

Heavy Metal Concentrations and Physicochemical Characteristics of Effluent along the Discharge Route from Hawassa Textile Factory, Ethiopia

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Abstract

Hawassa Textile Factory discharges virtually treated effluent into the nearby receiving environment. A study was carried out to assess the physicochemical characteristics and heavy metal levels of effluent released from biological treatment lagoon of the Factory. Heavy metals concentrations in sediment and macrophyte of the nearby stream to which the textile effluent is directed was also measured. Results indicated that some physico-chemical parameters such as pH, PO₄, conductivity and TDS of the waste water from the two sampling sites were above provisional discharge limits set at national and/or international levels. The concentration of almost all detected heavy metals in samples analyzed from both sites generally followed the order: sediment > macrophytes > flowing waste water. The heavy metals levels detected in sediment samples from both sites followed the order: Mn > Zn > Cu > Cr > Pb > Cd. The mean concentrations of heavy metals in macrophytes followed the same order as in sediment while the sequence in waste water followed the order: Cu > Mn > Zn > Cr. However, Pb and Cd were below detection limit in both macrophytes and waste water samples. Even though the concentrations of heavy metals in samples analyzed were below acceptable ranges of the provisional discharge limits, their accumulation over time and the potential threat on environment health and disruption of ecological integrity was overemphasized. This study suggests quick intervention and closes monitoring to arrest and solve the growing environmental pollution and associated problems in the area.

Keywords: Effluent; Hawassa textile factory; Heavy metals; Macrophytes; Sediment

Introduction

Industrial effluents are one of the principal sources of heavy metals responsible for environmental pollution [1]. Subsequently, contamination of soils, ground water, surface water and sediments with heavy metals is one of the major environmental problems. Textile industries are major sources of these effluents [2] due to the nature of their operations which is chemical and water intensive – eventually resulting in high wastewater generation. In developing countries, untreated or partially-treated industrial wastewaters are directly discharged to the nearby wetland and /or water bodies.

Ethiopian Environmental Protection Authority [3] indicated that, most factories in Ethiopia, including textile and leather industries, have no effluent treatment plants. Hawassa Textile factory is the largest factory located near Hawassa town at close proximity to small streams which are linked to Lake Hawassa by River 'Tikur Wuha'. The factory has both chemical and biological treatment ponds with the aim of reducing organic and inorganic pollutants in the effluent to acceptable level before discharge. However, there is still reports of high concentration of toxic substance in the effluent that is discharged after passing through treatment ponds [4,5] and this poses questions to efficiency of the existing treatment system. The effluent are directed into water bodies (streams, a river and then to lake) which are used for different purposes (household use; washing cloths; bathing; domestic animals drinking; crop, fruits and vegetable production, etc.) by the rural community living in the immediate vicinity.

According to Tamburlini et al. and WHO [6,7], effluent generated from textile industries contains different contaminants, mainly heavy metals. Siyanbola et al., [8] noted that the continuous discharge of effluent and consequent increase in concentration of heavy metals in different compartments of the environment can lead to bioaccumulation

of metals in fauna and flora. Heavy metals are not biodegradable so they accumulate in primary organs in the body and over time begin to fester, leading to various symptoms of diseases. Thus, untreated or incompletely treated textile effluent can be harmful to both aquatic and terrestrial life by adversely affecting on the natural ecosystem and long term health effects. Therefore, living organisms and other components of the environment in the immediate vicinity of Hawassa textile factory are at risk of pollution treat.

This study was designed to assess the physicochemical properties and heavy metals concentrations in flowing waste water, sediment and macrophytes very near to the biological treatment lagoon of the Hawassa textile factory. Assessment of heavy metals accumulation was carried out to ascertain the degree of contamination and its implications to safety of the immediate environment.

Materials and Methods

Description of the study area

The Hawassa textile factory and the sampling sites are shown in Figure 1. The factory is located at the eastern edge of Hawassa city, 275 km South of Addis Ababa along the international road to Kenya. The

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study area is characterized as sub-humid climate and has extended period of wet season from March to October, in addition to the main rainy season taking place from July to September. The maximum amount of mean annual rainfall goes up to 1150 mm. The study area has mean annual temperature of 19.5°C, with March and April having the highest and November and December having the lowest temperature [9].

