MANSOURA JOURNAL OF BIOLOGY
Official Journal of Faculty of Science, Mansoura University, Egypt
E-mail: scimag@mans.edu.eg ISSN: 2974-492X

Do Existing Wastewater Treatment Plants Meet Aspirations of Egypt's Vision 2030? Wastewater Treatment Plant at Shoha Model Village, Mansoura: A Case Study

Dagher, K.; Hagras, A. E; El-Naggar, A. A.

Environmental Sciences Division, Zoology Department, Faculty of Sciences

Mansoura University, Egypt

Received:3/1/2021
Accepted: 9/2/2021

Abstract: A comprehensive survey has been made of the operational status and potential environmental impacts of Shoha model village's primary wastewater treatment plant from January to December (2017). For this purpose, four water sources were sampled, namely raw wastewater (pretreatment), effluent discharge (post treatment), catfish muscles and sediment from Negeer Drain (the recipient watercourse of the treated wastewater) and the River Nile (the reference stream with comparatively low pollution regime). Analytical methods and measuring devices indicated that sediment of Negeer Drain which receives effluent discharge of Shoha model village's primary wastewater treatment plant accumulated greater amounts of heavy metals, organic pollutants, total dissolved solids, bicarbonates, sulphates, chlorides and minerals than sediment of the River Nile. A similar comparative trend was relevant for water and fish muscle between Negeer Drain and the River Nile except for a slight, non-significant increase in Cu and Ni in Negeer Drain. The amounts of heavy metals, TOC, N, P and K accumulated in sediment samples were significantly higher than corresponding levels in water and fish muscles, except for chromium which recorded the lowest level in sediment samples in either habitat. The amount of BOD_5 in water sampled from Negeer Drain was significantly higher than corresponding levels in water sampled from the River Nile. Nutrient enrichment, small-sized tanks and limited pumping vehicle, bacterial overload, organic pollution and heavy metals accumulation in Negeer Drain indicated that Shoha Primary Wastewater Treatment Plant is an inefficient treatment tool, in terms of potential environmental hazard and limited treatment capacity, and does not comply with Egypt's Vision 2030. An integrated wastewater treatment program is highly recommended, including the expansion and/or rehabilitation of the existing plant, expansion of the sewerage network in addition to installation of pumping facility and provision of evacuation vehicles to serve rural area and urban slums which are deprived of access to upgraded hygiene and sanitation systems. The suggested project aims at promoting sustainability of natural resources consumption, upholding pollution prevention and diminishing ecosystem degradation.

keywords: Wastewater, Treatment, Efficacy, Mansoura, Egypt 2030

1.Introduction

The wastewater treatment plant effluents are regarded as the most important sources of nutrient elements [1], inorganic [2] and organic contaminants [3] for aquatic ecosystems [4]. The structure of biological communities residing in polluted aquatic ecosystems may suffer directly [5] or indirectly [6],[7] investigated the impacts of municipal wastewater on the aquatic ecosystem structure and function in a receiving stream and observed that wastewater released from a common municipal Wastewater treatment plant influenced microbial activity, macroinvertebrate feeding activity and abundance, and fundamental ecosystem functions irrespective of the seasonal modifications in stream water level. According to the report of [8], wastewater treatment systems of Egypt treated approximately 25.5 million m^3 wastewater. The report also documented that a proportion of 23% of treated wastewater was allocated to for irrigation of the green landscapes, 29% for ground water reservoir, and 19% for growing fodder. The Planning and Statistics Authority of Egypt revealed that the amount of wastewater from stations in 2020 amounted to 25.516 million m^3. The quantities of treated water reached 24.954 million m^3 by 2020. About 7.900 million m^3 was used in agriculture, 5.730 million m^3 for irrigation in 2020 to water landscapes. According to the report of [8], the quantities of treated wastewater that were used for deep groundwater injection reached 7.322 million m^3 in 2020. The report also indicated that 4.817 million m^3 were discharged into lakes in 2020, and no treated wastewater was discharged into Red and Mediterranean seas in 2020. Regular reports on the operational process revealed that Wastewater Treatment Plant at Shoha was designed in 1996 and operated in 2007. The plant is powered by an old diesel engine. The technique adopted in this primitive plant is referred to as Primary Wastewater Treatment that is accomplished by activated sludge. The inside of a sewage pump/lift station is a very risky room. Poisonous gases, such as hydrogen sulfide and methane, can accumulate; an ill-equipped person entering the well would be overcome by fumes very quickly.

Wastewater Treatment Plant at Shoha is a small-scale wastewater treatment plant. The design capacity of the plant is approximately 3000 m^3/day, however the actual capacity is approximately 2000 m^3/day. During the treatment process of wastewater, dirty water passes through the following phases: primary (mechanical) treatment which reduces suspended solids by about 60%, and the biochemical oxygen consumed by 30-35%, and aims to rid the water of fairly large suspended solids, using filtering and sedimentation. Facilities utilized to accomplish primary treatment include refineries, the purpose of which is to hold outsized suspended solids; sand retention basins to retain inorganic suspended solids; primary sedimentation tanks, the purpose of which is to capture the largest amount of suspended organic solids. After treatment, to eradicate pathogenic bacteria, it undergoes a sterilization procedure with chlorine. Wastewater Treatment Plant at Shoha model village has neither chemical technicians nor water quality testing laboratory. Moreover, the plant has no oil retention basins which separate oils and greases. Many authors suggested that the lack of financial and technical resources in developing nations are the primary challenges for implementing wastewater treatment strategies, monitoring to identify inadequate treatment plants and impeding sustainable operation of small-scale wastewater treatment plants [9,10,11,12]. One of the objectives of the present study is to provide the national community with mirror data of the chemistry and microbiology of the treated wastewater discharged from Shoha Wastewater Treatment Plant, Mansoura City, Egypt which is regarded as one of the primitive treatment systems in Egypt. The present study also intends to explore and characterize the nature of raw wastewater discharged from suburban areas in the vicinity of Shoha, and its possible impacts on the aquatic ecosystem. Assessment of the Bioaccumulation Factor of heavy metals in fish is calculated. Specific objectives of the present investigation were to assess the technical, operational and maintenance status of the small-scale wastewater treatment plant in Shoha, and to discuss whether improper management of wastewater treatment plant increases the risks and suggest recommendations to diminish the threats on the environment, in particular the recipient streams

2. Materials and methods

Study area:

The study area is located at the edge of Manosura City, a highly populated area of the Nile Delta in the Lower Egypt. The present study extended between January and December 2018. Two aquatic habitats with different water quality were studied, namely Al Bahar Al Sagheer Canal in the vicinity of Al Sharqawiya Bridge at Mansouria Canal, a primary tributary of the River Nile which deviates, just similar to the Damietta and Rosetta Branches, from the mainstream of the River Nile south to Cairo and flows northwards (Figs. 1A, 1B, 1C and 1D). The upstream segment of Al Bahar Al Sagheer Canal opposite to Mit Mazzah village, with the coordinates: 31.0708° N, 31.4315° E. Shoha Primary Wastewater Treatment Plant is located at the northern border of Shoha district in Kafr Al Ilw and exhibits the coordinates: 31.0768° N, 31.4786° E (Figures 2A, 2B, 2C and 2D).

Shoha Primary Wastewater Treatment Plant:

Shoha primary treatment plant was operated 20 years ago. This plant aims at removing a limited pollution regime from the raw wastewater which is delivered with the aid of a powerful pumping station all the time. The first stage of treatment involves the coarse material which will either float or freely settle out by the force of gravity. This stage of treatment involves physical processes such as screening, gravel removal, comminution, and sedimentation. Screens are designed as long, closely spaced, slender metal bars and act to block floating debris such as wood, shreds, and other massive items that could clog pumps. The second stage involves biodegradation of the organic compounds (35-50% of biodegradable organic matter and 50-70% of suspended solids) with the aid of aerobic bacteria in aeration tanks.

Water sampling and analysis:

The subsurface water samples were collected on monthly basis from each locality at 50 cm in 1L polyethylene bottles to characterize the physical and chemical environmental parameters (abiotic factors). The hydrogen ion concentration (pH), water temperature (T), electrical conductivity (EC), and dissolved oxygen (DO) were detected by Multi–parameter Analyzer model YK-22DO and a numerical pH-meter (Orion Research Model PTI20). Each water sample was allocated into three fragments: the first was kept in dark glass bottle (500 ml) for BOD_5 test. The second fragment was preserved in refrigerant at 8^oC for future analysis of physicochemical environmental parameters which comprised total dissolved solids (TDS), bicarbonates (HCO_3^-), chlorides (Cl^-), sulphates ($SO4_2^+$), calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^+), potassium (K^+), nitrogen (N) and phosphorous (P). The trials were accomplished according to [13], [14], [15] and [16]. The third fragment was kept in glass bottle and adding 3ml Nitric acid (for preservation of concentration of heavy metals) and taken for heavy metal analysis. Chloride level (Mener method) was estimated as described by the American Public Health Association [16]. Water sulphates were assessed by a gravimetric method using 5% barium chloride solution ($BaCl_2$) according to [13]. Carbonates and Bicarbonates were determined by titration using 0.1N Hydrochloric acid with phenolphthalein and methyl orange as indicators for carbonate and bicarbonate anions, respectively [13]. Nitrogen in each collected water sample was estimated by a photometric method using (VARIAN 240 F.S.) flame photometer. Estimation of sodium and potassium cations of each collected water sample was carried out photometerically by using (VARIAN 240 F.S. model) flame photometer.

Calcium and magnesium were estimated by Versinate titration using ammonium purpurate as an indicator for calcium ions and Eriochrome Black T (EBT) as an indicator for both ions (calcium and magnesium) [17]. Total dissolved phosphorus was determined by digestion and followed by direct stannous chloride method as described in American Public Health Association [15]. TOC is the measure of the level of organic molecules or contaminants in water, sediment and tissues. TOC analysis measures the following: Total carbon (TC), Total organic carbon (TOC), Inorganic carbon (IC), Nonpurgeable organic carbon (NPOC) and Purgeable organic carbon (POC). There are three fragments of TOC analysis: sampling, oxidation and detection. Total organic carbon (TOC) is a non-specific assessment, which means TOC will not define which particular compounds are present. As an alternative, TOC will notify the operator of the sum of all organic carbon in those compounds.

Fish sampling:

Individuals of the catfish *Clarias gariepinus* (Burchell, 1822) (Fig. 3) were trapped on monthly basis between November (2015) and October (2016). Fish were collected, gently handled, washed, weighed and kept alive, in a proper fish tank and supplied with adequate oxygenation, and directly delivered to the aquarium. A total of 4 catfish specimens were sampled from each investigated area two times per season. Fish were sexed through the inspection of the external genitalia (Fig. 4A and 4B). Moreover, this demonstration was confirmed by the dissection of the fish to expose the gonads (testes in males and ovaries in females) (Fig. 5A and 5B). the genital papilla of male *Clarias* is more distinguished than that of female; it is elongated and tapered distally in male, however it is roughly circular in female (Fig. 4A and 4B).

