large.

4.2.2. Legal enforcement/ compliance

Proclamations and regulations of environmental protection and pollution control clearly state that discharging pollutants or hazardous material to the environment is a punishable criminal act. If the polluter happens to be a juridical person, the liability further escalates. Likewise, when there is a reason to believe that the continuation of the operation of a particular factory may entail serious pollution, the environmental protection organs can take strong measures that include closing down or transfer of a factory to another site. The licensing sectoral governmental bureaus can also suspend or cancel licenses. However, let alone to take such strong legal measures, less severe actions that can serve as warning signals to the offender and lesson for others are not reported or even known by the public. Thus, there is a critical problem of popularizing, reinforcing and compliance with the laws at grass root level and the public at large.

It is known that some of the existing factories in Hawassa , such as the textile and ceramic factories, are established before the present legislation on industrial pollution (Proclamation No. 300/ 2002) and its implementation law (Regulation No. 159/ 2008) were decreed. However, the five years grace period given to them is already overdue and compliance to both the proclamation and regulation should be mandatory. These industries besides establishing EMS need to adopt Best Available Technology Options to reduce the release of hazardous substances, use recycling, and demonstrate compliance with the minimum requirements. The regional environmental agency and licensing government organs should also make sure that this is already in place.

4.3. Social Arrangements for Pollution Control

4.3.1. Organizing environmental concern group

Environmental Pollution Control Proclamation No.300/2002 clearly states that protecting the environment, safeguarding human health, maintenance of the biota and the aesthetic value of nature are the duties and responsibilities of all citizens. The proclamation prohibits every action of a citizen that eventually pollutes the environment and demands of the citizens to serve as environmental watch dog when and where any other person is to pollute the environment by violating the relevant environmental standard. This mission is better performed if dedicated and committed citizens come together and form an environmental group. It is in view of the aforementioned rationale that an Environmental Group, hereafter named the Hawassa Environmental Concern Group (HECG) needs to be organized.