As shown in Figure 2, there are two sampling sites, designated as Site 1 (S1) and Site 2 (S2). Site 1 is located about 500m far from the Biological Lagoons at the point where the Wastewater from the Lagoon joins the nearby stream (called “Boietcha” by local resident) and Site 2 is downstream, about 1.5 km away from S1. Both sites are near local community residential area.

The Biological Treatment Ponds of the Hawassa Textile Factory are located 1.5 km away from the Factory very close to rural residential area (Figure 2). Effluent from the Factory reaches the Treatment Ponds through underground Concrete Channel. The effluent is detained in the treatment ponds for several days and then discharged out and finally reaches the nearby “Boietcha” Stream.

Effluent sampling and analysis

The 1L polyethylene sampling bottles were first cleaned by incubating with 10% nitric acid (to remove metal contaminants from the bottle) for 24 hours in a hot water bath and then washed and rinsed with distilled and de-ionized water [10,11]. These bottles were thoroughly rinsed with the wastewater at sites before sampling. Effluent samples were taken from the two sampling sites (Figure 2) in May following sample collection method of APHA [12].

A portion of each effluent-sample was used for in-situ measurement of some physicochemical parameters such as Total Dissolved Solids (TDS), Electrical Conductivity (EC), pH and temperature of the wastewater with portable Hanna Waterproof pH/TDS/EC/Temperature Meters (HI 991300). Prior to measurement, the portable field instrument was calibrated using buffers of pH (at pH 4.0, 7.0 and 10.0) and Potassium Chloride Solution for pH and Conductivity, respectively. The remaining portion of each effluent-sample was transported right away to the Chemistry Laboratory of Hawassa University to determine Nitrate (NO_3^-), Ammonia (NH_3), Phosphate (PO_4^{3-}), and Sulphate (SO_4^{2-}) concentrations using Spectrophotometer (DR. 5000, USA) according to manufacturer (HACH) instructions. Turbidity levels (Nephelometric Turbidity Units or NTU) were assessed using the HACH 2100A Turbidity Meter.

Samples for heavy metal analyses were immediately preserved with concentrated nitric acid. Subsequent to acidification, the samples were stored at 4°C in refrigerator to prevent change in volume due to evaporation. Analysis of heavy metals was carried out using Flame Atomic Absorption Spectrophotometer (FAAS) as described in the standard methods for the examination of Water and Wastewaters [12]. The Heavy Metals analyzed in the present study include Copper (Cu), Manganese (Mn), Zinc (Zn), Chromium (Cr), Lead (Pb) and Cadmium (Cd).

Sediment and macrophyte samples collection, treatment and analysis

Concurrent to effluent sample, sediment samples were first collected using Eckman Grab and put in plastic bags that were previously cleaned with detergent and treated with 10% nitric acid. The composite samples of emergent macrophytes growing on the pathway of effluent discharge were collected by hand-pick, washed with wastewater at the sampling

site, and packed in plastic bag. In the laboratory, the macrophyte samples were washed further with 5% Ethylene Diamine Tetra Acetic Acid (EDTA) solution and then rinsed with distilled water to remove the adsorbed substances. Both samples (sediment and macrophyte) were stored in a deep freezer at -10°C prior to treatment and analysis.

The sediment samples were air-dried at room temperature for one week until totally dried and grounded using mortar and pestle and then passed through a sieve with mesh size 250 µm to remove coarse materials. The Macrophytes samples were dried in hot air oven at 70°C for 48 hours cooled and grounded using mortar and pestle. Both samples (sediment and macrophyte) were put under 105°C for three hours separately to remove if there is any moisture.

Digestion of sediment and macrophyte samples was carried out based on the standard method [11]. Analysis of the samples for heavy metals was carried out using FAAS according to the standard method of [12].

Statistical analysis

Data generated in this study were analyzed using Microsoft excel spreadsheet and SPSS (version 20). Measured values of Physico-chemical parameters and heavy metals were analyzed using student t-test (independent T-test) to generate means, standard deviation and significance with alpha set at 0.05. The data are represented as mean ± standard deviation. Differences in concentration levels obtained for a given parameter along sampling sites were considered significant if calculated P-values were < 0.05. Simple correlation was applied to test the relationship between various parameters along sampling sites.