Biological indices of fish:

Gonadosomatic index, abbreviated as GSI, is the calculation of the gonad mass as a proportion of the total body mass. This biological index is denoted by the formula: GSI = [Gonad weight/Fish weight] × 100. The condition factor (CF) reflects the overall fish health prominence and is considered as a pointer of the quality of the surrounding environment. CF is estimated according to [18]; the distinctive weight of the fish (g) is relative to the cube of its length (cm). As fish become lengthier, they become heavier. This association is formulated as follows: $K = 100 (W/L^3)$ [19]. The total length of fish was measured in centimeters with the aid of an ordinary ruler and the total body weight was estimated with an ordinary balance. The viscera were weighed with a balance.

For characterization of nutritional and reproductive activities of *C. gariepinus*, the following biological indices were used: the viscerosomatic index (VSI), defined as the ratio of the total weight of viscera to the total weight of body; gonadosomatic index (GSI), defined as the ratio of the weight of gonads to the total weight of body. This biological index is indicated by the formula: VSI = [Viscera weight/Fish weight] × 100.

Heavy metals analysis:

The following heavy metals were analyzed in each water, sediment and fish sample (e.g. Cr, Zn, Ni, Fe, Co, Cu, Cd, Mn and Pb) with the aid of Atomic Absorption Spectrophotometer (WFXAA 130B).

Statistical analysis and treatment of data:

All data were recorded as (Mean ±SD). Correlation analysis (Pearson Correlation Coefficient) was run on (SPSS statistical program) between physical and chemical factors of analyzed samples (water, sediment and fish tissues) in the River Nile as well as in Negeer Drain. The Analysis of Variance (One-way ANOVA on SPSS package: 20) was conducted to test for differences in investigated physicochemical environmental parameters as well as heavy metals among water, sediment and fish tissues. One-way ANOVA test was employed to demonstrate distribution of the physical and chemical environmental parameters as well as the heavy metals among different analyzed waterbodies. Any significant output of ANOVA test was followed by Least Significant Difference test selected from the PostHoc window to detect the significance among tested groups. Differences in the concentrations of the physical and chemical environmental parameters between the River Nile and Negeer Drain were verified statistically with the aid of the Student's *t*-Test on the same statistical software. Probability values ≤ 0.05 were designed significant, those ≤ 0.01 as highly significant, ≤ 0.001 as very highly significant, while > 0.05 as non-significant

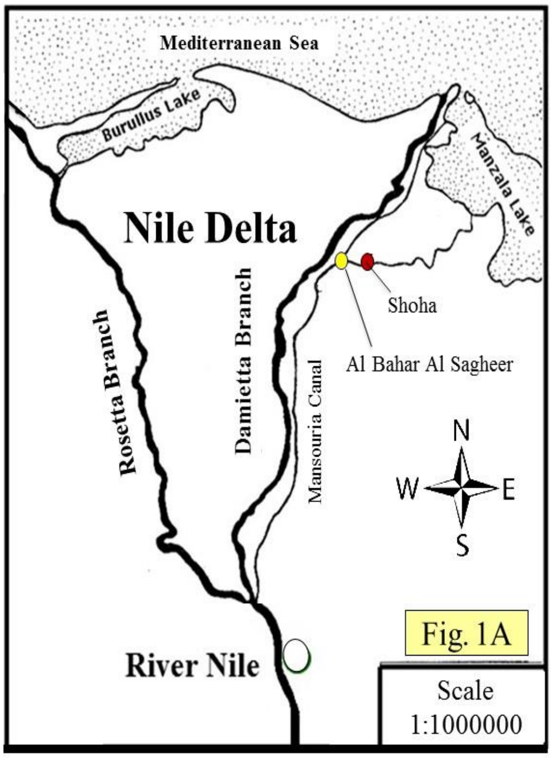

Fig. 1A. Hand drawn map of the investigation area at the Nile Delta, Egypt.

Fig. 1B. Google Earth map of the investigation area at the Nile Delta, Egypt. Scale bar = 400 m.

Fig. 1C. Google Earth map of Al Bahr Al Sagheer locality at the Nile Delta, Egypt. Scale bar = 100 m. Yellow solid circle, Al Sharqawiya Bridge.

Fig. 1D. Mobile photograph of Al Bahr Al Sagheer stream, Mansoura, Egypt. Scale bar = 300 cm.

Fig. 2A. Google Earth map of Shoha Wastewater Treatment Plant (red solid circles) in agricultural landscape (yellow solid circles), Mansoura, Egypt. Scale bar = 50 m.

Fig. 2B. Mobile photograph of the Drainage canal terminating into Negeer Drain, Nile Delta, Egypt. Scale bar = 100 cm. Yellow arrows, infrastructure of Shoha Wastewater Treatment Plant; white arrow, excessive vegetation cover.

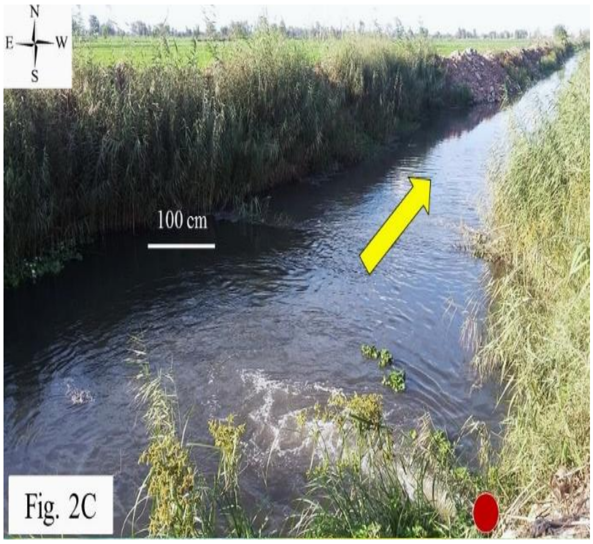

Fig. 2C. Mobile photograph of the Drainage canal, Nile Delta, Egypt. Scale bar = 100 cm. Red solid circle, outlet of the treatment plant; yellow arrow, watercourse.

Fig. 2D. Mobile photograph of the Drainage canal, Nile Delta, Egypt. Scale bar = 200 cm. Note the flora flourishing on the banks of the waterway.

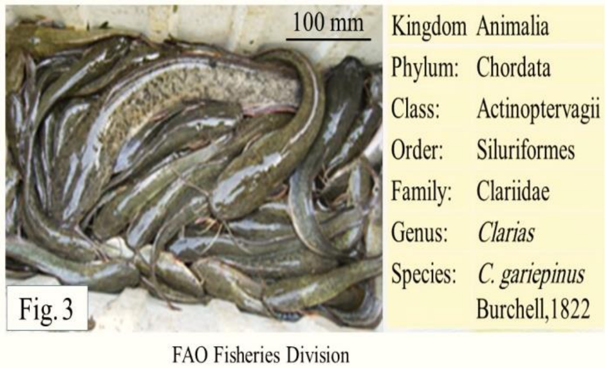

Fig. 3. The African Sharptooth catfish, *Clarias gariepinus*. Scale bar = 100 mm.

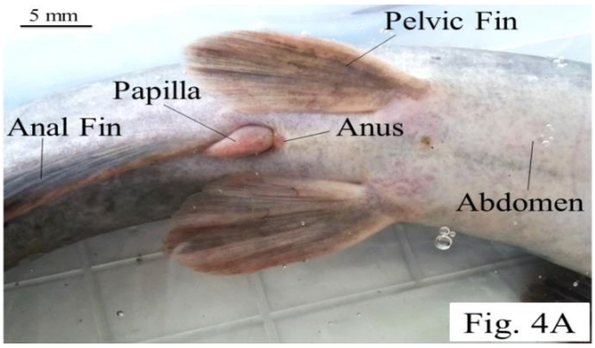

Fig. 4A. Mobile photograph showing the external genitalia of male African Sharptooth catfish, *Clarias gariepinus*. Scale bar = 5 mm.

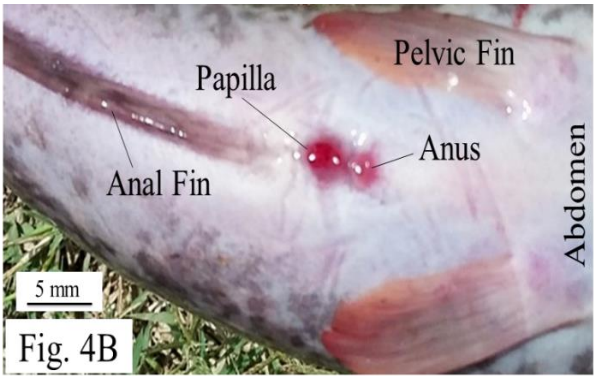

Fig. 4B. Mobile photograph showing the external genitalia of female African Sharptooth catfish, *Clarias gariepinus*. Scale bar = 5 mm.

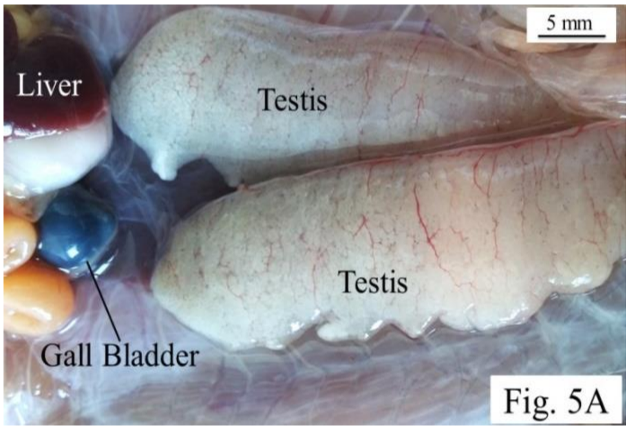

Fig.5A. Mobile photograph showing the exposed testes of male African Sharptooth catfish, *Clarias gariepinus*. Scale bar = 5 mm.

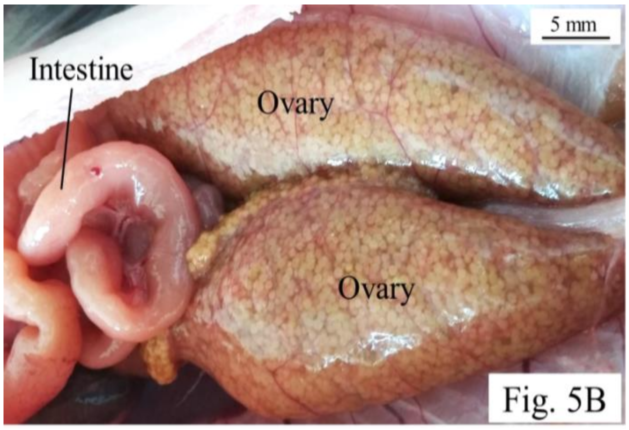

Fig. 5B. Mobile photograph showing the exposed ovaries of female African Sharptooth catfish, *Clarias gariepinus*. Scale bar = 5 mm.

