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Evaluation of the Efficiency of Wastewater Treatment and Use of *Chironomus calipterus* (Diptera: Chironomidae) as a Bioindicator in El-Tall El-Keber, Egypt

N.S. El-Shenawy, R.S. Saleh Ahmed, F.M. Ismail and A. Abo-Ghalia
Department of Zoology, Faculty of Science, Suez Canal University,
Ismailia, 41522, Egypt

Abstract: This study evaluated the quality of the effluent water of El-Tall El-Keber wastewater treatment plant, Egypt by using aquatic insect *Chironomus calipterus* larvae as bioindicator. Larvae, water and sludge samples were collected from input and output lagoons to determine the levels of heavy metals (Mn, Fe, Zn and Pb) throughout the process of treatment. The results of the heavy metals analysis of samples collected at the input lagoon indicated that Fe was the most abundant metal at different seasons, while Pb exhibited the lowest abundance in all sludge samples collected from either input and output lagoons. The levels of Fe and Zn were reduced in output lagoon by 8.4-64.5% and 20.7-37.4% at different seasons, respectively. Accumulation of heavy metals in the larval tissues differed by different seasons for the same lagoon and can be arranged descending as following: Fe>Zn>Mn>Pb. The results indicated that larvae of *C. calipterus* Kieffer had high capabilities to accumulate certain heavy metals and could be used as heavy metal bioindicator. The potential use of these larvae in wastewater treatment is worth to do further exploration.

Key words: Wastewater treatment, *Chironomus calipterus*, heavy metals, bioindicator, Egypt

INTRODUCTION

Increasing water shortage in Egypt approaches an alarming level (Abulnour *et al.*, 2002). Control of water resources quality is a vital task for all countries. Wastewater and plant effluents can seriously deteriorate the quality of their receiving waters. Advanced treatments are often required to produce an acceptable effluent that in turn can increase the potential of water reuse (Taebi and Droste, 2008). In Egypt, wastewater treatment receives greater attention from the government that built a number of wastewater treatment plants; one of them located in El-Tall El-Keber that services 40,000 people, its capacity is 20,000 m daily and receives wastewater from houses. Their effluent water could be used for irrigation crops therefore, the detection of the effluent water quality and the capacity of the plant station are very necessary (Saleh-Ahmed *et al.*, 2008).

Heavy metals are excessively released into the environment due to rapid industrialization and have created a major global concern. Cadmium, zinc, copper, nickel, lead, mercury and chromium are often detected in industrial wastewater, which originate from metal plating, mining activities, smelting, battery manufacture, tanneries, paint manufacture, pigment

Corresponding Author: Dr. Nahla Soliman El-Shenawy, Department of Zoology, Faculty of Science, Suez Canal University, Ismailia, 41522, Egypt

manufacture and printing (Kadirvelu *et al*., 2001). Of all the heavy metals, Zn is an essential element for plant growth and easily taken up by roots, but it is regarded as poisonous at tissue concentration of 150-200 $\mu g\ g^{-1}$ in plant and may create an important environmental problem (Liu *et al*., 2007). Pb is not essential for plant growth and considered as toxic at the concentration of 30-300 $\mu g\ g^{-1}$ in plant tissues. It has received much attention as a hazardous pollutant to human and animals (Roos, 1994). Iron and manganese in potable water cause aesthetic and operational problems such as odor and brown color, stain and deposition in the water distribution systems leading to high turbidity (Sharma *et al*., 2005). A high concentration of iron and manganese in the raw water is also problematic for a water supply plant since, the hydrolysis product of trivalent iron can clog the filter, shorten the backwashing period and increase the backwashing frequency (Qin *et al*., 2009).

Wastewater treatment leads to the generation of large quantities of sludge that must be disposed off. Heavy metals that are existent in the wastewater tend to accumulate in the generated sludge. There are seasonal variability of heavy metal content and its chemical forms in sewage sludge from different wastewater treatment plants (García-Delgado *et al*., 2007). Unlike organic wastes, heavy metals are non-biodegradable and they can be accumulated in living tissues and bio-magnification through the food-chain, causing various diseases and disorders for human health (Kurniawan *et al*., 2006) and environmental concerns (Stylianou *et al*., 2007) therefore, they must be removed before discharge (Wan-Ngah and Hanafiah, 2008).