Results of the present study were compared with the available standard limits of Ethiopian Environmental Protection Agency (EEPA) and World Health Organization (WHO).

To compare the total content of metals at different sampling sites, the metal pollution index (MPI) was used. It was obtained according to the equation described in Usero et al. [13] as:

$$\text{MPI} = (\text{Cf}_1 \times \text{Cf}_2 \times \dots \times \text{Cf}_n)^{1/n} \quad (1)$$

Where: Cf_1 = concentration of the first metal, Cf_2 = concentration of the second metal, Cf_n = concentration of metal n, and n = the total number of studied metals in the sample.

To further evaluate the efficiency of metal bioaccumulation in macrophyte, the biosediment accumulation factor (BSAF) was calculated. The BSAF is defined as the ratio of the metal concentration

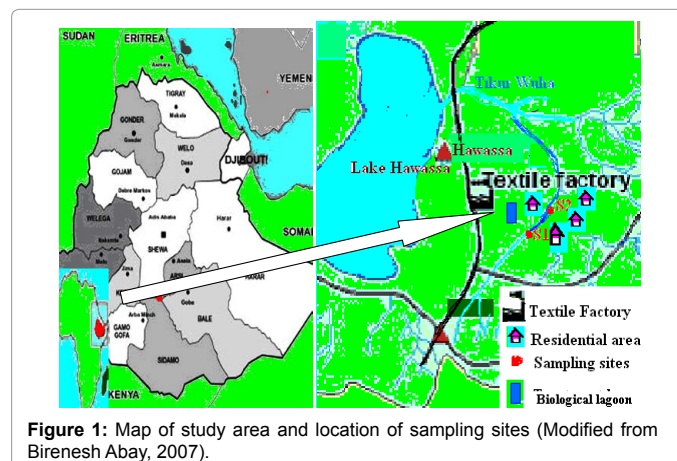


Figure 1: Map of study area and location of sampling sites (Modified from Birenes Abay, 2007).

in the macrophyte to that in the wastewater/sediment as described in Szefer et al. [14].

$$BSAF = C_x/C_s \quad (2)$$

Where: C_x and C_s are the average concentrations of a given metal in the macrophyte and the associated sediment, respectively.

Results and Discussion

Physicochemical characteristics of the wastewater

The Physicochemical characteristics of Wastewaters sampled from Hawassa Textile Factory are presented in Table 1. Except for PO_4 concentration in Site 2, which is more than three times higher than Site 1, all other variables measured were more or less similar in both sites.

Temperature of effluent samples from site 1 and 2 was 29.27°C and 29.87°C, respectively. Both values are below the maximum permissible temperature limits (40°C) for industrial effluent discharges set by both EEPA [3] and WHO [15]. It has been reported that textile and other dye effluents are produced at relatively high temperatures [16]. However, the low temperature recorded in the present study would be the result of cooling as the effluent is arrested for several days in the biological treatment lagoon. The effluent will also cool down as it joins the stream that slowly flowing under tree shades.

The pH values recorded, 9.88 and 9.87, for S1 and S2 respectively, are very close to 10.32 and 9.70 values documented by Abay [5] for the two sites. Both values are higher than recommended pH standard limits (6.0 to 9.0) of EEPA [3] and WHO [17]. Exposure to high pH value usually results in tissue damage and skin disorders on human body [18]. This would be a threat to downstream users because the streams and Tikurwuha river that receives the textile factory effluent is used by domestic animals and people living in the area.

Electrical Conductivity (EC) recorded at S1 (upstream) and S2 (downstream) was 2047 $\mu S/cm$ and 2038 $\mu S/cm$, respectively. These EC values are nearly two times higher than the 1000 $\mu S/cm$ maximum limit assigned by EEPA [3]. Much higher EC values, 3548 $\mu S/cm$ and 2668 $\mu S/cm$ for S1 and S2 respectively, were recorded by Abay [16].