Results

Monthly Fluctuations of Physicochemical Parameters of Water from Al Bahar Al Sagheer Stream and Negeer Drain:

Table 1 shows the monthly recorded levels of water temperature, hydrogen ion concentration, electrical conductivity, total dissolved solids and amounts of bicarbonate anions in Al Bahar Al Sagheer Stream (freshwater habitat) and Negeer Drain (agricultural and domestic drainage canal). As shown in Table (1), the two aquatic habitats exhibited a relatively similar thermal regime, with mean water temperatures of 25.05±5.00 °C and 26.28±5.03 °C, respectively. Table 1 shows a gradual increase of water temperature from February to August, followed by a gradual decline from September to January. Statistically, difference in the water temperature between the two habitats was non-significant (Student's *t*-Test: t= -0.603, p> 0.05).

As perceived from Table (1), hydrogen ion concentration of water from the two aquatic habitats is assorted on the weak alkaline scale. The mean values of the hydrogen ion concentration were 7.38±0.07 and 7.87±0.15, respectively. This difference was very highly significant statistically (Student's *t*-Test: t= -9.12, $p \leq 0.001$).

The monthly recorded levels of water electrical conductivity from Al Bahar Al Sagheer Stream and Negeer Drain are illustrated in Table (1). The waterbody of Negeer Drain is more conductive than that of Al Bahar Al Sagheer Stream (Table 1). No marked monthly fluctuations of this physicochemical parameter were relevant in both aquatic habitats (Table 1). The mean values of the electrical conductivity were 0.35±0.05 and 0.90±0.03 dS/m in Al Bahar Al Sagheer Stream and Negeer Drain, respectively. Student's *t*-Test indicated a very highly significant difference in the level of the electrical conductivity between the two aquatic habitats (t= -26.35, $p \leq 0.001$).

Table (1) records the monthly fluctuations of total dissolved solids in water from Al Bahar Al Sagheer Stream and Negeer Drain. Obviously, Al Bahar Al Sagheer Stream incorporated fewer amounts of the total dissolved solids than Negeer Drain. The mean values of the total dissolved solids in the two habitats were 261.72±13.62 and 578.77±20.54 mg/L, respectively. The maximum amount of the total dissolved solids in Al Bahar Al Sagheer Stream was recorded in April (283.70 mg/L); however, the minimum amount was recorded in July (202.24 mg/L). On the other hand, the maximum amount of the total dissolved solids in Negeer Drain was recorded in August (628.48 mg/L); however, the minimum amount was recorded in July (517.76 mg/L). Student's *t*-Test revealed a very highly significant difference in the level of the total dissolved solids between the two aquatic habitats (t= -27.20, $p \leq 0.001$).

As shown in Table (1), the amounts of water bicarbonates varied greatly between Al Bahar Al Sagheer Stream and Negeer Drain. It can be noticed from Table (1) that there is a summer peak of water bicarbonates from Negeer Drain. The mean values of water bicarbonates in the two aquatic habitats were 49.24±1.45 and 102.69±10.16 mg/L, respectively. The maximum amount of water bicarbonates in Al Bahar Al Sagheer Stream was recorded in August (54.17 mg/L); however, the minimum amount was recorded in in July 40.63 mg/L). On the other hand, the maximum amount of water bicarbonates in Negeer Drain was recorded in August (121.88 mg/L); however, the minimum amount was recorded in in June (89.38 mg/L). This difference was very highly significant statistically (Student's *t*-Test: t= -15.53, $p \leq 0.001$).

The waterbody of Al Bahar Al Sagheer Stream is more oxygenated than Negeer Drain (Table 2). The mean levels of dissolved oxygen in water from the two aquatic habitats were 7.41±0.70 and 3.69±0.28 mg/L, respectively. In both aquatic habitats, the dissolved oxygen recorded higher levels in cold than in hot months (Table 2). The highest concentration of dissolved oxygen was recorded in January and February (8.60 and 4.40 mg/L) in Al Bahar Al Sagheer Stream and Negeer Drain, respectively. In contrast, the lowest concentration of dissolved oxygen was recorded in August (6.23 and 2.80 mg/L) in Al Bahar Al Sagheer Stream and Negeer Drain, respectively. Statistically, difference in the water temperature between the two habitats was very highly significant (Student's *t*-Test: t= 14.78, $p \leq 0.001$).

The monthly changes of the biological oxygen demand in water from Al Bahar Al Sagheer Stream and Negeer Drain are shown in Table (2). The mean levels of this water parameter in Al Bahar Al Sagheer Stream and Negeer Drain were 0.30±0.05 and 1.64±0.32 mg/L, respectively. The waterbody of Negeer Drain is more conductive than that of Al Bahar Al Sagheer Stream (Table 2). The highest concentration of biological oxygen demand in Al Bahar Al Sagheer Stream was measured in March (0.50 mg/L); however, the lowest concentration of this parameter was measured in December (0.10 mg/L). On the other hand, highest concentration of biological oxygen demand in Negeer Drain was recorded in March (3.1 mg/L); however, the minimum amount was recorded in December (1.1 mg/L). Student's *t*-Test indicated a very highly significant difference in the level of biological oxygen demand between the two aquatic habitats (t= -8.31, p≤ 0.001).

Table (2) records the monthly fluctuations of chloride anions in water from Al Bahar Al Sagheer Stream and Negeer Drain. Obviously, Negeer Drain incorporated greater amounts of the chloride anions than Al Bahar Al Sagheer Stream. The mean values of the chloride anions in the two habitats were 25.43±4.07 in Al Bahar Al Sagheer Stream and 92.97±2.50 mg/L in Negeer Drain. The maximum amounts of chloride anions in Al Bahar Al Sagheer Stream was recorded in September (31.25 mg/L) and in Negeer Drain in August (106.78 mg/L). In contrast, the minimum amounts of chloride anions in Al Bahar Al Sagheer Stream was recorded in February (19.64 mg/L) and in Negeer Drain in July (80.09 mg/L). Student's *t*-Test revealed a very highly significant difference in the level of the chloride anions between the two aquatic habitats (t= -28.32, p≤ 0.001).

The monthly fluctuations in the levels of the sulphate cations in water from Al Bahar Al Sagheer Stream and Negeer Drain are shown in Table (2). This physicochemical parameter scored higher levels in the waterbody of Negeer Drain than that of Al Bahar Al Sagheer Stream, with mean values of 205.69±15.47 and 96.84±5.04 mg/L, respectively. The highest levels of sulphate cations were recorded in August (119.33 mg/L) and September (243.21 mg/L), while the lowest levels of sulphate cations were recorded in June (87.20 mg/L) and March (186.65 mg/L) in Al Bahar Al Sagheer Stream and Negeer Drain, respectively. Statistically, there was a very highly significant difference in the level of sulphates between the two aquatic habitats (Student's *t*-Test: t= -18.17, p≤ 0.001).

Table (3) records the amounts of the cations calcium, magnesium, sodium and potassium in water from Al Bahar Al Sagheer Stream and Negeer Drain over a year round. It can be seen from Table (3) that sodium is the most abundant mineral at Al Bahar Al Sagheer Stream (53.39±4.49 mg/L) and Negeer Drain (150.62±9.13 mg/L) as well. However, the least abundant mineral was magnesium at Al Bahar Al Sagheer Stream (3.93±0.53 mg/L) and potassium at Negeer Drain (8.01±0.61 mg/L). Data obtained showed that water sampled from Negeer Drain incorporated greater amounts of calcium, magnesium, sodium and potassium than water sampled from Al Bahar Al Sagheer Stream. Student's *t*-Test revealed very highly significant differences in the level of calcium (t= -16.17, p≤ 0.001), magnesium (t= -32.52, p≤ 0.001), sodium (t= -5.11, p≤ 0.001) and potassium (t= -11.46, p≤ 0.001) between the two aquatic habitats.

Data of the total organic carbon and organic matter are documented in Table (3). It is obvious that the waterbody of Al Bahar Al Sagheer Stream is blended with lower levels of organic compounds than that of Negeer Drain. The mean values of the total organic carbon and organic matter in Al Bahar Al Sagheer Stream were 13.91±0.46% and 16.87±0.39% respectively. On the other hand, the mean values of total organic carbon and organic matter in Negeer Drain were 22.41±0.84% and 25.82±0.66%, respectively. Statistically, Student's *t*-Test revealed very highly significant differences in the level of total organic carbon (t= -13.56, p≤ 0.001) and organic matter (t= -30.64, p≤ 0.001) between the two aquatic habitats.

As shown in Table (4), the waterbody of Negeer Drain received more nitrogen, phosphorous and potassium than that of Al Bahar Al Sagheer Stream, with mean values of (5.03±0.25 and 8.14±0.28 mg/L), (0.06±0.02 and 0.11±0.01 mg/L) and (8.76±0.93 and 13.57±0.27 mg/L) in Al Bahar Al Sagheer Stream and Negeer Drain respectively. Differences in the three nutrients between the two studied habitats were very highly significant statistically (Student's *t*-Test: t = -13.47, -13.56 and -13.57; p≤ 0.001 respectively).

One-way ANOVA test revealed very highly significant differences in the levels of hydrogen ion concentration (pH) (F-ratio= 70.99, F-probability: p≤ 0.001), electrical conductivity (EC) (F-ratio= 70.73, F-probability: p≤ 0.001), total dissolved solids (TDS) (F-ratio= 67.84, F-probability: p≤ 0.001), bicarbonate anions (HCO_3^-) (F-ratio= 32.25, F-probability: p≤ 0.001), dissolved oxygen (DO) (F-ratio= 73.95, F-probability: p≤ 0.001), biological oxygen demand (BOD_5) (F-ratio= 43.67, F-probability:

p≤ 0.001), chloride anions (Cl^-) (F-ratio= 58.81, F-probability: p≤ 0.001), sulphate anions (SO_4^{-2}) (F-ratio= 79.40, F-probability: p≤ 0.001), calcium cations (Ca^{+2}) (F-ratio= 23.10, F-probability: p≤ 0.001), magnesium cations (Mg^{+2}) (F-ratio= 27.69, F-probability: p≤ 0.001), potassium cations (K^+) (F-ratio= 21.52, F-probability: p≤ 0.001), nitrogen (N) (F-ratio= 562.74, F-probability: p≤ 0.001), phosphorous (P) (F-ratio= 113.13, F-probability: p≤ 0.001), potassium (K) (F-ratio= 232.58, F-probability: p≤ 0.001), total organic carbon (TOC) (F-ratio= 12.63, F-probability: p≤ 0.001) and organic matter (OM) (F-ratio= 27.61, F-probability: p≤ 0.001).

Further statistical analysis (PostHoc options: Least Significant Difference, LSD) on SPSS package indicated significant differences in EC, TDS, Cl^-, SO_4^{-2}, K^+ between AL Bahar Al Sagheer Stream (low values) and other waterbodies (high values). Similarly, LSD test revealed significant differences in BOD, Ca^{+2}, N, K, TOC and OM between AL Bahar Al Sagheer Stream (low values) and raw wastewater (pretreatment) as well as Negeer Drain (high values). Moreover, LSD test revealed significant variations in EC, TDS, SO_4^{-2}, Na^+, N, P and K between the raw wastewater (high values) and other explored waterbodies (low values). Furthermore, LSD test indicated significant differences in BOD, K^+, Mg^{+2}, TOC and OM between Negeer Drain (high values) and other investigated waterbodies (low values). A similar output was obtained for Cl^-, HCO_3^- and Ca^{+2}, between Negeer Drain and Al Bahar Al Sagheer Stream as well as between Negeer Drain and treated wastewater (post treatment). According to the output of LSD test, DO showed a significant difference between Al Bahar Al Sagheer Stream (high value) and other waterbodies (low values).