Among freshwater macroinvertebrates, benthic organisms such as chironomid larvae are considered a promising indicator of water quality because of their ubiquity and abundance in aquatic ecosystems (Pinder, 1986). The extraordinary number of species and ecological ranges within this family group adds a high degree of resolution and sensitivity to environmental interpretations as biomonitors (Mousavi *et al*., 2003). There is on chironomid tolerance to pollution, responses to contaminants and their use as indicators of water quality (Seire and Pall, 2000). The family Chironomidae has been used to investigate heavy metal pollution (Bervoets *et al*., 1997) and changes in lake salinity (Heinrichs *et al*., 2001). Chironomidae larvae have been used as bioindicators of an acid mine drainage in Portugal (Bervoets *et al*., 2003). Additionally, they are essential components in the efficient biological processing that takes place in the oxidation ponds of sewage treatment plants. A *Chironomus* bioassay was employed for toxicological evaluation at the wetland input and output, in South Africa, the study revealed an 89% reduction in toxicity below the wetland during runoff (Schulz and Peall, 2001). *Chironomus calipterus* Kieffer was the dominant species compared to all other chironmid species found in both input and output lagoons at the El-Tall El-Keber, Egypt, wastewater treatment system (Saleh-Ahmed *et al*., 2008). Sediment-dwelling organisms such as larval *C. calipterus* can bioaccumulate metals by two potential routes: via the external surface from the pore water or overlying water or via the gut wall from sediment and food ingestion (Bervoets *et al*., 2003). Chironomids are able to regulate concentrations of some metals (e.g., Cu, Ni, Zn) under some exposure regimes (Krantzberg, 1989) and thus, the biota-sediment accumulation factor (BSAF) tends to decrease in the presence of very high levels of metals in sediment (Chapman and Anderson, 2005; Campbell *et al*., 2006).

Therefore, this study evaluated the effluent water quality and the efficiency of wastewater treatment plant systems in El-Tall El-Keber, Egypt. This study also compared the concentration of some heavy metals between biotic and abiotic samples. Furthermore, the possibility of using chironomidae specie as bioindicator of heavy metals pollution in wastewater treatment was evaluated.

MATERIALS AND METHODS

Site Description

The system of wastewater treatment plant is located at El-Tall El-Kabeer city, Egypt. The station was built on five Feddans (1 Feddan = 4200.8335 m^2) by the Egyptian government; it lies in the Eastern South of El-Tal El-Kbeer city. The length of the station is about 150 Km and the diameter of the station pipes range from 8 to 12 inches (Saleh-Ahmed *et al.*, 2008). The exact areas that feed the station are El-Tal El-Sagheer, Abd Al Dayem suburb, El-Tal City and North of railway station. The output water runs through Al Wadi drain from El-Tal El-Kbeer to Ismailia waterway to reduce the underground water level. The wastewater treatment includes 3 main steps; mechanical, biological and tertiary treatment. In the mechanical stage, solids are allowed to settle and removed from wastewater. In the biological treatment two wastewater treatment oxidation ditches are provided. In each one, organic matter of the wastewater is decomposed biologically by oxygen consuming microorganisms; therefore, it is called activated sludge. Rotors located in the ditches are horizontally positioned shafts equipped with a large number of blades. When the shafts rotate at great speed, the blades agitate the wastewater thus mixing air (oxygen) with wastewater. Oxidation ditches is controlled by a time program situated in the main control panel. The purified water is separated from the activated sludge in the two settling tanks.

Physico-Chemical Parameters of Water Sample

Water samples were collected from input and output lagoons and were analyzed monthly during September 2003 to August 2004. The most important physico-chemical properties of the water such as Dissolved Oxygen (DO), pH and temperature were measured in the field with portable meters. The samples were transferred in an ice box to the laboratory where they were analyzed for 5-day Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Total Dissolved Solids (TDS), ammonia (NH_4-N), chlorine (Cl^-), nitrate (NO_3^-), sulfide (S^-) and oil and grease (APHA, 1989).

Biota and Sludge Samples

Short sweeps were taken to collect chironomid larvae from input and output lagoons at depth up to about 1 m. In each lagoon, samples were taken as three strikes from three marked locations which were spaced at meter intervals. In addition, four dips were taken in each site to cover one square meter. The mean number was equal to the total number of collected larva chironomidae from all strikes and divided by three which is the number of strikes (Saleh-Ahmed *et al.*, 2008). Sludge samples were collected by Ekman grab bottom sampler and sieved using a 500 μm-mesh sieve. Samples were collected monthly for seasonal determination of heavy metals and to detect the efficacy of the treatment plant.