Langeneggar [19] stated that EC result from total dissolved ions in aquatic ecosystem and according to Walakira and Okot-Okumu [20] it is indicative of some influence from human activities in the catchments. In this study, however, it is most attributed to the release of chemical salts and high TDS from the Hawassa textile effluent. This is reflected in the high TDS recorded at both S1 (1046.7 mg/L) and S2 (1025 mg/L), both of which are more than 10 times the national limit of 80 mg/L [3]. As described by Kambole [21], such high concentrations of TDS might be attributed to the various textile processes, including de-sizing, bleaching, and the various dyestuffs used in the factory. High concentration of dissolved solid elements affects the density of water, influences osmoregulation of freshwater organisms, and reduces solubility of gases (like oxygen) and utility of water for drinking, irrigational, and industrial purposes [22].

Waters can be classified based on the concentration of TDS as, desirable for drinking (up to 500 mg/L), permissible for drinking (up to 1,000 mg/L), useful for irrigation (up to 2,000 mg/L), not useful for drinking and irrigation (above 3,000 mg/L). Based on the above classification, it was observed that the effluent of HTF can be considered safe only for irrigation purpose [23,24].

Turbidity values recorded at S1 and S2 were 270.7 and 265.3 NTU, respectively. These values are more than 50 times higher than the

maximum limit value of EEPA [3]. The high turbidity is an indication that the effluent is heavily loaded with suspended and dissolved matter. Turbidity in water interferes with sunlight penetration and affects photosynthesis. They would also affect aquatic organism respiration and expose them to risks from prey.

The textile effluent released from the treatment lagoon was also loaded with nutrients. The concentration of phosphate recorded at site 1 and 2 was 6.33 and 21 mg/L respectively, and these values are much higher than the 4 and 2.3 mg/L recorded by Abay [16]. Such higher values may result not only from the textile effluent but from agricultural run-off, because there are small scale irrigation activities very near to the stream by down stream users. According to Walker et al. [25] and Mayer et al. [26], agricultural run-off increases concentration of phosphate along stream and Krenkel and Novotny [27] noted that this consequently could cause excessive algal growth that would deplete oxygen availability in the water body. This may cause death to different species of aquatic animals [26].

The Nitrate concentrations found in this study were 3.97 and 4.87 mg/L at site 1 and 2, respectively and these are far below the 50 mg/L maximum permissible limit set by EEPA [3] and the 10 mg/L limit of WHO [15]. Although the nitrate concentration recorded at site 1 is closer to 3.80 mg/L recorded by Abay [16], the concentration recorded at site 2 in the present study is more than two times the value recorded by the earlier researcher. This is still attributed to additional source of nitrate from the near by agricultural activities. Likewise, the concentrations of ammonia recorded in this study was 21.3 mg/L and 24.0 mg/L at site 1 and 2, respectively both values are far below the 30 mg/L maximum permissible national limit [3]. Even though the recorded concentration of ammonia was below national limit, the pungent smell of the effluent as characteristic of ammonia was perceived during the field sampling. According to WHO [28] ammonia gas may lead to poor air quality of the area and it is a severe respiratory tract irritant.

The concentration of sulfate recorded (44.7 mg/L and 51.0 mg/L) at site 1 and 2, respectively, were much below the provisional discharge limits set by the EEPA [3] and WHO [16], which is 200 mg/L and 400 mg/L, respectively. Even though the recorded phosphate concentration is below the maximum limits, as described by WHO [28], sulfate could pose toxicological hazards even at low concentrations if the effluent discharged does not pass through proper treatment system.

Heavy metal concentrations

The average levels of heavy metals assessed for effluent samples are presented in Figure 2 whereas Table 2 presents the corresponding levels determined for sediment and macrophytes samples. The heavy metal concentrations in the samples collected and analyzed from both sites generally followed the order: sediment > macrophytes > wastewater. In the present study, a total of six heavy metals (Cu, Mn, Zn, Cr, Pb and Cd) were assessed in the samples.

Heavy metal concentrations in wastewater: It have been reported that the major problem associated with textile processing effluents is presence of heavy metal ions, which arise from material used in the dyeing process or in a considerably high amount, from metal containing dye [29]. Of the total six heavy metals analyzed, four were detected in effluent of the factory. The heavy metals concentration in wastewater samples was found in the order of $Cu > Mn > Zn > Cr$ at both sites.