There were non-significant variations in the levels of Cl^-, HCO_3^- and Ca^{+2} between the raw wastewater and Negeer Drain. A similar output was recorded for HCO_3^- and Ca^{+2} between Al Bahar Al Sagheer Stream and treated wastewater (post treatment).

Regarding pH, further statistical analysis showed significant differences in this physicochemical parameter between Al Bahar Al Sagheer Stream (lightly alkaline) and raw wastewater (moderately acidic) as well as treated wastewater (lightly acidic). A similar statistical result was evident between Negeer Drain (fairly alkaline) and the raw wastewater as well as treated wastewater. However, no significant differences were relevant for pH between Al Bahar Al Sagheer Stream and Negeer Drain.

Statistical analysis indicated significant differences in DO between the raw wastewater and treated wastewater as well as Negeer Drain, Cl^-, Ca^{+2}, K^+ and HCO_3^- between raw wastewater and treated wastewater, N and K between treated wastewater and Negeer Drain, and K^+ and Mg^{+2} between Al Bahar Al Sagheer Stream and treated wastewater.

Comparative Study of the Heavy Metals, Macronutrients and Organic Fragments in Water, Sediment and Fish Muscle of *Clarias gariepinus* from Al Bahar Al Sagheer Stream and Negeer Drain:

Tables (5, 6 and 7) show a comparison of the heavy metals iron and manganese among water, sediment and catfish muscle from Al Bahar Al Sagheer Stream (freshwater habitat). It can be seen from Tables (5, 6 and 7) that sediment stored higher levels of iron (3.40±0.22 mg/L) than fish muscle (1.65±0.13 mg/L) and water (0.15±0.04 mg/L). It can be also noticed from Tables (5, 6 and 7) that sediment stored higher levels of manganese (7.13±0.07 mg/L) than fish muscle (0.58±0.10 mg/L) and water (0.04±0.01 mg/L). One-way ANOVA test revealed that differences of the heavy metals iron and manganese among water, sediment and fish muscle were very highly significant (F-ratio= 486.79 and 12726.91; F-probability: p≤ 0.001, respectively).

Similar to iron and manganese, the heavy metals zinc and copper attained higher levels in sediment than fish muscle and water from Al Bahar Al Sagheer Stream (Tables 5, 6 and 7). The mean values of these heavy metals in water, sediment and fish muscle were (0.07±0.01 and 0.11±0.01, 2.22±0.01 and 1.36±0.04, and 0.85±0.06 and 0.28±0.10 mg/L, respectively). One-way ANOVA test indicated that differences of the heavy metals zinc and copper among water, sediment and fish muscle were very highly significant (F-ratio= 4048.52

and 498.02; F-probability: p≤ 0.001, respectively).

A similar distribution pattern was exhibited by the heavy metals cadmium and lead. These pollutants were more available in sediment (4.56±0.22 and 0.89±0.02) than water (0.02±0.001 and 0.02±0.01) and fish muscle (0.04±0.01 and 0.04±0.01 mg/L) respectively. Statistically, these differences were very highly significant for cadmium (One-way ANOVA test: F-ratio= 1765.64 F-probability: p≤ 0.001) and lead (One-way ANOVA test: F-ratio= 3648.41 F-probability: p≤ 0.001).

As represented in Tables (5, 6 and 7), the mean values of nickel and chromium in water, sediment and fish muscle were (0.06±0.01 and 0.02±0.01), (0.77±0.03 and 0.09±0.003), and (0.15±0.01 and 0.03±0.01 mg/L) respectively. Statistically, differences in the amounts of nickel and chromium among water, sediment and fish muscle were very highly significant (One-way ANOVA test: F-ratio= 2027.94 and 177.60; F-probability: p≤ 0.001) respectively.

Further statistical analysis (PostHoc options: Least Significant Difference, LSD) on SPSS package detected significant differences in the amounts of the heavy metals iron, manganese, zinc, copper and nickel between sediment and water, fish muscle and water, as well as between sediment and fish muscle. LSD test also revealed significant differences in the amounts of the heavy metals cadmium, lead and chromium between sediment and water, as well as between sediment and fish muscle.

Tables (5, 6 and 7) show a comparison of the heavy metals iron and manganese among water, sediment and catfish muscle from Negeer Drain (agricultural and domestic drainage canal). It can be seen from Tables (5, 6 and 7) that sediment stored higher levels of iron (3.81±0.04 mg/L) than fish muscle (2.05±0.26 mg/L) and water (0.25±0.01 mg/L). It can be also noticed from Tables (5, 6 and 7) that sediment accumulated higher amounts of manganese (7.46±0.13 mg/L) than fish muscle (0.68±0.10 mg/L) and water (0.13±0.01 mg/L). One-way ANOVA test revealed that differences of the heavy metals iron and manganese among water, sediment and fish muscle were very highly significant (F-ratio= 529.82 and 7926.08; F-probability: p≤ 0.001, respectively).

Similar to iron and manganese, zinc and copper recorded higher levels in sediment than fish muscle and water from Negeer Drain (Tables 5, 6 and 7). The mean values of these heavy metals in water, sediment and fish muscle were (0.66±0.13 and 0.12±0.01), (2.64±0.09 and 1.50±0.07), and (0.95±0.06 and 0.40±0.08 mg/L, respectively). One-way ANOVA test indicated that differences of the heavy metals zinc and copper among water, sediment and fish muscle were very highly significant (F-ratio= 494.55 and 526.99; F-probability: p≤ 0.001, respectively).

A similar distribution pattern was exhibited by the heavy metals cadmium and lead. These contaminants were more abundant in sediment (5.14±0.08 and 1.08±0.03) than water (0.58±0.06 and 0.08±0.01) and fish muscle (0.08±0.01 and 0.13±0.01 mg/L) from Negeer Drain, respectively (Tables 5, 6 and 7). Statistically, these variations were very highly significant for cadmium (One-way ANOVA test: F-ratio= 9615.79 F-probability: p≤ 0.001) and lead (One-way ANOVA test: F-ratio= 3348.79 F-probability: p≤ 0.001).

As represented in Tables (5, 6 and 7), the mean values of nickel and chromium in water, sediment and fish muscle from Negeer Drain were (0.07±0.01 and 0.04±0.01), (1368±0.03 and 0.14±0.003), and (0.22±0.02 and 0.07±0.02 mg/L) respectively. Statistically, differences in the amounts of nickel and chromium among water, sediment and fish muscle were very highly significant (One-way ANOVA test: F-ratio= 5709.69 and 93.82; F-probability: p≤ 0.001) respectively.

Further statistical analysis (PostHoc options: Least Significant Difference, LSD) on SPSS package detected significant differences in the amounts of all analyzed heavy metals between sediment and water, fish muscle and water, as well as between sediment and fish muscle.

Tables (8, 9 and 10) show a comparison of the nutrients nitrogen, phosphorous and potassium among water, sediment and catfish muscle from Al Bahar Al Sagheer Stream (freshwater habitat). It can be seen from Tables (8, 9 and 10) that sediment stored higher levels of nitrogen, phosphorous and potassium (67.48±13.51, 13.63±1.33 and 90.50±6.35 mg/L) than water (5.03±0.59, 0.06±0.01 and

8.76±1.04 mg/L) and fish muscle (1.28±0.13, 0.003±0.001 and 0.49±0.12 mg/L) respectively. It can be also noticed from Tables (8, 9 and 10) that water stored higher levels of these nutrients than fish muscle. One-way ANOVA test revealed that differences of nitrogen, phosphorous and potassium among water, sediment and fish muscle were very highly significant (F-ratio= 198.65, 941.30 and 1449.87; F-probability: $p \leq 0.001$, respectively). LSD test revealed significant differences in the amounts of potassium between water and fish muscle.

Tables (8, 9 and 10) illustrate a comparison of the total organic carbon and organic matter among water, sediment and catfish muscle of *C. gariepinus* from Al Bahar Al Sagheer Stream (freshwater habitat). It can be seen from Tables (8, 9 and 10) that sediment is blended with greater amounts of total organic carbon and organic matter than water and fish muscle. It can be also noticed from Tables (8, 9 and 10) that the amounts of total organic carbon and organic matter in water are lower than the corresponding levels in fish muscle. The mean values of the total organic carbon and organic matter in water, sediment and fish muscle were (13.91±0.46 and 16.87±0.39%), (19.46±2.05 and 33.09±3.15%), and (16.40±4.12 and 23.33±1.04 %), respectively. One-way ANOVA test revealed that these variations were very highly significant for the total organic carbon (F-ratio= 12.41, F-probability: $p \leq 0.001$) and the organic matter (F-ratio= 197.84, F-probability: $p \leq 0.001$). Further statistical analysis (LSD test) indicated significant differences in the ratios of total organic carbon and organic matter from Al Bahar Al Sagheer Stream between sediment and water, fish muscle and water, as well as between sediment and fish muscle.

Tables (8, 9 and 10) show a comparison of the nutrients nitrogen, phosphorous and potassium among water, sediment and catfish muscle from Negeer Drain. It can be seen from Tables (8, 9 and 10) that sediment stored higher levels of nitrogen, phosphorous and potassium (85.50±3.52, 17.00±0.42 and 101.00±2.71 mg/L) than water (8.14±0.54, 0.12±0.01 and 13.57±0.65 mg/L) and fish muscle (2.02±0.27, 0.01±0.001 and 0.77±0.09 mg/L) respectively. It can be also noticed from Tables (8, 9 and 10) that the concentrations of these nutrients in water were higher than those in fish muscle. One-way ANOVA test revealed very highly significant differences in the levels of nitrogen (F-ratio= 4188.90, F-probability: $p \leq 0.001$), phosphorous (F-ratio= 14394.57, F-probability: $p \leq 0.001$) and potassium (F-ratio= 8529, F-probability: $p \leq 0.001$) among water, sediment and fish muscle. LSD test revealed significant differences in the amounts of the three nutrients between sediment and water, as well as between sediment and fish muscle. LSD test also detected significant differences in the amounts of nitrogen and potassium between water and fish muscle.

As shown from the comparison of the total organic carbon and organic matter among water, sediment and catfish muscle of *C. gariepinus* from Negeer Drain illustrated in Tables (8, 9 and 10), fish muscle accumulated higher amounts of these organic elements (28.61±3.09 and 50.06±1.61%) than sediment (23.68±3.78 and 41.93±6.63%) and water (22.41±0.84 and 25.82±0.66%) respectively. One-way ANOVA test revealed that these variations were very highly significant for the total organic carbon (F-ratio= 12.38, F-probability: $p \leq 0.001$) and the organic matter (F-ratio= 122.89, F-probability: $p \leq 0.001$). Further statistical analysis (LSD test) indicated significant differences in the ratios of total organic carbon and organic matter from Negeer Drain between fish muscle and water, as well as between fish muscle and sediment. Moreover, LSD test indicated significant difference in the organic matter between sediment and water.