Heavy Metals Determination

All samples (larvae, water and sludge) were stored at 4°C till heavy metals analysis. The water samples (25 mL) were analyzed by mixing with 1 mL of concentrated HNO_3. They were heated to concentrate the volume to 5 mL and then the samples were diluted with distilled water to 25 mL (APHA, 1989). However, all collected larvae were first killed by deep freezing. The Chironomus samples had been washed to remove particulates before analysis. Samples were dried overnight at 105 °C. Pooled samples were weighed (0.5 g) in small beaker then 3.5 mL of concentrated HNO_3 and 10.5 mL of concentrated HCl were added and left for 24 h. The samples were heated for digestion with more addition of concentrated HNO_3 till brown fumes disappeared. The digested samples were filtered and diluted with ultrapure water to 25 mL (Saleh and El-Shenawy, 2001). The sludge samples were dried at 105°C and digested in a mixture of HNO_3 and $HOCl_4$ (4:1) (Chevereuil *et al*., 1996). The heavy metals concentrations (Mn, Fe, Zn and Pb) in water, biota and sludge samples were measured by flame atomic absorption spectrophotometer, AAS (Perkin-Elmer 2380). The present study focused on these metals because the survey on the water samples in the wastewater treatment plant showed that Mn, Fe, Zn and Pb were the main pollutants in the preliminary study. Detection limit found with this method for the analysis of heavy metals was 0.001 ppm. A comparison between the amount of heavy metals when added either before or after digestion revealed that there was no loss of the metals during the digestion process with a recovery value of 98-102% for all the heavy metals. All reagents used in this investigation were of analytical grade from Merck, Darmstadt (Germany).

Statistical Analysis

All processing of data was conducted with the software packages Microsoft Excel XP (for data storage) and SPSS version 13.0, for statistical evaluation. The results are presented as Mean±SE of values. Kruskall-Wallis one way ANOVA was used to determine if the differences between influent and effluent concentrations were statistically significant at $p<0.05$ (Bailey, 1981). Correlations between metal concentrations in larvae tissue and water or sediment samples were evaluated using Pearson correlation coefficients.

$$\text{Efficiency of wastewater treatment plant} = \frac{(\text{Concentration of mater in output of water sample} - \text{Concentration of mater in input samples})}{\text{Concentration of mater in input sample}} \times 100$$

The mater could be heavy metal or any other chemicals.

RESULTS

Physico-Chemical Characters of Water

The maximum temperature during the study period (29 and 30°C) was recorded in the Summer season mainly in August at input and output point, respectively. The average temperature of input lagoon the year was 24.2°C, while the average temperature of output lagoon was 23.7°C. A noticeable drop in water temperature was observed during Spring and Autumn for both lagoons (Table 1). The pH values of input lagoon were fluctuating during

Table 1: Summary of field parameters at in- outlet lagoons in El-Tall El-Keber wastewater-treatment plant

	Parameters					
	Dissolved oxygen (mg L^{-1})		pH		Temperature (°C)	
Time (monthly)	In	Out	In	Out	In	Out
January	0.3±0.01	5.4±0.1	6.5±0.3	7.5±0.1	19±1.0	18±1.0
February	0.2±0.01	5.6±0.3	6.7±0.1	7.6±0.1	18±1.0	17±2.0
March	0.6±0.04	6.1±0.2	7.2±0.1	7.3±0.1	19±1.0	18±1.0
April	0.5±0.03	6.0±0.1	7.5±0.2	7.4±0.1	21±1.0	20±1.0
May	0.4±0.01	5.8±0.3	7.6±0.1	7.3±0.1	23±1.0	22±1.0
June	0.1±0.01	6.8±0.2	7.7±0.1	7.5±0.1	28±1.0	29±2.0
July	0.1±0.01	6.2±0.4	7.5±0.2	7.4±0.1	30±1.0	31±2.0
August	0.2±0.01	6.5±0.2	7.4±0.1	7.2±0.2	29±1.0	30±1.0
September	0.2±0.01	5.2±0. 1	6.8±0.2	7.3±0.1	28±1.0	27±2.0
October	0.4±0.03	5.4±0.2	6.7±0.3	7.4±0.1	27±2.0	26±2.0
November	0.3±0.01	5.2±0.04	6.4±0.5	7.2±0.2	27±1.0	26±2.0
December	0.5±0.02	5.0±0.04	6.2±0.3	7.3±0.2	21±1.0	20±1.0