Analysis results (Figure 2) revealed that the average concentration of Cr in effluents of Hawassa Textile Factory recorded were 0.093 mg/L and 0.076 mg/L from site 1 and 2, respectively, indicating a slight

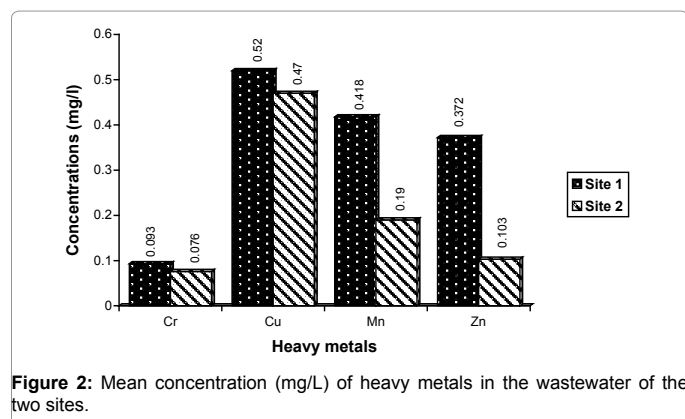


Figure 2: Mean concentration (mg/L) of heavy metals in the wastewater of the two sites.

decrement in site 2 (downstream) as compared to site 1. The maximum concentration of Cr recorded in the present study (0.093 mg/L in site 1) is much lower than that recorded from effluent of Textile Factory in metropolis Lagos, Nigeria (0.255 mg/L or 63.5% greater) [30] and that of a study conducted near Haridwar, India (2.38 mg/L or 96.1% greater) [31]. On the other hand, the higher concentration of Cr (2.0 mg/l to 4.0 mg/l) was found in a Textile Industry Effluent in Pakistan [32]. However, no Cr was detected in all samples from Textile Mills effluent of Kaduna, Nigeria [33].

The concentrations of Cr determined in present study are much below the provisional discharge limit values (1 mg/L) of EEPA [3] but higher than the 0.05 mg/L limit of WHO [15]. Altas et al., [34] noted that Cr is much more toxic to many plants and animals even at low concentration. The direct discharge of these pollutants to the environment observed in this study would cause negative effects on the receiving river water quality as well as would cause harm to the aquatic life and people in the area who use the wastewater downstream and their domestic animals due to its cumulative effect. According to Turkdogan et al. [35] its accumulation may induce gastro-intestinal ulceration and cancer and Cr can cause allergic reactions in the skin, damage the lungs, and cause asthma attacks in humans [36].

The average concentration of Cu recorded in present study was 0.52 and 0.47 mg/L from sites 1 and 2, respectively. These are below the EEPA [3] provisional discharge limit values (2 mg/L). More recently Deepali et al. [31] reported lower concentration (0.011 mg/L) of Cu from effluent of textile factory that located near Haridwar, India. On the other hand, much higher concentrations of Cu were reported which ranged between 1.16 and 5.14 mg/L [32] and 2.0 to 4.0 mg/L [33] as compare to the aforesaid values of present study. The low levels of Cu recorded along the stream may be attributed to the natural purification processes within the streams.

Copper is an essential element in mammalian nutrition as a component of metallo-enzymes in which it acts as an electron donor or acceptor. Conversely, exposure to high levels of Cu can result in a number of adverse health effects [37]. Adriano [38] stated that aquatic organisms are potentially at risk from exposures to Cu and according to Sawyer and McCarty [39] Cu is toxic to aquatic plants at concentrations greater than 1.0 mg/L, while concentrations near this level can be toxic to fish. Cu can bio-accumulated in human bodies and have important health implications. Its toxicity may induce diarrhea, vomiting, and sporadic fever [40,41]. Even though the recorded concentrations of Cu in this study were below the national provisional limit, the direct discharge of this pollutant to the environment would cause negative

effects due to its bioaccumulation nature.

Present study result revealed that the average concentration of Mn was 0.42 mg/L and 0.19 mg/L (Table 1) in textile effluents from site 1 and 2, respectively. A Mn concentration of 0.11 mg/L was recorded in India [42]; while slightly higher values (0.3 to 1.65 mg/L) were reported in Nigeria [33], as compared to the value of present study.