As illustrated from Table 11, treated wastewater discharged from Shoha Treatment Plant showed improved conditions in terms of TCB, pH, EC, TDS and HCO_3^-. A similar improvement could be followed for DO, BOD, Cl^- and SO_4^{2-} in Table (12) and for Ca^{++}, Mg^{++}, Na^+ and K^+ in Table (13). Overall, the count of the total coliform bacteria in raw wastewater (pretreatment) and purified wastewater (post treatment) was 15.5 x 10^6 (± 1.29 x 10^6) (CFU/100 ml) and 8.75 x 10^3 (± 1.7 x 10^3) (CFU/ 100 ml), respectively. On the other hand, the count of the total coliform bacteria in Al Bahr Al Sagheer stream and Negeer Drain was 1.29 x 10^3 (± 85.39) (CFU/100 ml) and 54.50 x 10^3 (± 2.08 x 10^3) (CFU/ 100 ml), respectively.

One-way ANOVA test revealed very highly significant differences in the levels of hydrogen ion concentration (pH) (F-ratio= 70.99, F-probability: $p \leq 0.001$), electrical conductivity (EC) (F-ratio= 70.73, F-probability: $p \leq 0.001$), total dissolved solids (TDS) (F-ratio= 67.84, F-probability: $p \leq 0.001$), bicarbonate anions (HCO_3^-) (F-ratio= 32.25, F-probability: $p \leq 0.001$), dissolved oxygen (DO) (F-ratio= 73.95, F-probability: $p \leq 0.001$), biological oxygen demand (BOD_5) (F-ratio= 43.67, F-probability: $p \leq 0.001$), chloride anions (Cl^-) (F-ratio= 58.81, F-probability: $p \leq 0.001$), sulphate anions (SO_4^{-2}) (F-ratio= 79.40, F-probability: $p \leq 0.001$), calcium cations (Ca^{+2}) (F-ratio= 23.10, F-probability: $p \leq 0.001$), magnesium cations (Mg^{+2}) (F-ratio= 27.69, F-probability: $p \leq 0.001$), potassium cations (K^+) (F-ratio= 21.52, F-probability: $p \leq 0.001$), nitrogen (N) (F-ratio= 562.74, F-probability: $p \leq 0.001$), phosphorous (P) (F-ratio= 113.13, F-probability: $p \leq 0.001$), potassium (K) (F-ratio= 232.58, F-probability: $p \leq 0.001$), total organic carbon (TOC) (F-ratio= 12.63, F-probability: $p \leq 0.001$) and organic matter (OM) (F-ratio= 27.61, F-probability: $p \leq 0.001$).

Further statistical analysis (PostHoc options: Least Significant Difference, LSD) on SPSS package indicated significant differences in EC, TDS, Cl^-, SO_4^{-2}, K^+ between AL Bahar Al Sagheer Stream (low values) and other waterbodies (high values). Similarly, LSD test revealed significant differences in BOD, Ca^{+2}, N, K, TOC and OM between AL Bahar Al Sagheer Stream (low values) and raw wastewater (pretreatment) as well as Negeer Drain (high values). Moreover, LSD test revealed significant variations in EC, TDS, SO_4^{-2}, Na^+, N, P and K between the raw wastewater (high values) and other explored waterbodies (low values). Furthermore, LSD test indicated significant differences in BOD, K^+, Mg^{+2}, TOC and OM between Negeer Drain (high values) and other investigated waterbodies (low values). A similar output was obtained for Cl^-, HCO_3^- and Ca^{+2}, between Negeer Drain and Al Bahar Al Sagheer Stream as well as between Negeer Drain and treated wastewater (post treatment). According to the output of LSD test, DO showed a significant difference between Al Bahar Al Sagheer Stream (high value) and other waterbodies (low values).

There were non-significant variations in the levels of Cl^-, HCO_3^- and Ca^{+2} between the raw wastewater and Negeer Drain. A similar output was recorded for HCO_3^- and Ca^{+2} between Al Bahar Al Sagheer Stream and treated wastewater (post treatment).

Regarding pH, further statistical analysis showed significant differences in this physicochemical parameter between Al Bahar Al Sagheer Stream (lightly alkaline) and raw wastewater (moderately acidic) as well as treated wastewater (lightly acidic). A similar statistical result was evident between Negeer Drain (fairly alkaline) and the raw wastewater as well as treated wastewater. However, no significant differences were relevant for pH between Al Bahar Al Sagheer Stream and Negeer Drain.

Biological indices of *Clarias gariepinus* from Al Bahar Al Sagheer Stream and Negeer Drain:

Female catfish attained higher biological indices than male ones. The gonadosomatic index in females of *C. gariepinus* was 7.0 ± 1.83 and 7.0 ± 5.29, whereas in males was 2.59 ± 1.16 and 1.86 ± 2.32 in the River Nile and Negeer Drain, respectively. Statistical analysis indicated significant differences in the gonadosomatic index between the two genders in each habitat ($t = -2.731$, $p < 0.05$ in the River Nile; $t = -2.35$, $p = 0.05$). At both habitats, the viscerosomatic index in females of *C. gariepinus* (3.25 ± 2.63 and 6.33 ± 1.15, respectively) was higher than corresponding levels in males (2.80 ± 2.39 and 3.60 ± 2.61, respectively). Statistically, these differences were non-significant ($p > 0.05$ in all cases). A similar trend was revealed for the condition factor in either habitat; CF in females of *C. gariepinus* (0.85 ± 0.13 and 1.30 ± 0.61, respectively) was higher than that in males (0.80 ± 0.19 and 0.76 ± 0.17, respectively). However, these differences were non-significant statistically ($p > 0.05$ in all cases)

Table 1: Some physicochemical parameters of water from the River Nile (Al Bahar Al Sagheer Canal) and Negeer Drain receiving the discharges of Shoha Treatment Plant.

Month	**Al Bahar Al Sagheer Canal**(Freshwater Stream)					**Negeer Drain**(Drainage Canal)				
	°C	**pH**	**EC**(dS/m)	**TDS**(g/)	**HCO_3** (mg/l)	**°C**	**pH**	**EC** (dS/m)	**TDS** (mg/)	**HCO_3** (mg/)
Jan.	18.60	7.35	0.31	254.55	47.08	20.10	7.90	0.81	573.12	92.63
Feb.	17.20	7.30	0.29	263.51	46.45	17.90	7.75	0.88	585.14	98.65
March	21.10	7.22	0.31	278.80	49.30	21.50	7.80	0.92	599.68	97.61
April	24.10	7.32	0.34	283.70	53.60	24.70	7.65	0.89	568.50	91.42
May	26.30	7.35	0.31	270.10	49.80	27.40	7.80	0.84	530.32	94.62
June	29.40	7.37	0.37	278.20	45.30	29.80	7.75	0.87	546.32	89.38
July	31.60	7.39	0.40	202.24	40.63	32.00	7.85	0.81	517.76	94.79
Aug.	32.80	7.48	0.42	270.08	54.17	33.70	8.30	0.98	628.48	121.88
Sept.	28.10	7.45	0.40	261.57	51.42	31.50	8.10	0.96	615.11	115.21
Oct.	26.70	7.43	0.39	265.24	53.21	28.40	7.90	0.93	611.31	114.10
Nov.	23.90	7.41	0.37	244.16	52.63	25.30	7.85	0.95	588.08	108.34
Dec.	20.80	7.43	0.33	239.46	47.32	23.10	7.80	0.91	581.40	113.65
Mean	25.05	7.38	0.35	259.30	49.24	26.28	7.87	0.90	578.77	102.69
±SD	5.00	0.07	0.04	22.41	4.06	5.03	0.17	0.06	33.95	11.21

°C = temperature, pH = hydrogen ion concentration, EC = Electric conductivity, TDS = Total dissolved solids, HCO_3^-= bicarbonates.

Table 2: Some physicochemical parameters of water from the River Nile (Al Bahar Al Sagheer Canal) and Negeer Drain receiving the discharges of Shoha Treatment Plant.

Month	**Al Bahar Al Sagheer Canal**(Freshwater Stream)				**Negeer Drain**(Drainage Canal)			
	DO (mg/l)	**BOD** (mg/)	**Cl^-**(mg/l)	**SO_4^{2-}**(mg/l)	**DO** (mg/)	**BOD** (mg/l)	**Cl^-**(mg/l)	**SO_4^{2-}** (mg/l)
Jan.	8.60	0.20	20.69	93.79	3.90	1.30	93.37	192.75
Feb.	8.30	0.30	19.64	96.85	3.50	1.40	96.45	189.45
March	7.90	0.50	23.36	98.05	4.30	3.10	90.04	186.65
April	7.63	0.40	21.75	91.65	3.80	1.70	93.25	193.87
May	7.10	0.30	22.32	94.15	3.60	1.40	91.23	200.35
June	6.93	0.20	24.15	87.20	4.20	1.80	89.84	208.32
July	6.57	0.15	23.36	88.13	3.80	1.70	80.09	205.44
Aug.	6.23	0.25	30.03	119.33	2.80	1.60	106.78	231.07
Sept.	7.00	0.60	31.25	102.47	4.40	2.10	102.20	243.21
Oct.	7.12	0.35	30.97	100.55	3.80	1.30	96.98	229.25
Nov.	7.62	0.25	30.03	92.54	3.20	1.20	86.74	201.07
Dec.	7.91	0.10	27.65	97.35	2.90	1.10	88.64	186.85
Mean	7.41	0.30	25.43	96.84	3.68	1.64	92.97	205.69
±SD	0.71	0.14	4.28	8.44	0.51	0.54	7.07	18.95

DO=dissolve oxygen, BOD = biological oxygen demand, Cl=chlorides, SO_4=Total dissolved solids.

Table 3: Some phyicochemical parameters of water from the River Nile (Al Bahar Al Sagheer Canal) and Negeer Drain receiving the discharges of Shoha Treatment Plant.

Month	**Al Bahar Al Sagheer Canal**(Freshwater Stream)						**Negeer Drain**(Drainage Canal)					
	Ca^{++} (mg/l)	**Mg^{++}**(mg)	**Na^+** (mg/)	**K^+** (mg/)	**TOC%**	**OM**	**Ca^{++}** (mg/l)	**Mg^{++}** (m/)	**Na^+**(m/)	**K^+** (m)	**TOC** (%)	**OM** (%)
Jan.	11.80	3.40	51.14	4.93	14.21	16.93	29.60	9.40	136.72	7.50	21.86	24.86
Feb.	12.58	3.51	54.96	5.21	13.24	16.71	29.45	9.62	163.57	7.60	22.54	25.67
March	14.80	4.52	56.40	5.35	13.36	17.21	28.60	9.96	146.15	9.00	22.31	25.86
April	15.62	4.57	52.94	5.73	14.42	16.35	27.80	9.65	150.41	8.13	22.94	26.43
May	17.64	4.75	58.12	5.13	14.53	16.85	28.53	9.95	154.32	8.84	23.87	26.54
June	17.60	4.80	63.80	5.50	14.67	17.67	30.80	10.32	165.07	9.50	23.92	26.65
July	13.20	3.60	47.36	5.56	13.67	16.87	22.00	9.84	137.79	7.00	21.92	24.65
Aug.	14.61	3.23	54.37	5.89	13.78	17.32	27.25	9.45	142.75	7.35	21.54	25.31
Sept.	13.21	3.89	59.34	5.11	13.68	16.58	26.62	9.68	134.89	7.75	22.37	25.43
Oct.	12.24	3.73	45.13	5.43	13.85	16.34	29.81	9.97	150.45	7.87	21.52	26.13
Nov.	13.20	3.68	47.57	5.50	13.56	16.72	28.00	10.08	175.87	7.53	21.43	26.42
Dec.	12.72	3.49	49.54	5.31	13.94	16.87	29.30	9.85	149.48	8.10	22.65	25.83
Mean	14.10	3.93	53.39	5.39	13.91	16.87	28.15	9.81	150.62	8.01	22.41	25.82
±SD	1.98	0.57	5.54	0.27	0.46	0.39	2.26	0.27	12.49	0.75	0.84	0.66

Ca^{++-}= Calcium ions, Mg^{++-}= Magnesium ions, Na^{+}= Sodium ions, K^{+-}= Potassium ions.