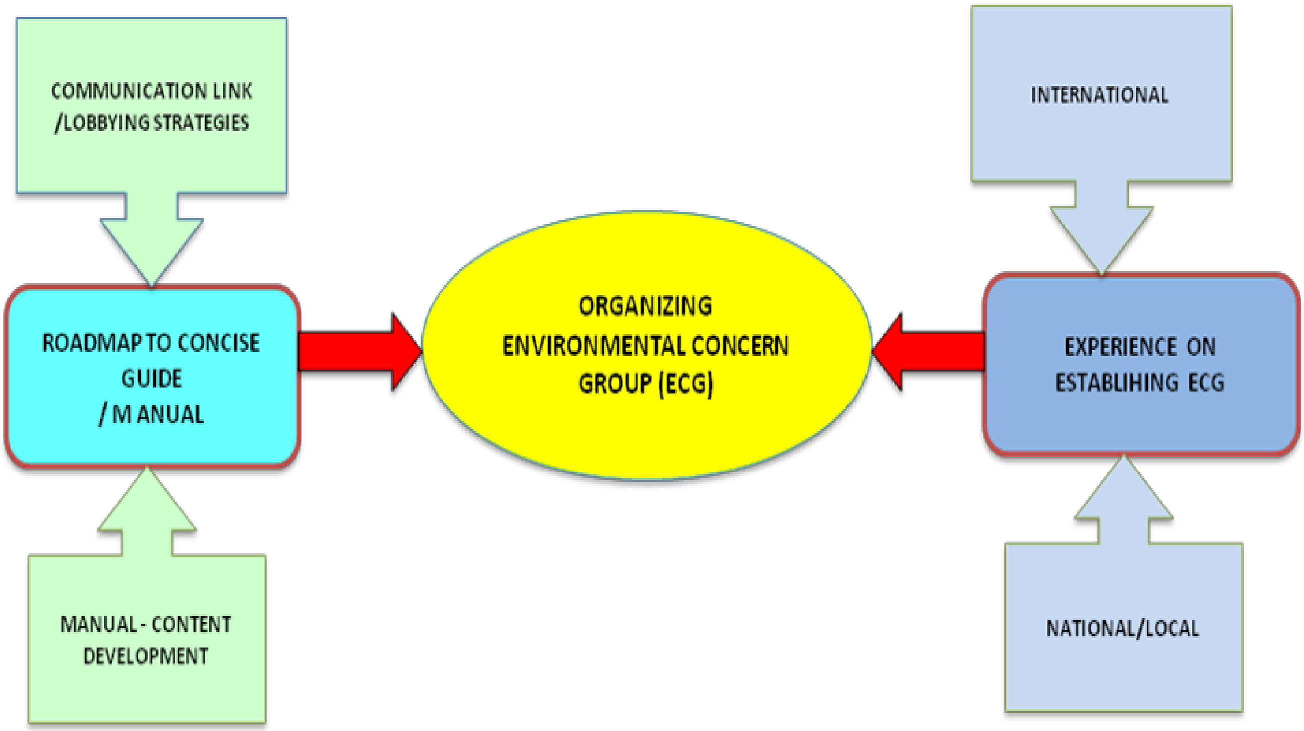

Fig. 4.4. Conceptual Framework towards organizing Environmental Concern Group (ECG)

As shown in Fig. 4.4., the establishment of ECG requires consolidating international and national/local experience. The ECG also needs a guide/manual that shows the structure, composition, duties and responsibilities as well as activities, communication link and lobbying strategy to involve decision/policy makers and the public at large. Such integrated, multidisciplinary and participatory approach that involves different stakeholders and the community at the grass root level will ensure environmental protection and pollution control on a sustainable basis.

4.3.2. Experience on organizing ECG

4.3.2.1 International experience: Toronto environmental alliance (TEA)

The Toronto Environmental Alliance (TEA) is a "not- for – profit" organization that advocates on behalf of all Torontonians for a green, healthy and equitable Toronto city. The alliance has a history of more than 25 years with a membership base of over 37,000 volunteers. TEA gets unrestricted public donation from members and supporters that allow it to promote a greener Toronto, spend time talking to city administrators, lobby policy makers and engage residents in public policy debate and the implementation of pollution prevention and waste management.

4.3.2.2 National /local experience : Forum for Environment (FfE)

The Forum for Environment is a platform for communication among people concerned with the Ethiopian environment. It was established in June 1997 by a small group of people committed to the preservation and betterment of the environment. The Forum for Environment is open to anyone involved in environment-related activities in Ethiopia. Adherents come from government departments, university departments, research community, community-based organizations, non-governmental organisations, the media, the donor community, international agencies and the business sector, without distinction of occupation or nationality.

The Forum for Environment is committed to:

- organize public meetings to publicize and discuss issues of environmental concern;
- publish a magazine, written primarily in Amharic, designed to discuss and reflect on environmental issues in Ethiopia and to be distributed throughout the country;
- carry out speaking engagements on environment at different institutions and organizations;
- facilitate access to advisory services on the environment;
- create an information center;
- act as a liaison bureau for funding projects that focus on improving or protecting the environment.

4.3.3. Roadmap to concise guide /manual for ECG

4.3.3.1. Frame work and content

In this section of the report the Research Team intends to provide only a skeleton of the will be guide/manual as the development of the guide itself is beyond the scope of our assignment. Such an undertaking requires the proper professional mix and adequate time of its own. In light of this understanding the general framework/structure/ and content of the concise guide is outlined as follows:

A) Preface – This is the preamble /prologue which shortly states the rational and significance of handling environmental issues by environmental concerned group /activists with particular emphasis on its neutrality to politics.