The highest concentration of Mn recorded at site 1 of the present study is almost two-times higher than the standard (0.2 mg/L) set by WHO [16]. According to Soetan [43] Mn is essential element for animal and plants growth with small amount. However, Maryse et al. [44] stated that exposures to higher levels of Mn (in drinking water) are associated with increased mental retardation and reduced intelligence in school-age children, and also chronic exposure to excessive Mn levels can lead to a motor disturbance.

The concentration of Zn recorded at site 1 and 2 was 0.372 and 0.103 mg/L, respectively. These are below the EEPA [3] provisional discharge limit values (1 mg/L). Yusuff and Sonibare [32] reported nearly similar concentration of Zn (0.19 to 0.36 mg/L) from textile factories effluents in Kaduna City, Nigeria. But, more recently, Ohioma et al. [45] reported the highest concentration of Zn from textile factories in the same city as compared to the present study.

According to Walker et al. [25], Zn is an essential element for animal and plants growth with small amount. However, Bradl [46] described that at higher concentration, it is toxic to living organisms and its accumulation in human body may cause fatigue and gastro intestinal discomfort.

Cd and Pb were not detected in wastewater samples of both sites. A similar result of Cd and Pb was reported by Ugoji and Aboaba [30] and Deepali et al. [42]. However, lower concentrations of Pb (0.18-0.59 mg/L) were detected in the effluent of textile industry collected from Panipat district of Haryana, India [47].

According to Wynne et al. [48], textile effluents vary in composition over time and from factory to factory based on the materials used in wet processing. None detection of Cd and Pb in the present study doesn't mean that they are totally absent in the samples; rather, they were below the level of detection limit of the instrument (FAAS) used. This might be due to the composition of materials used in wet process by the factory during the study time.

Heavy metals concentration in sediment and macrophytes: The mean concentrations of heavy metals in the sediment samples from Site 1 and 2 are presented in Table 2. The mean concentrations of heavy metals in sediment for both sites generally followed the order of Mn > Zn > Cu > Cr > Pb > Cd. The concentrations in the sediment for site 1 and site 2, respectively, were 1.03 and 0.92 mg/Kg for Cd; (29.53 mg/Kg and 32.53 mg/Kg for Cr; 77.73 mg/Kg and 56.33 mg/Kg for Cu; 884.75 mg/Kg and 882.24 mg/Kg for Mn; 6.69 mg/Kg and 6.11 mg/Kg for Pb; and 259.53 mg/Kg and 210.70 mg/Kg for Zn (Table 2). This shows the highest concentrations recorded in sediment were Mn and Zn, and the lowest concentrations were Cd and Pb at both sites.

According to McBride [49], of the three possible oxidation states (Mn²⁺, Mn³⁺, and Mn⁴⁺) of Mn, Mn²⁺ is the only stable and hence, soluble form in water. At high pH (>7), however, Mn²⁺ forms hydroxides and carbonate precipitates as well as bonds with organic matter, oxides, and silicates which eventually diminishes its solubility. Similarly, the same researcher described that at higher pH, Zn undergoes Chemisorption on oxides and aluminosilicates, and complexation with humus, which

noticeably lower its solubility. Therefore, the highest concentrations of Mn and Zn recorded in the sediment samples in this study would be because of the above mentioned chemical reaction behavior of the metals due to higher pH (about 9.9) recorded for the factory wastewater.

The concentrations of heavy metals in the macrophytes for site 1 and 2 respectively were 18.92 mg/Kg and 35.63 mg/Kg for Cu; 309.52 mg/Kg and 359.76 mg/Kg for Mn; and (71.50 mg/Kg and 58.87 mg/Kg for Zn (Table 2). The relatively higher content of Mn in the macrophytes could be ascribed to its comparatively higher accumulation in the sediment (Table 2).

In macrophytes samples, Cr was detected only at site 1 (2.94 mg/Kg), where as Pb and Cd were not detected at both sampling sites (Table 2). With few exceptions, the concentration of heavy metals determined for macrophyte samples generally followed the order of Mn > Zn > Cu > Cr at both sites. This result is consistent with that reported from India [50]. The concentration of Cr and Cu in site 1 are more than 2 times that in site 2 (Table 2).