Table 4: Some physicochemical parameters of water from the River Nile (Al Bahar Al Sagheer Canal) and Negeer Drain receiving the discharges of Shoha Treatment Plant.

Month	**Al Bahar Al Sagheer Canal**(Freshwater Stream)			**Negeer Drain**(Drainage Canal)		
	N(mg/l)	**P**(mg/l)	**K**(mg/l)	**N**(mg/l)	**P**(mg/l)	**K**(mg/l)
Jan.	4.30	0.04	7.20	7.56	0.11	13.90
Feb.	4.67	0.05	8.33	7.94	0.12	13.40
March	5.20	0.04	6.80	8.76	0.11	12.70
April	5.84	0.06	9.35	8.93	0.12	13.26
May	4.93	0.05	8.35	8.20	0.11	13.21
June	5.04	0.04	10.40	8.12	0.13	15.20
July	4.41	0.07	8.80	7.56	0.11	13.60
Aug.	5.20	0.08	9.65	8.97	0.12	13.61
Sept.	5.94	0.06	9.86	8.32	0.12	12.87
Oct.	5.87	0.08	9.21	7.67	0.11	13.85
Nov.	4.58	0.07	8.60	8.22	0.11	14.00
Dec.	4.43	0.05	8.57	7.45	0.11	13.22
Mean	5.03	0.06	8.14	8.76	0.12	13.57
±SD	0.59	0.02	1.04	0.54	0.01	0.65

N=Nitrogen, P=Phosphorous, K, Potassium.

Table 5: Analysis of some heavy metals in water from the River Nile (Al Bahar Al Sagheer Canal) and Negeer Drain receiving the discharges of Shoha Treatment Plant.

Season	**Al Bahar Al Sagheer Canal**(Freshwater Stream)								**Negeer Drain**(Drainage Canal)							
	Fe	**Mn**	**Zn**	**Cu**	**Cd**	**Pb**	**Ni**	**Cr**	**Fe**	**Mn**	**Zn**	**Cu**	**Cd**	**Pb**	**Ni**	**Cr**
Winter	0.148	0.029	0.06	0.101	0.020	0.021	0.062	0.021	0.237	0.132	0.60	0.113	0.571	0.076	0.064	0.037
Spring	0.135	0.038	0.07	0.102	0.22	0.024	0.071	0.030	0.246	0.126	0.70	0.122	0.623	0.081	0.079	0.043
Summr	0.196	0.039	0.06	0.112	0.022	0.014	0.051	0.020	0.256	0.145	0.81	0.123	0.621	0.081	0.073	0.043
Autun	0.112	0.034	0.08	0.113	0.021	0.012	0.069	0.025	0.251	0.113	0.52	0.117	0.502	0.064	0.051	0.025
Mean	0.15	0.04	0.07	0.11	0.02	0.02	0.06	0.02	0.25	0.13	0.66	0.12	0.58	0.08	0.07	0.04
±SD	0.04	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.011	0.13	0.01	0.06	0.01	0.01	0.01

Fe= Iron, Mn= Manganese, Zn= Zinc, Cu= Copper, Cd, Cadmium, Pb, Lead, Ni, Nickel, Cr, Chromium.

Table 6: Analysis of some heavy metals in sediment from the River Nile (Al Bahar Al Sagheer Canal) and Negeer Drain receiving the discharges of Shoha Treatment Plant.

Season	**Al Bahar Al Sagheer Canal**(Freshwater Stream)								**Negeer Drain**(Drainage Canal)							
	Fe	**Mn**	**Zn**	**Cu**	**Cd**	**Pb**	**Ni**	**Cr**	**Fe**	**Mn**	**Zn**	**Cu**	**Cd**	**Pb**	**Ni**	**Cr**
Winter	3.26	7.14	2.215	1.35	4.38	0.862	0.736	0.088	3.83	7.60	2.751	1.54	5.17	1.114	1.701	0.139
Spring	3.64	7.21	2.228	1.40	4.83	0.913	0.789	0.091	3.78	7.50	2.624	1.50	5.08	1.094	1.692	0.140
Summer	3.53	7.12	2.224	1.30	4.63	0.911	0.788	0.092	3.77	7.43	2.525	1.40	5.06	1.042	1.690	0.143
Autumn	3.18	7.03	2.207	1.38	4.39	0.879	0.762	0.094	3.86	7.30	2.648	1.57	5.23	1.089	1.631	0.145
Mean	3.40	7.13	2.22	1.36	4.56	0.89	0.77	0.09	3.81	7.46	2.64	1.50	5.14	1.09	1.68	0.14
±SD	0.22	0.07	0.01	0.44	0.22	0.03	0.03	0.003	0.04	0.13	0.09	0.07	0.08	0.03	0.03	0.003

Fe= Iron, Mn= Manganese, Zn= Zinc, Cu= Copper, Cd, Cadmium, Pb, Lead, Ni, Nickel, Cr, Chromium.

Table 7: Analysis of some heavy metals of fish (muscle) from the River Nile (Al Bahar Al Sagheer Canal) and Negeer Drain receiving the discharges of Shoha Treatment Plant.

Season	**Al Bahar Al Sagheer Canal**(Freshwater Stream)								**Negeer Drain**(Drainage Canal)							
	Fe (mg/)	**Mn** (mg)	**Zn** (mg/)	**Cu** (mg/)	**Cd** (mg/)	**Pb** (mg/l)	**Ni** (mg/)	**Cr** (mg/l)	**Fe** (mg/l)	**Mn** (m)	**Zn** (mg/l)	**Cu** (mg)	**Cd** (mg/l)	**Pb** (mg/l)	**Ni** (m/)	**Cr** (mg/)
Winter	1.50	0.50	0.80	0.20	0.04	0.04	0.15	0.03	1.80	0.60	0.90	0.30	0.08	0.12	0.24	0.06
Spring	1.60	0.50	0.80	0.30	0.05	0.03	0.14	0.04	1.90	0.60	0.90	0.40	0.09	0.13	0.21	0.07
Summer	1.70	0.60	0.90	0.20	0.03	0.04	0.16	0.03	2.10	0.70	1.00	0.40	0.08	0.11	0.19	0.09
Autumn	1.80	0.70	0.90	0.40	0.04	0.06	0.13	0.02	2.40	0.80	1.00	0.50	0.06	0.14	0.23	0.05
Mean	1.65	0.58	0.85	0.28	0.04	0.04	0.15	0.03	2.05	0.68	0.95	0.40	0.08	0.13	0.22	0.07
±SD	0.13	0.10	0.06	0.10	0.01	0.01	0.01	0.01	0.27	0.10	0.06	0.08	0.01	0.01	0.02	0.02

Fe= Iron, Mn= Manganese, Zn= Zinc, Cu= Copper, Cd, Cadmium, Pb, Lead, Ni, Nickel.

Table 8: Some physicochemical parameters of water from the River Nile (Al Bahar Al Sagheer Canal) and Negeer Drain receiving the discharges of Shoha Treatment Plant.

Season	**Al Bahar Al Sagheer Canal**(Freshwater Stream)					**Negeer Drain**(Drainage Canal)				
	N(mg/l)	**P**(mg/l)	**K**(mg/l)	**TOC**(%)	**OM**(%)	**N**(mg/l)	**P**(mg/l)	**K**(mg/l)	**TOC**(%)	**OM**(%)
Winter	4.7233	0.0433	7.4433	13.6033	16.9500	8.0867	0.1133	13.3333	22.2367	25.4633
Spring	5.2700	0.0500	9.3667	14.5400	16.9567	8.4167	0.1200	13.8900	23.5767	26.5400
Summer	5.1833	0.0700	9.4367	13.7100	16.9233	8.2833	0.1167	13.3600	21.9433	25.1300
Autumn	4.9600	0.0667	8.7933	13.7833	16.6433	7.7800	0.1100	13.6900	21.8667	26.1267
Mean	5.03	0.08	8.768	13.91	16.87	8.14	0.12	13.57	22.41	25.82
±SD	0.59	0.01	1.04	0.46	0.39	0.54	0.01	0.65	0.84	0.66

N=Nitrogen, P=Phosphorous, K, potassium, TOC, total organic carbon, OM, organic matter.

Table 9: Some physicochemical parameters of sediment from the River Nile (Al Bahar Al Sagheer Canal) and Negeer Drain receiving the discharges of Shoha Treatment Plant.

Season	**Al Bahar Al Sagheer Canal**(Freshwater Stream)					**Negeer Drain**(Drainage Canal)				
	N(mg/l)	**P**(mg/l)	**K**(mg/l)	**TOC**(%)	**OM**(%)	**N**(mg/l)	**P**(mg/l)	**K**(mg/l)	**TOC**(%)	**OM**(%)
Winter	47.25	12.00	100.00	16.67	28.74	81.38	16.50	99.00	18.24	32.78
Spring	73.12	15.10	87.00	19.31	33.28	84.37	17.30	100.00	24.08	41.50
Summer	74.22	14.20	88.00	20.43	34.12	86.52	16.80	100.00	25.72	45.66
Autumn	75.32	13.20	87.00	21.42	36.22	89.74	17.40	105.00	26.66	47.76
Mean	67.48	13.63	90.50	19.46	33.09	85.50	17.00	101.00	23.68	41.93
±SD	13.52	1.33	6.35	2.05	3.15	3.53	0.42	2.71	3.78	6.63

N=Nitrogen, P=Phosphorous, K, potassium, TOC, total organic carbon, OM, organic matter.

Table 10: Some physicochemical parameters of fish (muscle) from the River Nile (Al Bahar Al Sagheer Canal) and Negeer Drain receiving the discharges of Shoha Treatment Plant.