B) Nomenclature : Name , Logo

C) Mission and core values of the ECG

D) Structure, composition , and mode of operation of the group
E) Roles and responsibilities of the members of the ECG
F) Focus areas of concern, approaches and processes of environmental campaigns
G) Possible mechanisms to attract members and build collaborative team
H) Lobbying and Effective communication with policy makers/facilitators and the public– winning the passion
I) Fund raising and accountability

4.3.3.2. Some useful hints in content development

A) Organizational structure

The ECG will have a steering group coordinated by a secretariat. SOS – Sahel Ethiopia can serve as the secretariat (at least for the first few years), and act as the official intermediary for the ECG. The steering group should comprise representatives of members indicated in table 4.1. The ECG will be recognized and supported by the Regional EPA.

B) Composition, role & responsibilities of ECG

The ECG can be composed of the following team members with descriptions of their profiles, major roles and responsibilities summarized in the following table (Table 4.1)

No.	Members /working group	Description	Roles and responsibilities
1.	**Lobbyists/ Mavens**	high profile volunteers that are popular, influential well respected and recognized by policy/decision makers	Take advantage of their recognition and trust to convince decision /policy makers for enforcement and compliance with environmental laws and activities
2.	**Intermediaries /connectors**	are individuals with close access to higher authorities, decision /policy makers. They can be counsellors, influential and close friends of higher officials.	Approach and convince authorities, Create short and quick access/ link (appointment), simplify the work of lobbyists
3.	**Community mobilizers**	are environmental activists with special talent /art (They can be singers, writers, composers, … etc.)	sensitize and mobilize the community to prevent or control environmental pollution
4.	Researchers	Professionals/academicians that give volunteer	Conduct research, monitoring,

	/Educators	service in their area of expertise	assessment, development of materials and training
5.	GOs & NGOs	Regional Environmental Protection Agency, Environmental units of sectoral institutions Hawassa City Municipality and Environmental protection agency, Donor community and NGOs working to protect Lake Hawassa	Popularize and reinforce proclamations and regulations on pollution; mobilize and involve to the community in the design and implementation of environmental project.

C) Mission and activities of the ECG

The Hawassa Environmental Concern Group (HECG) as an alliance of volunteers or friends of Lake Hawassa will have the following vision.

Mission: Sustain a healthy environment by circumventing the threat of pollution on the ecological integrity of Lake Hawassa and the associated risk to the livelihood of the community.

HECG promotes pollution prevention and works with concerned individuals, community groups, professionals, researchers, and other workers and encourages the participation of the public at large on environmental issues. The group focuses on the following five areas (but not limited to them) where it can take research, education and/ or actions or mitigation measures:

- ✓ Public awareness/Education and community participation for integrated pollution and waste management.
- ✓ Enforcement and compliance to environmental laws, regulations and guidelines
- ✓ Promotion of cleaner Technology, recycling or recovery /reuse of waste.
- ✓ Source – based control of generation and discharge of waste
- ✓ Management of waste receiving environment (Impact management)