Cd and Pb were detected in sediment samples but not in wastewater and macrophyte samples. This may be due to rapid adsorption of these heavy metals to sediment which essentially removes the same from the wastewater and consequently, indicating their lower tendency to accumulate in macrophytes [50].

Furthermore, it has been suggested [49] that drops in heavy metal levels with increasing distance (downstream) could be due to their precipitation as insoluble salts (e.g., carbonate, hydroxide, phosphate, or sulfide). The above researcher also indicated that above pH 7, Cd can co-precipitate with CaCO₃, or precipitate as CdCO₃, and Cd Phosphate, which ultimately may limit solubility as well. Consequently, mobility

and bioavailability of Cd in neutral to alkaline pH is low. Moreover, Pb is reckoned as the least mobile heavy metal, particularly under reducing or non-acid conditions. This is ascribed to the complexation with organic matter, chemisorption on oxides and silicate clays, and precipitation as carbonate, hydroxide, or phosphate that are all favored at higher pH [49]. This could be the reason why Pb was present in sediment samples in this study but not in wastewater and macrophyte samples.

In general, the concentrations of all heavy metals detected in sediment at site 1 were higher than site 2. Furthermore, the concentrations of all the metals detected in sediment at the two sampling sites have exceeded their concentrations in macrophyte and water (Table 2). This result is similar to the findings of Amoo et al. [51] where higher levels of these metals in sediment were obtained than in water of Lake Kainji in Nigeria. As described earlier and by Sabo et al. [52], this may be due to the fact that when metal pollutants are discharged into aquatic environment, they do not remain in aqueous phase but instead adsorbed onto the sediment. Thus, sediment serves as a sink for pollutants, hence the reason for its higher concentration of these metals. Moreover, as described by Untawale et al. [53] and HO [54], as the macrophytes die and decay, the accumulated metals in the decaying macrophytes can increase in the concentration of heavy metals in the sediments [50]. The present study result is similar to the findings of Amoo et al. [51] where higher levels of these metals in sediment were obtained than in water of Lake Kainji in Nigeria.

Similarly, the concentrations of all the metals detected in macrophytes at the two sampling sites have exceeded their concentrations in water, except Cr in site 2. As described by Vardanyan and Ingole [50], the higher concentration recorded in macrophyte may

Physico-chemical Parameters	Concentrations in samples (mg/L)		Standards	
	Site 1	Site 2	EEPA (2003)	WHO (2002)
Temperature (°C)	29.27 ± 0.9	29.87 ± 0.12	40	40
pH	9.88 ± 0.015	9.87 ± .02	6-9	6-9
Conductivity (µS/cm)	2047.3 ± 0.58	2038 ± 4.36	1000	-
TDS (mg/L)	1046.7 ± 2.3	1025.7 ± 1.5	80	1000
Turbidity (NTU)	270.7 ± 2.08	265.3 ± 1.2	≤ 5	-
PO ₄ (mg/L)	6.33 ± 0.58	21.0 ± 1.0	10	350
NO ₃ (mg/L)	4.87 ± 0.21	3.97 ± 0.15	50	10
NH ₃ (mg/L)	21.3 ± 2.08	24.0 ± 3.0	30	1
SO ₄ (mg/L)	51.0 ± 1.7	44.7 ± 0.6	200	400

Table 1: Values of physico-chemical parameters analyzed in wastewater of the textile factory.

Heavy metals	Sample sites	Concentration in samples (mg/Kg)	
		Sediment	Macrophytes
Cadmium	Site 1	1.03 ± 0.86	ND*
	Site 2	0.92 ± 0.094	ND*
Chromium	Site 1	32.53 ± 0.74	2.94 ± 0.74
	Site 2	29.53 ± 0.74	ND*
Copper	Site 1	77.73 ± 2.47	35.63 ± 0.39
	Site 2	56.33 ± 1.52	18.92 ± 0.39
Lead	Site 1	6.69 ± 1.0	ND*
	Site 2	6.11 ± 1.0	ND*
Manganese	Site 1	884.75 ± 8.70	359.76 ± 0.01
	Site 2	882.24 ± 11.51	309.52 ± 4.35
Zinc	Site 1	259.53 ± 0.98	71.50 ± 1.25
	Site 2	210.70 ± 0.86	58.87 ± 0.08

ND: Not detected

Table 2: Heavy metals concentrations in sediment and macrophytes samples at site 1 and 2.