Season	**Al Bahar Al Sagheer Canal**(Freshwater Stream)					**Negeer Drain**(Drainage Canal)				
	N(mg/l)	**P**(mg/l)	**K**(mg/l)	**TOC**(%)	**OM**(%)	**N**(mg/l)	**P**(mg/l)	**K**(mg/l)	**TOC**(%)	**OM**(%)
Winter	1.44	0.003	0.62	22.43	22.43	2.12	0.005	0.81	24.38	48.75
Spring	1.13	0.002	0.36	13.25	22.80	1.61	0.005	0.64	28.25	48.70
Summer	1.23	0.003	0.42	14.45	23.30	2.12	0.006	0.77	30.57	50.83
Autumn	1.32	0.003	0.54	15.45	24.80	2.21	0.006	0.86	31.22	51.95
Mean	1.28	0.003	0.49	16.40	23.33	2.02	0.006	0.77	28.61	50.06
±SD	0.13	0.001	0.12	4.12	1.04	0.27	0.001	0.09	3.09	1.61

N=Nitrogen, P=Phosphorous, K, potassium, TOC, total organic carbon, OM, organic matter.

Table 11: Some physicochemical and bacteriological parameters of raw wastewater pumped by the sewerage system and in treated wastewater discharged from Shoha Treatment Plant.

Season	**Pretreatment status**(Raw wastewater)					**Posttreatment status**(Treated wastewater)				
	TCB(CFU/100ml)	**pH**	**EC** (dS/m)	**TDS** (mg/l)	**HCO_3^-** (mg/l)	**TCB**(CFU/100 ml)	**pH**	**EC** (dS/m)	**TDS** (mg/l)	**HCO_3^-** (mg/l)
Winter	14×10^6	3.40	1.45	928.00	94.79	54×10^3	5.50	0.89	567.04	67.71
Spring	16×10^6	4.40	1.87	1196.80	108.34	57×10^3	5.70	0.75	481.28	54.17
Summer	17×10^6	5.00	2.11	1350.40	135.42	52×10^3	5.80	0.67	427.52	40.63
Autumn	15×10^6	4.80	1.90	1210.50	120.36	55×10^3	5.30	0.80	520.40	60.72
Mean	15.5×10^6	4.408	1.83	1171.43	114.73	54.5×10^3	5.56	0.78	499. 06	55.81
±SD	1.29×10^6	0.71	0.28	176.50	17.30	2.08×10^3	0.23	0.09	59.19	11.53

TCB=Total Coliform Bacteria, pH=hydrogen ion concentration, EC=Electric conductivity, TDS=Total dissolved solids, HCO_3^-=bicarbonates.

Table 12: Some physicochemical and bacteriological parameters of raw wastewater pumped by the sewerage system and in treated wastewater discharged from Shoha Treatment Plant.

Season	**Pretreatment status**(Raw wastewater)				**Posttreatment status**(Treated wastewater)			
	DO(mg/l)	**BOD**(mg/l)	**Cl^-**(mg/l)	**SO_4^{2-}**(mg/l)	**DO**(mg/l)	**BOD**(mg/l)	**Cl^-**(mg/l)	**SO_4^{2-}**(mg/l)
Winter	1.40	0.50	73.41	522.14	3.20	0.40	63.40	286.27
Spring	2.00	0.80	93.44	686.02	5.00	0.40	50.06	250.66
Summer	1.80	0.60	96.77	775.39	3.80	0.60	40.04	234.53
Autumn	1.70	0.70	85.31	643.28	4.30	0.30	35.30	223.57
Mean	1.73	0.65	87.23	656.71	4.08	0.43	47.20	248.76
±SD	0.25	0.13	10.40	105.25	0.76	0.13	12.43	27.37

DO=dissolve oxygen, BOD=biological oxygen demand, Cl=chlorides, SO_4=Total dissolved solids.

Table 13: Some physicochemical and bacteriological parameters of raw wastewater pumped by the sewerage system and in treated wastewater discharged from Shoha Treatment Plant.

Season	**Pretreatment status**(Raw wastewater)				**Posttreatment status**(Treated wastewater)			
	Ca^{++}(mg/l)	**Mg^{++}**(mg/l)	**Na^+**(mg/l)	**K^+**(mg/l)	**Ca^{++}**(mg/l)	**Mg^{++}**(mg/l)	**Na^+**(mg/l)	**K^+**(mg/l)
Winter	22.00	2.16	301.41	4.50	15.30	1.60	172.58	3.00
Spring	26.40	1.44	393.45	6.00	17.60	0.96	148.82	3.50
Summer	35.20	6.53	427.90	7.50	13.20	3.60	128.91	4.50
Autumn	27.60	3.85	340.65	5.20	12.60	2.30	120.65	3.00
Mean	27.80	3.50	365.85	5.81	14.68	2.12	142.74	3.50
±SD	5.49	2.26	55.98	1.29	2.27	1.13	23.14	0.71

Ca^{++-}= Calcium ions, Mg^{++-}= Magnesium ions, Na^+= Sodium ions, K^{+-}= Potassium ions.

Discussion

Design of the water resources policies of Egypt for the current century requires a major shift from the classical model adopted in the planning and management of the water resources to a new advanced model [20]. The per capita share of water is always declining; water share in recent years dropped under 1000 cubic meters / capita year, and reached the water poverty limit for a population nowadays. This water share might drop to 500 cubic meters/capita/year in 2025 [21], which would indicate water scarcity. Data available on the quality of surface and groundwater are rather few and indicate that there exists a prompt degradation in this strategic natural resource [22]. In this respect, regular evaluation of available water resources and rationalization of water consumption in Egypt are strongly recommended strategies to maintain water wealth. Amounts of water devoted to the agricultural sector could be supplemented through the reuse of treated wastewater which is available in huge quantities and is daily dumped into coastal water. Accordingly, dozens of highly advanced wastewater treatment plants should be operated during the current and coming decades. Some water types may be involved in this project, for example treated agriculture water, treated domestic water, treated industrial water and treated saltwater. These waterbodies may supplement the water sector with some billions of valid water for particular purposes under specific control measures. Moreover, the requirement of satisfying diverse quality criteria is an urgent issue and treated water should comply with its intended uses.

To remove pollutants, the wastewater discharges undergoes treatment prior to discharge into the receiving system. Effluents from the wastewater treatment plant reach the receiving system where water experiences new modifications, as a result of dilution and self-purification processes. [21] highlighted the management of water resources in Egypt. Apart from the floods and random rainfall, Egypt receives 55.5 billion M^3/year of water. As droughts occur occasionally, it is imperative to stock water in the Lake Nasser during the periods of great Nile inflow. Wastewater Management of has been an important measure of civilizations during the millennium, therefore verifying many sociological features and technological improvements all over the ages [23]. Europe had planned the first modern wastewater treatment in the middle of the nineteenth century, attaining a proven rank by the end of the twenty century, leading to regular advances in public health and environmental quality within the continent [24, 25]. Most industrialized countries have proper functioning infrastructures for wastewater collection and treatments to cover more than 91% of population) [26]. However, concerns are moving towards the existence of tangible contaminations at the present time [27, 28], with procedures now under way to reduce their occurrence in the environment [29]. However, wastewater treatment state varies considerably in developing countries across the world.

As reported by [30], while improvements have been accomplished over the last decades, with more than 2.1 billion individuals gained access to upgraded sanitation service since 1990, difficulties remain to reach necessary level of wastewater treatment around the globe. [26] reported that about 2.5 billion people are deprived of proper sanitation services, which can promote spread of diseases and significant health and environmental problems. Consequently, a great effort in the building and operation of wastewater treatment plants should be carried out in these developing populations in the coming decades [31]. To select proper applied technology for wastewater treatment, compliance with specified standards of the environmental regulation and technology budgets must be considered in conjunction with other characteristics such as geographic location, socioeconomic circumstances or the local and global environmental influences [32,33,34]. Concerning environmental impacts, life cycle assessment approach is often used to evaluate the environmental influences of products and services, considering a set of inputs and outputs related to the energy and materials during the course of their life cycle to quantify the impacts of the whole system under investigation [35]. However, the life cycle assessments are rarely measured during the design and evaluation of wastewater treatment in developing countries [36], though this method permits superior decision making due to involvement of more variables [37,38].

[39] evaluated an array of Wastewater Treatment Plants (WWTP) utilizing variable biological treatment methods in El-Gharbia Governorate, Egypt. These techniques involved the oxidation ditch, rotating biological contactors, an extended aeration, conventional activated sludge, and aerated lagoons processes. Influent and effluent wastewater samples were collected from each treatment plant and the performance was estimated relying on the treated wastewater quality data. These authors correlated between some critical elements from influent and effluent discharges, for example TSS, COD and BOD_5. The highest performance efficiency was estimated for Kotour WWTP which operates with the oxidation ditch technology; however the lowest performance efficiency was estimated for Tanta WWTP operating with conventional activated sludge technology. Kotour WWTP discharges coped with the Egyptian regulations, however Tanta WWTP discharges exceeded the Egyptian Permissible limits (COD: 80 mg/l). These are six methods of sewage management and disposal, namely municipal sewage systems have treatment plants connected to them (remove at least 95% of bacteria present in sewage) and the sludge is subjected to an anaerobic process to eliminate disease-causing microbes, off-site sewer systems came as a result of increased urbanization, where the sewer line collects waste from toilets, kitchens, and laundry, on-site systems, full sewage systems, lagoons (large open affluent ponds) and pit latrines utilized by marginalized communities and comprise borehole, ventilated improved pit, and shallow trench latrines. Many bacterial, viral and helminth parasites can be spread from the disposal of wastewater, untreated or improperly treated wastewater (a review by [40] and many references therein; [41, 42, 43]), and hence prevention of wastewater-borne diseases and protection of public health are primary objectives of sanitary wastewater disposal [39]. To meet requirements of dumping or reuse, domestic wastewater typically needs proper preparation or treatment before it is cleansed and becomes fit for disposal or reuse [39]. Mostly, in many circumstances comprising the domestic wastewater runoffs, the treatment encompasses the removal of suspended solids and BOD_5, which are the two common factors of primary concern. If treated effluent is to be released into a stream or a landscape, the grade of treatment

provided to wastewater will mainly be based on specific standards prescribed by the regulatory agency. If the discharge is to be reused, the quality of the effluent required will specify the grade of treatment. As reported by [39], comprehensive treatment of wastewater is conducted a successive processes of physical, chemical and biological processes. The common benchmark of assessing the performance of a sewage treatment plant is the grade of reduction in BOD_5 and suspended solids, which create organic contamination. The performance efficiency of treatment plants depend on appropriate design and construction in addition to professional operation and maintenance [44,45].

Polluted sediment can threaten living organisms in the benthic habitat of aquatic ecosystem, leading to the exposure of worms, insects and crustaceans to higher levels of toxic chemicals. As a consequence, the food availability for fish as well as other aquatic organisms is reduced [46]. According to [47], sediment contaminants are incorporated into the benthic organisms via a biological progression referred to as bioaccumulation. Toxins are transferred to predatory organisms of benthic fauna, moving up the aquatic food chains and food webs at higher levels in a process called biomagnification. [48] suggested that pollutants in the aquatic environment which alter the physiological mechanisms, developmental progression and/or fish survival will influence organisms on the top of food chains and food webs. Nevertheless, some heavy metals are essential elements for living organisms, they are poisonous at higher levels as they cause oxidative stress through the release of free radicals [49]. Moreover, heavy metals can replace essential metal elements in enzymes, pigments, and other biochemical compounds, leading to the disruption of their functions [50, 51, 52]. Therefore, heavy metals can destroy the biodiversity of fauna and flora [53]. Unlike copper and iron, zinc does not correlate to the formation of free radicals; fortunately, this heavy metal exhibits antioxidant characters where it is a component of many enzymes, for example protease, anhydrates, superoxide dismutase that play a significant role in the biosynthesis of proteins, production of energy and protection of fertility against damage induced by superoxide radicals [54,55].