The data represented as mean of the three reading±SE. Monthly changes of surface water for dissolved oxygen, pH and temperature (°C) during the sampling period (September 2003 to August 2004) the study period between 6.2 and 7.7 (Table 1), while the pH values for the output lagoon were range from 7.2 to 7.6. The DO concentrations were detected in the input lagoon with a maximum value of 0.6 ppm during the spring and a minimum value was 0.1 ppm during summer (Table 1). On the other hand, the highest values of DO were found in Summer mainly in June (6.8 ppm) at the output lagoon. The annual range of DO values for input were 0-0.6 ppm with an annual average of 0.3 ppm. While, the annual range were 5-6.8 ppm with an annual average about 5.8 ppm for output lagoon.

Table 2 shows the BOD values at input lagoon were higher than those of output lagoon. The annual range of BOD at input lagoon varied from 62 to 68 ppm with an annual average of 65.2 ppm. However, at output lagoon the annual range of BOD varied from 24 to 48 ppm with an annual average of 40 ppm. Statistical analysis showed highly significant difference between input and output lagoons in the levels of BOD ($p<0.001$). Moreover, COD levels were fluctuated from 77 to 86 ppm depend on the season. At output lagoon, the mean values of COD were decreased significantly ($p<0.001$) to 33.0 and 36.0 ppm in Winter and Summer, respectively (Table 2). The TSS values were between 35-58 ppm and 10-12 for the input and output effluent, respectively (Table 2). The elimination of TDS from output lagoon was range from 11.1 to 19.4 ppm. NH_4-N was not found in the output water throughout the investigation period. The levels of chlorine in output lagoon were range from 1.0 to 2.0 ppm (Table 2). The S^-, NO_3^-, oil and grease were removed completely from output water.

Evaluation of Heavy Metal

The concentration of heavy metals in water, larval tissue and sludge are presented in Fig. 1a-h. At input lagoon, the highest level of Mn in water was 0.31 ppm during Autumn and the lowest level was 0.05 ppm during Summer. Mn values in larval tissue had a noticeable seasonal variation especially during Summer that was 1.11 ppm and the lowest value was recorded during spring (0.24 ppm). The highest and the lowest levels of Mn in sludge were 3.78 and 1.2 ppm during Summer and Autumn, respectively (Fig. 1a). On the other hand, Mn concentrations in water were 0.01, 0.05, 0.05 and zero ppm during Autumn, Spring, Winter and Summer, respectively at output lagoon. The highest Mn concentration was detected in larval tissue during autumn and recorded the lowest value during Summer (0.03 ppm). The highest level of Mn in sludge samples was detected during Summer (2.47 ppm), while the lowest value was measured during Spring and Winter (0.43 ppm) (Fig. 1b). The Mn attended to accumulate the sludge more than water and larval tissue.

The levels of Fe were evidently very high in the different types of samples during the period of study than the other metals. At input lagoon, the highest values of Fe in the water, larval tissue and sludge were recorded during Autumn (42.06, 23.41 and 59.41 ppm, respectively). The minimum value of Fe in the water sample was 1.43 ppm during Summer, while in the larval tissue it was 1.24 ppm during Spring and Winter. However, the minimum value of Fe in sludge samples was 14.85 ppm during Winter. At output lagoon, the highest values of Fe in the water, larval tissue and sludge samples were also during Autumn (38.16, 16.04 and 55.08 ppm, respectively). The lowest values of Fe for water and sludge samples were 0.82 and 10.43 ppm, respectively during Spring. In the meanwhile, the minimum level of Fe was 0.85 ppm in larval tissue during Summer (Fig. 1c, d).