D) **Lobbying decision/policy makers**

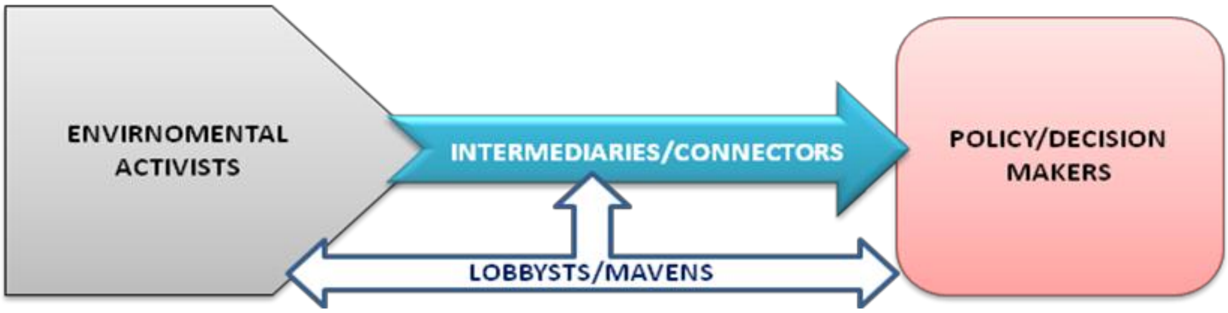

Fig. 4.5. Communication link with policy/decision makers

Lobbying/ Communicating with policy/decision makers requires

- ✓ To know the key policy/decision makers, their background and trigger points
- ✓ To Align the interest of the ECG with the interests of policy/decision makers
- ✓ To present the case without being critical of other personalities or motives. Explain why support is in the best interest of the decision makers but do not over sale your case.
- ✓ Lobbying should be exchange of information. Be prepared to give the policy/decision makers information he/she can use, but make sure that information contains evidences to substantiate your arguments.
- ✓ To simplify data and arguments to a level that can be easily grasped by all decision makers and stakeholders involved.
- ✓ To know that policy makers are always impressed by professional behaviour. A little professionalism goes a long way.
- ✓ Build coalitions and look for allies within or out of the organization, groups who can influence the decision makers. Use their testimony to reinforce your message (build trust)

4.3.3.3. Where to start

Given that the culture of neutral activism is not developed in the Ethiopian taste, it is very important to find a very appropriate point of departure in establishing the ECG - lest it be hijacked by unintended groups. The RT believes that the following process can be a very ideal departure point:

I. Plan a workshop where the findings of this study can be presented to all stakeholders, including high level representatives from government offices, the CEOs of the factories, NGOs, influential personalities, the academia, the media, etc.

II. Present the existing scenario with respect to pollution in Lake Hawassa

III. Show the clear picture of the danger ahead and the possible intervention mechanisms

IV. Establish the importance of participation of the public in the intervention and the need for organized move – hence the ECG

V. Show how a starter of such an organized group can be initiated with few members – a starter ECG

VI. Obtain the support of the government representatives and the CEOs of factories (the CEOs can be motivated to collaborate in further studies which will make information on pollutants available to build a data base).

VII. Some members of the ECG can join the team that will prepare the guide/manual, structure of the ECG, etc.,

4.4. Recommended Intervention Strategies

After critical assessment of the institutional arrangement, legal framework and social arrangements at regional level that are critical for the protection of Lake Hawassa from pollution, the RT recommends the following intervention strategies:

- The threat of pollution on Lake Hawassa is huge, multifaceted and complex. The pollution control requires a multidisciplinary and integrated approach. In this regard the Regional Environmental Protection Agency should have strong institutional capacity, i.e., adequate number of qualified staff with proper professional mix, as well as equitable financial and material support, if it is to play its leading and regulatory role as expected in the proclamation and regulation for the prevention and control of environmental pollution.

- Effective and efficient implementation of the Proclamations and Regulations for the prevention and control of pollution cannot be granted by the Regional EPA alone. The agency should give priority and work hard to create a joint forum or venture with sectoral environmental units. It has to establish strong functional linkage and interactive regular communication among the environmental units working for the same goal.
- The relevant sectoral institutions such as ministry of water resources (MOWR), Ministry of Health (MOH), Ministry of Justice (MOJ), and Urban administrations (city council, sub-cities and kebeles) are working in an isolated manner at the moment. They should collaborate and work together to build comparative advantages for each partner and ensure synergistic benefits to be achieved more than any of the actors working alone.
- The Regional EPA should also initiate the establishment of a consortium of NGOs, CBOs and Civic societies working on environmental protection and pollution control. This not only avoids duplication of efforts but solves the human, material resources, and financial deficit of the agency.
- Several proclamations of pollution control are declared and instituted both at federal and regional level. However, their implementation suffers from lack of public awareness and little or no enforcement/compliance. There must be strong and continuous environmental awareness and education program to adequately involve the different environmental actors and promote the empowerment of the community to participate in prevention and control of pollution.
- Prevention and control of environmental pollution, safeguarding human health, maintenance of the biota and the aesthetic value of nature are the duties and responsibilities of all citizens. This mission is better performed if dedicated and committed citizens come together and form an environmental group. It is in view of this rationale that an Environmental Group, named the Hawassa Environmental Concern Group (HECG) needs to be organized

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