References

1 Martí, E.; Riera, J. and Sabater, F. (2010). Effects of wastewater treatment plants on stream nutrient dynamics under water scarcity conditions. In: Sabater S, Barceló D, editors. Water scarcity in the Mediterranean perspectives under global change. Springer; p. 173–195.

2 Dyer, S. D. and Wang, X. (2002). A comparison of stream biological responses to discharge from wastewater treatment plants in high and low population density areas. Environmental Toxicology and Chemistry, **21**: 1065–1075.

3 Bueno, M. J. M.; Gomez, M. J.; Herrera, S.; Hernando, M. D.; Agüera, A. and Fernández-Alba, A. R. (2012). Occurrence and persistence of organic emerging contaminants and priority pollutants in five sewage treatment plants of Spain: two years pilot survey monitoring. Environmental Pollution, **164**: 267–273.

4 Schwarzenbach, R. P.; Escher, B. I.; Fenner, K.; Hofstetter, T. B.; Johnson, C. A. and von Gunten, U. (2006). The challenge of micropollutants in aquatic systems. Science, **313**: 1072–1077.

5 Bundschuh, M.; Pierstorf, R.; Schreiber, W. H. and Schulz, R. (2011a). Positive effects of wastewater ozonation displayed by in situ bioassays in the receiving stream. Environmental Science and Technology, **45**: 3774–3780.

6 Bundschuh, M.; Zubrod, J. P.; Kosol, S.; Maltby, L.; Stang, C. and Duester L (2011b). Fungal composition on leaves explains pollutant-mediated indirect effects on amphipod feeding. Aquatic Toxicology, **104**: 32–37.

7 Englert, D.; Zubrod, J. P.; Schulz, R. and Bundschuh, M. (2013). Effects of municipal wastewater on aquatic ecosystem structure and function in the receiving stream. Science of the Total Environment, 454–455: 401-410.

8 Central Agency for Public Mobilization and Statistics (2020). Wastewater treatment of Egypt. Monthly Bulletin, June 2020.

9 Massoud, M. A.; Tarhini, A. and Nasr, J. A. (2009). Decentralized approaches to wastewater treatment and management: applicability in developing countries. *Journal of Environmental Management*, **90**: 652–659.

10 Qadir, M.; Wichelns, D.; Raschid-Sally, L.; McCornick, P. G.; Drechsel, P.; Bahri, A.; Minhas, P. S. (2010). The challenges of wastewater irrigation in developing countries. Agricultural Water Management, **97**: 561–568.

11 Noyola, A.; Padilla-Rivera, A.; Morgan-Sagastume, J. M.; Guereca, L. P. and Hernandez-Padilla, F. (2012). Typology of municipal wastewater treatment technologies in Latin America. CLEAN - Soil, Air, Water, **40**: 926–932.

12 Mara, D. (2013). Domestic wastewater treatment in developing countries. London: Routledge.

13 Piper, C. S. (1947). Soil and plant analysis. Interscience, New York. 368 p.

14 Hesse, P. R. (1971). A Textbook of Soil Chemical Analysis. London: John Murray (1971), pp. 520.

15 Olsen, S. R. and Sommers, L. E. (1982). Phosphorus. In A. L. page et al., (ed) Methods of soil analysis, 2nd ed. Agronomy **9**: 403-430.

16 APHA (2005). American Public Health Association, Standard Methods for the Examination of Water and Wastewater. 21st Ed., Washington, DC, USA.

17 Jackson, M. L. (1973). Soil chemical analysis. Prentice Hall of India. Pvt Ltd., New Delhi. p.498.

18 Fulton, T. W. (1904). The rate of growth of fishes. 22nd Annual Report of the Fishery Board of Scotland, 1904, Part3, pp. 141–241.

19 Richter, H.; Luckstadt, C.; Focken, U. L. and Becker, K. (2000). An improved procedure to assess fish condition on the basis of length–weight relationships. Archive of Fishery and Marine Research, **48**: 255–264.

20 Omar, M. and Moussa, A. (2016). Water management in Egypt for facing the future challenges. *Journal of Advanced Research*, **7(3):** 403-412.

21 Ashour, M. A.; El Attar, S. T.; Rafaat, Y. M. and Mohamed, M. N. (2009). Water Resources Management in Egypt. *Journal of Engineering Sciences, Assiut University*, **37(2**): 269-279.

22 Attia, B. B. (2004). Water as a Basic Human Right In Egypt.

23 Lofrano, G. and Brown, J. (2010). Wastewater management through the ages: A history of mankind. Science of the Total Environment, **408 (22**): 5254–64.

24 Angelakis, A., Snyder S., 2015. Wastewater Treatment and Reuse: Past, Present, and Future. Water, **7 (9)**: 4887–4895.

25 Shifrin, N. (2005). Pollution Management in the Twentieth Century. *Journal of Environmental Engineering*, **131(5):** 676-691.

26 UNICEF and WHO (2017). Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines. Geneva, Switzerland: World Health Organization.

27 Gavrilescu, M.; Demnerova, K.; Aamand, J.; Agathos, S. and Fava, F. (2014). Emerging pollutants in the environment: Present and future challenges in biomonitoring, ecological risks and bioremediation. New Biotechnology, **32 (1**): 147–156.

28 Archer, E., Petrie, B., Kasprzyk-Hordern, B., Wolfaardt, G. M. (2017). The fate of pharmaceuticals and personal care products (PPCPs), endocrine disrupting contaminants (EDCs), metabolites and illicit drugs in a WWTW and environmental waters. Chemosphere, **174**, 437–446.

29 Barbosa, M. O.; Moreira, N. F. F.; Ribeiro, A. R.; Pereira, M. F. R. and Silva, A. M. T. (2016). Occurrence and removal of organic micropollutants: An overview of the watch list of EU Decision 2015/495. Water Research, **94**: 257–279.

30 UNDP (2016). Human Developing Report. New York, USA: United Nations Developing Countries.

31 UN-Water (2017). The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource. UNESCO, Paris.

32 Marlow, D.R.; Moglia, M.; Cook, S. and Beale, D.J. (2013). Towards sustainable urban water management: A critical reassessment. Water Resources, **47**: 7150–7161.
33 Ren, J. and Liang, H. (2017). Multi-criteria group decision-making based sustainability measurement of wastewater treatment processes. Environmental Impact Assessment Review, **65**: 91-99.
34 Arroyo, P., Molinos-Senante, M., 2018. Selecting appropriate wastewater treatment technologies using a choosing-by-advantages approach. Science of the Total Environment, **625**: 819–827.
35 ISO-14040 (2006). Environmental management-Life cycle assessment-Principles and framework. International Organization for Standardization, Geneva, Switzerland.
36 Ahmed, M. T. (2010). Life Cycle Analysis in Wastewater: A Sustainability Perspective. In Waste Water Treatment and Reuse in the Mediterranean Region, eds. D. Barceló, M. Petrović, pp. 125–154. Springer-Verlag, Berlin, Germany.
37 Flores-Alsina, X.; Gallego, A.; Feijoo, G. and Rodriguez-Roda, I. (2010). Multiple-objective evaluation of wastewater treatment plant control alternatives. *Journal of Environmental Management*, **91 (5**): 1193-1201.
38 Larrey-Lassalle, P.; Catel, L.; Roux, P. and Rosenbaum, R. K. (2017). An innovative implementation of LCA within the EIA procedure: Lessons learned from two Wastewater Treatment Plant case studies. Environmental Impact Assessment Review, **63**: 95-106.
39 Ramadan, M. A.; Abdullah, A. M. and Eltawab, O. A. (2017). Evaluation of Wastewater Treatment Plants in El-Gharbia Governorate, Egypt. Organic Chemistry Current Research, 168:42.
40 Ikehata, K.; Liu, Y. and Sun, R. (2009). Health Effects Associated with Wastewater Treatment, Reuse, and Disposal. Water Environment Research, **81(10**): 2126-2146.
41 Aluma, A.; Rubinob, J. R. and KhalidIjazb, M. (2010). The global war against intestinal parasites-should we use a holistic approach? *International Journal of Infectious Diseases*, **14(9):** e732-e738.
42 Amoah, I. D.; Kumari, S. and Bux, F. (2020). Coronaviruses in wastewater processes: Source, fate and potential risk. Environment International, **143**, 105962 (12 pages).
43 Food and Agriculture Organization of the United Nations (FAO), World Organization for Animal Health (WOAH) and World Health Organization (WHO) (2020). Technical brief on water, sanitation, hygiene (WASH) and wastewater management to prevent infections and reduce the spread of antimicrobial resistance. 32 pages.
44 Pedersen, J. and Sinkjaer, O. (1992) Test of the activated sludge models capabilities as a procnostic tool on a pilot scale wastewater treatment plant. Water Science and Technology, **25**: 185-194.
45 Petersen, B.; Gernaey, K. V. Henze, M. and Vanrolleghem, P. A. (2002). A Comprehensive Model Calibration Procedure for Asm1. Proceedings of the Water Environment Federation, 2001(13).
46 Khayatzadeh, J. and Abbasi, E. (2010). The Effects of Heavy Metals on Aquatic Animals. The First International Applied Geological Congress, Department of Geology, Islamic Azad University - Mashad Branch, Iran, 26-28 April 2010.
47 Begum, A.; HariKrishna, S. and Khan, I. (2009). Analysis of Heavy metals in Water, Sediments and Fish samples of Madivala Lakes of Bangalore, Karnataka. *International Journal of Chemical and Technical Research*, **1(2):** 245-249.
48 Bassem, S. M. (2020). Water pollution and aquatic biodiversity. *Biodiversity International Journal*, **4(1):** 10-16.
49 Jaishankar, M.; Testen, T.; Anbalagan, N.; Mathew, B. B., and Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. Interdisciplinary Toxicology, **7(2):** 60–72.
50 Sharma, R. K. and Agrawal, M. (2005). Biological effects of heavy metals: An overview. *Journal of Environmental Biology*, **26(2):** 301-313.
51 Golovanova, I. L. (2008). Effects of heavy metals on the physiological and

biochemical status of fishes and aquatic invertebrates. Inland Water Biology, **1(1**): 93-101.

52 Singh, R.; Gautam, N.; Mishra, A. and Gupta, R. (2011). Heavy metals and living systems: An overview. *Indian Journal of Pharmacology*, **43(3):** 246–253.

53 Ghosh, M. and Singh, S. P. (2005). Review on phytoremediation of heavy metals and utilization of its byproducts. Applied Ecology Research, **3(1):** 1-18.

54 Athar, M. and Vohora. S. B. (2001). Heavy metals and environment, New Delhi. New Age International Publisher, 3-40.

55 Kacaniova, M.; Andreji, J.; Stranai, I.; Hascík, P.; Cubon, J. and Felsociova, S. (2007). Microbiological quality of fish meal and the effect on the heavy metalscontents. *Slovak Journal Animal Science*,**40(4):** 185 -188.