At input lagoon, Zn concentrations of water sample were 1.31 and 0.29 ppm during Apring and Summer, respectively. During Autumn, the minimum level of Zn in larval tissue and sludge samples were detected (0.68 and 0.8 ppm, respectively). The highest Zn level (2.0 ppm) of larval tissue sample was recorded during Spring and it was 2.45 ppm in sludge sample during Summer. At the output lagoon, the maximum values of Zn

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Table 2: Summarizes concentrations of the main chemical parameters at in-and outlet lagoons

Time	Parameters BOD5		COD		TSS		TDS		NH4-N		Cl^- (total residual)		S^-		NO_3		Oil and grease	
(monthly)	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
January	68.0±0.1	45.1±0.1 (33.7)	88.0±0.1	34.0±0.1 (61.4)	60.0±1.0	11.0 ±1.0 (81.6)	645±3.0	520±2.0 (19.4)	8.0±0.1	-- (100)	--	2.0±0.1	7.1±0.1	-- (100)	1.8±0.1	-- (100)	5.4±0.3	-- (100)
February	65.0 ±1.0	45.1±0.1 (30.6)	84.0±2.0	34.0±0.7 (59.9)	45.0±3.1	12.0±0.5 (73.3)	650±1.0	560±4.0 (13.8)	10.0±0.3	-- (100)	--	1.8±0.1	7.3±0.1	-- (100)	3.0±0.1	--	5.8±0.2	--
March	64.0±0.1	42.3±2.1 (33.9)	80.0±1.0	32.0±2.4 (60)	60.0±1.0	14.0±0.1 (76.6)	640±5.0	520±5.1 (18.8)	14.0±0.1	--	--	2.0±0.1	7.3±0.1	--	1.7±0.1	--	5.6±0.1	--
April	62.0±0.1	45.1±0.6 (27.3)	78.0±1.0	34.0±0.2 (56.4)	55.0±2.5	12.0±0.2 (78.2)	615±6.0	525±3.4 (14.6)	16.0±0.1	--	--	1.8±0.1	7.8±0.1	--	2.5±0.1	--	8.1±0.1	--
May	62.0±1.0	48.0±0.4 (22.6)	76.0±2.0	36±0.5 (52.6)	60.0±1.0	10.0±0.2 (83.3)	610±3.0	520±2.1 (14.7)	18.0±0.1	--	--	1.6±0.1	7.7±0.1	--	2.7±0.1	--	7.8±0.1	--
June	65.0±1.0	24.0 (63.1)	75.0±1.0	35 (53.3)	35.0±3.0	10.0±0.2 (71.4)	600±2.0	540±1.4 (10)	5.0±0.1	--	--	1.2±0.1	7.8±0.1	--	2.0±0.1	--	9.0±0.1	--
July	68.0±0.1	25.0±0.4 (64.9)	80.0±1.0	38±1.2 (52.5)	30.0±1.0	9.0±2.1 (70)	595±3.0	535±2.1 (10.1)	4.0±0.1	--	--	1.0±0.1	8.0±0.1	--	1.5±0.1	--	7.8±0.1	--
August	65.0±0.2	25.0±0.2 (61.5)	77.0±3.0	36±0.2 (53.2)	40.0±1.6	12.0±0.3 (70)	600±4.0	538±3.2 (10.3)	6.0±0.3	--	--	1.5±0.1	7.5±0.1	--	3.0±0.1	--	9.8±0.1	--
September	64.0±0.2	42.3±4.1 (33.9)	78.0±0.2	32±2.1 (58.9)	55.0±1.0	10.0±0.4 (81.8)	610±1.0	535±4.4 (12.3)	10.0±0.1	--	--	1.4±0.1	7.1±0.3	--	1.8±0.1	--	8.1±0.1	--
October	65.0±1.0	48.0±0.2 (26.1)	82.0±5.6	36±2.1 (56.1)	50.0±1.0	12.0±1.2 (76)	620±4.3	540±2.1 (12.9)	12.0±0.1	--	--	1.5±0.1	7.2±0.1	--	3.0±0.2	--	6.2±0.3	--
November	66.0±1.0	48.0±4.2 (27.3)	84.0±0.2	36±2.4 (57.1)	45.0±2.0	14.0±0.2 (68.9)	630±1.0	560±4.2 (11.1)	8.0±0.1	--	--	1.8±0.1	7.5±0.1	--	2.0±0.1	--	5.1±0.2	--
December	68.0±0.1	42.3±2.2 (37.8)	85.0±1.0	32±0.3 (62.4)	50.0±1.0	13.0±0.2 (74)	640±3.0	540±2.3 (12.6)	12.0±0.1	--	--	2.0±0.1	7.4±0.1	--	1.5±0.1	--	4.8±0.2	--