Sampling sites	MPI values	BSAF of heavy metals					
		Cd	Cr	Cu	Pb	Mn	Zn
Site 1	(1.403) ^{1/4}	NC [*]	0.09	0.46	NC [*]	0.41	0.28
Site 2	(0.834) ^{1/4}	NC [*]	NC [*]	0.34	NC [*]	0.35	0.28

NC^{*}: Not calculated (because the heavy metals were not detected in macrophyte samples).

Table 3: The Metal Pollution Index (MPI) values and the Bio-sediment Accumulation Factor (BSAF) of analyzed heavy metals at the two sites.

be due to their uptake of elements in excess of needed and accumulation to concentration higher than those of the surrounding waters. This may be an indication that aquatic macrophytes play a role in removing the different metals from the ambient environments.

To compare the total content of metals at different sampling sites, the metal pollution index (MPI) and to evaluate the efficiency of metal bioaccumulation in macrophyte, the BSAF values; were calculated and the results are presented in Table 3.

The MPI of site 1 is higher than site 2 (Table 3). The concentrations of heavy metals detected in wastewater, sediment and macrophytes were higher at site 1 than site 2 (Figure 1 and Table 2). This indicates that the pollution level of the waste decreases down the wastewater stream. This is expected to be due to metals adsorption to sediment and removal from wastewater; and also uptake and filtration capacity of the macrophytes.

Denny [55,56] noted that main route of heavy metal uptake in aquatic plants occur through the roots in the case of emergent plants. This indicates that emergent microphytes accumulate heavy metals primarily from sediments. According to Liu et al. [57], bioaccumulation is expected to occur in organisms if the BSAF is >1. As can be seen from Table 3, all the values of BSAF for all the metals analyzed was <1, indicating almost no marked bioaccumulation of these metals in macrophyte at both sampling sites. Even though results of the present study indicated no marked accumulation of the heavy metals analyzed, detection of some of them at concentrations greater than wastewater may be indicative of macrophytes acting as natural filter of pollutants. This idea is consistent with that of Dhote and Dixit [58] which states, macrophytes function as living filters for nutrients and metals that become bound to living plant material.

Conclusion

The results of this study showed that the effluents released to the surrounding from the biological treatment lagoon of Hawassa textile factory contains some physico-chemical parameters higher than the standards given by the EEPA and/or WHO. The presence of such high parameters in the effluent after treatment questions the functionality of the treatment plant of the factory. Therefore, to reduce the potential environmental impact, there is urgent need to follow adequate and efficient effluent treatment methods in Hawassa textile factory. Thus, strict environmental laws and compliance monitoring become imperative so as to curb this stress and the factory should undergo regular environmental audits as required by National Environmental Law.

The present study revealed that the aquatic macrophytes play a role in removing the different metals from the ambient environments and probably play a major role in reducing the effect of high concentration of heavy metals. Therefore, the macrophyte community along the wastewater discharge way of Hawassa textile factory needs to be protected and restored in order to minimize the amount of heavy metals that reach the nearby Tikur-Wuha River and its receiver, Lake Hawassa.

Even though concentrations of most of the heavy metals recorded in the effluent were within acceptable ranges of the provisional national discharge limits, it should be noted that continuous release to the surrounding could result its accumulation in the environment. Heavy metals if present even in low concentrations are toxic to living organisms, including humans as well as the microbial population present in the effluent treatment processes. Therefore, the inefficiency of biological treatment revealed in the present study would be because of heavy metals presence in the wastewater; and this requires further microbiological study.

People living near and around effluent discharge way use the wastewater for various purposes and directly or indirectly exposed to pollutants in the discharge. Therefore, its adverse effect on aquatic life and the life and livelihood of the community living in the immediate vicinity should be investigated and addressed through comprehensive multidisciplinary research-based evidences.

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