The data represented as Mean±SE of the three reading (mg L^{-1}) during the sampling period (September 2003 to August 2004). The elimination efficiency (%) in outlet lagoon as compared to the inlet lagoon was presented between the parentheses. Removal efficiency (%) = {(effluent value –influent value)/influent value}×100. --: Not detected

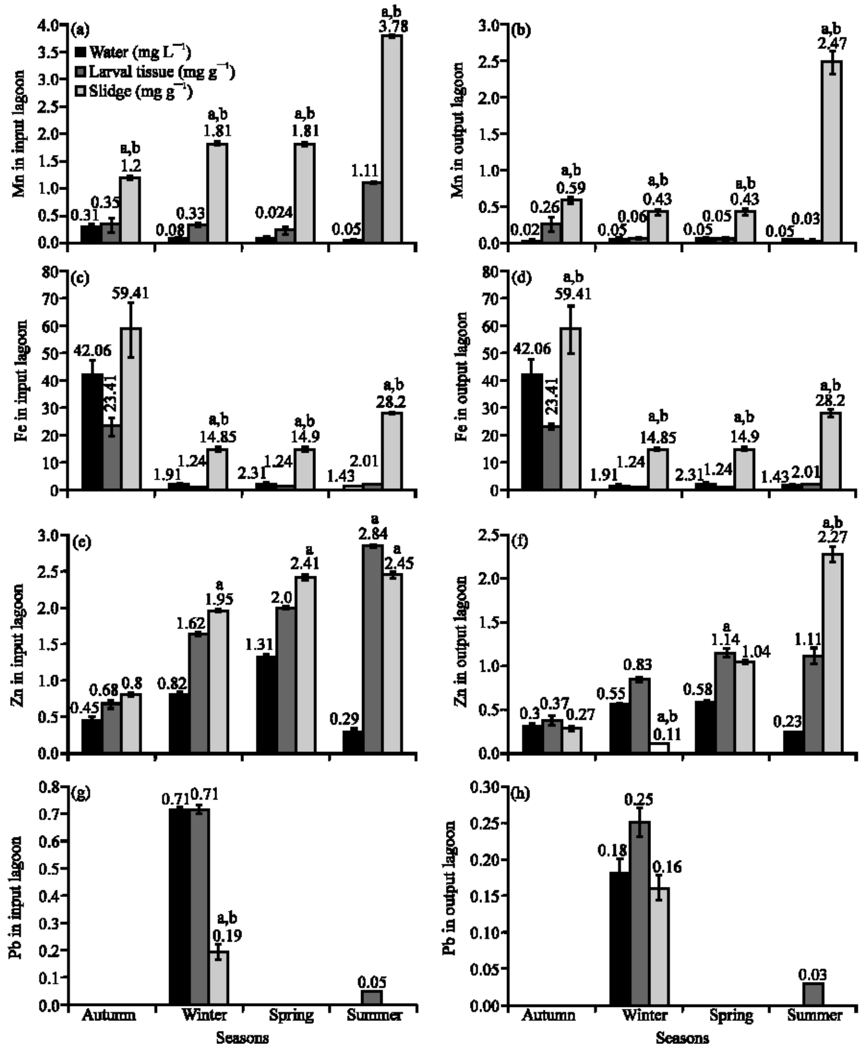

Fig. 1: Mn, Fe, Zn and Pb concentrations in water, tissue of larva and sludge samples at both input and output lagoons of El-Tall El-Kabeer wastewater treatment plant. The data was presented as mean and the error bars indicate +/-SE. There was significant difference between input and output lagoon at different seasons. [a]Significant different as compared to the water samples (ANOVA, $p<0.05$). [b]Significant different as compared to the tissue of larva (ANOVA, $p<0.05$)

concentrations were measured in water and sludge samples during Spring and Summer, respectively (Fig. 1e, f). Zn concentration of the larval tissue collected from output lagoon recorded the highest value during Summer (2.84 ppm) but the lowest value was 0.11 ppm during Winter. Moreover, the Zn lowest values of water and sludge samples were 0.23 and 0.37 ppm during Summer and Autumn, respectively (Fig. 1e, f).

Level of Pb was zero in all collected samples from both output and input lagoons during Autumn and Spring (Fig. 1g, h). It was found that the Pb levels were significantly higher in larval tissue samples (0.25 ppm) than water and sludge samples (18 and 0.16 ppm, respectively) in Winter. Levels of Pb in water and sludge samples were not detected; however, it was found in larval tissue in input and output lagoons (0.05 and 0.03 ppm, respectively) in Summer. Accumulation of heavy metals in larvae tissue has positive correlation with water ($r = 0.6$, $p<0.05$) and with sediment samples ($r = 0.7$, $p<0.05$).

DISCUSSION

The conventional water quality constituents associated with wastewater treatment are: BOD, TSS, phosphorus and nitrogen (Muga and Mihelcic, 2008). These reuse schemes such as agricultural irrigation is guided by EPA guideline criteria for wastewater reuse (US EPA, 2005) which include the control of conventional parameters such as BOD, turbidity, pH and residual chlorine, in order to protect public and the environmental health.

In the present study, lagoon treatment system has high annual removal efficiency of TSS (74.7%) and COD (57.1%) but has medium removal efficiency of BOD (38.5%) and low removal efficiency of TDS (13.7%). These effluent qualities ultimately determine if further treatment is required and most importantly their potential for reuse (Crites *et al*., 2000; US EPA, 2002; Metcalf and Eddy, 2003). Generally, a high value of the BOD to COD ratio indicates that biological processes for organics removal can be effective. Conversely, a low value of this ratio indicates that non-biological methods must be investigated for organics removal (Taebi and Droste, 2008). In the house wastewater that was applied to the El-Tall El-Keber system, the annual mean of BOD to COD ratio for influent and effluent were 0.81 and 1.15, respectively (Table 3). Therefore, these data indicated that the fairly good performance of the Tal ElKbeer treatment plant system, besides biological and non-biological processes is also significant. The results obtained revealed that the aerobic treatment improved the COD level as organic load of the studied wastewater. Mean effluent of COD was acceptably close to the standard level at those in the US. Therefore, the output water from wastewater treatment system could meet the irrigation and discharge standards. The removal efficiencies of NH_4-N, S^{-}, oil and grease were very high (Table 3) as described by Oakley (2005) that aerobic lagoon can remove between 61 and 80% (average 68%) of the same organic compounds. Lagoons system provides sufficient removal of BOD, TSS and pathogens (Muga and Mihelcic, 2008). The system displayed a good efficiency in decreasing the values of S^{-}, NH_4-N, oil and grease of output water. In the present study, the concentration of nitrates reduced below the established discharge limits in surface water of non-sensitive areas as recommended by Directive 91/271/EEC. The pH of the output lagoon was in the range of 7.2 to 7.6 that results in agreement with water quality standards, in which pH for the protection of fish and aquatic life shall lay within the range of 6.5 to 9.0.

Fate and removal of hazardous and toxic compounds is a generally accepted challenge in wastewater treatment and indicators that carry information on flows of these compounds

Table 3: Annual removal of water quality constituents, based on three measurements in each month for one year (September 2003 to August 2004)

Constituents (mg L^{-1})	BOD_5	COD	TSS	TDS	NH_4-N ammonia	S-sulfide	NO_3 nitrate	Oil and grease
Influent	65.16	80.58	45.75	621.6	10.25	7.7	2.2	6.5
Effluent	40.02	34.58	11.75	536.1	0.0	0.0	0.0	0.0
Removal efficiency (%)[a]	38.5	57.1	74.7	13.7	100	100	100	100
Permissible limits law 48/1982	30.0	40.0	30.0	1200	--	--	0.01-0.03	5.0

The data represents the mean annual textile wastewater treatment of lagoon system at El-Tall El-Kabeer. Removal efficiency (%) = {(effluent value-influent value)/ influent value} X 100 are often recommended (Malmqvist and Pamlqvist, 2005; Palme *et al*., 2005). Furthermore, removal efficiencies of heavy metals have major implications on water reuse schemes. The values of Mn and Pb in water samples recorded the lowest values and Fe had higher value than Zn. Also, the treatment processes of the wastewater were found to be suitable for removing the Zn more than Fe. The highest heavy metal removal efficiency from water samples was 100% for Mn, 8.4% for Fe and 20.7% for Zn in Summer. Furthermore, removal efficiency of heavy metals was very low; 34.7% for Mn, 28.7% for Fe and 7.3% for Zn in Summer. However, Hannah *et al*. (1986) reported that lagoon systems have removal performance of heavy metal range from 32 to 79%. It is obvious in the present study that removal efficiency of heavy metals depends on various parameters, such as the initial concentration metals, type of samples, type of heavy metals and season therefore, the temperature should be effective factor in the removal efficiency. This is why the results cannot be directly compared with the previous studies. The results provide evidence that lagoon system is effective for the decontaminating of heavy metal contaminated wastewater originated from houses runoff and it is also an economic system for the protection of water environment from heavy metal pollution for its low-cost in operation and maintenance.

Quality objectives exist in Egypt for the wastewater treatment plants that discharge into the sea and for irrigation purposes for all the heavy metals are 1ppm according to the law 48 of the year 1982. In the present study, the heavy metals were concentrated mostly in the sludge especially Fe, a result consistent with the findings by Wang *et al*. (2006).

The study of bioindicators and heavy metal accumulation in biotic samples has drawn a great deal of attention during recent years. Metal concentrations in the tissues of bioindicators can provide information on the concentration, bioavailability and potential risk posed by metals. Detection of the quality of the output water of El-Tall El-Keber wastewater treatment plant by using bioindicators was the subject of our present study and considered a first investigation for this station. The levels of heavy metals *C. calipterus* larvae were arranged descending as following; Fe > Zn> Mn> Pb. Most of the larval tissue samples were collected from input lagoon had significantly higher contents of heavy metals than that collected from output lagoon during the whole time of study. Chironomids are relevant bioindicators of metal bioaccumulation because they burrow into sediment and the majority of the metal they accumulate comes from sediment ingestion rather than from pore-water exposure (Bervoets *et al*., 1997; Filion and Morin, 2000). Mn concentrations in the larval tissues samples were significantly higher ($p<0.05$) than that detected in water samples during the four seasons. There were relationships between the accumulation of metals (Mn, Pb, Fe and Zn) in chironomids and their concentrations in sludge. On the other hand, a positive correlation between the Pb concentrations in chironomids and those in sludge samples could be confirmed by the ability of *Hexagenia rigida* to absorbed Pb on its surface (Hare *et al*., 1991). The lack of a relationship between Zn concentration in tissue of *C. calipterus* samples and sludge concentrations samples is not surprising because this metal is essential for benthic organisms and its accumulation is regulated (Timmermans, 1992). In the present study, the high concentration of Fe in the tissue of the larvae samples seems related to the high level of Fe in sediment and water samples. Bioaccumulation in larvae samples tissue could be inversely proportional to exposure concentrations that reflecting active regulation or uptake rate limitation as described before by McGeer *et al*. (2003). This is also associated with the dependence of metal bioavailability or transfer to overlying water on site-specific geochemical characteristics such as organic matter content, metal-binding phase's concentrations or sediment grain size (Desrosiers *et al*., 2008). Based on the analysis of cadmium (Cd) in several *Ischnura elegans* (Vander Linden) and surrounding water samples, it has been found that *I. elegans* exhibited a strong ability of accumulation on Cd in water. No statistical difference among the contents of heavy metal existed in male adult *I. elegans* from same sites at the same time, suggesting that the organism be an indicator for contamination of Cd in water system (Zhou *et al*., 2008). Dose-related bioaccumulation of lead was also observed in *I. elegans* from Donghu Lake, Jiangxi province showed the indication function of *I. elegans* in lead-polluted water (Zhou *et al*., 2008).

It can be concluded from this research that the output water from wastewater treatment system could be used in irrigation and discharge in the sea. The results provide evidence that lagoon system is effective for removing the NH_4-N, S-, oil, grease, TSS, BOD and COD and worse for TDS. Most of the heavy metals were ineffectively removed via the lagoon system. There is relationship between the accumulation of heavy metals in the larvae tissue and their concentration in water. Moreover, heavy metal concentrations in chironomid larvae tissue could be related to their level in sludge samples. Therefore, the larvae of aquatic insect *C. calipterus* will be good indication for heavy metal concentration in the wastewater plant and can be used successfully to differentiate between sites with varying degrees of pollution.

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