Desalination and Water Treatment
www.deswater.com

doi: 10.1080/19443994.2015.1012342

57 (2016) 2355–2364
January

Taylor & Francis
Taylor & Francis Group

Seasonal variation in microbiological and physicochemical characteristics of municipal wastewater in Al-Sharqiya province, Egypt (case study)

Samir Mahgoub[a,b,*], Petros Samaras[b], Howaida Abdelbasit[a], Hassan Abdelfattah[a]

[a]*Faculty of Agriculture, Microbiology Department, Zagazig University, Zagazig 44511, Egypt, Tel./Fax: +20 552287567; email: mahgoubsamir@gmail.com (S. Mahgoub)*
[b]*Laboratory of Water and Wastewater Technology, Department of Food Technology, Technological Educational Institute of Thessaloniki, 57400 Sindos, Thessaloniki, Greece*

Received 26 May 2014; Accepted 14 January 2015

ABSTRACT

This study was conducted to evaluate the changes in microbiological, physical and chemical quality in wastewater during treatment operations of 17 wastewater treatment plants (WTPs) in cold and hot climate over a one-year period and to evaluate the quality of wastewater in drainages that discharges from these WTPs distributed in the province of Al-Sharqiya, in Egypt, in order to examine their potential environmental impacts and assess their disposal options. Total bacterial count (TBC), total yeasts count (TYC), total *Candida* count (TCC), total coliform count (TCFC), total *Escherichia coli* (TEC) and total *Salmonella* and *Shigella* (TSSC) counts were analysed in several samples subjected to various treatment processes sequentially, including untreated wastewater (UW), aeration treatment wastewater, oxidation treatment wastewater, anaerobic treatment wastewater and effluent (treated) wastewater (TW). Physicochemical parameters (temperature, pH, total suspended solids (TSS), total dissolved solids (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrates (NO^{3-}), sulphites (SO^{4-}) and oil mg/l values of UW and TW in the WTPs) were examined in samples collected in different seasons. The results revealed that the influent wastewater was heavily contaminated with cultivable bacteria and inorganic and organic substances. Coliform bacteria were important indicators of pathogenic bacteria concentration reduction during the various wastewater processes; however, no correlation was found to *Candida* contamination. The TBC, TYC, TCC, TCFC, TEC and TSSC were significantly decreased ($p < 0.05$) in treated water, and the maximum removal of TBC (60%), TYMC (59%), TCC (75%), TCFC (77%), TEC (75%) and TSSC (74%) took place during treatment resulting in an effluent of high quality. Moreover, TSS, TDS, BOD, COD, sulphite, nitrate and oil levels were significantly reduced ($p < 0.05$) in the effluent, resulting in maximum removal of pH (6%), BOD (90%), COD (89%), TSS (88%) and SO_4 (86%), obtained at the effluent. The results indicated that the treatment plants had a significant role in the control of pollution load from microbial, organic and inorganic pollution at the province of Al-Sharqiya, Egypt. Furthermore, microbiological parameters are essential for monitoring the appropriate WTPs operation, while *Candida* might be a significant indicator of effluent microbiological quality.

---

*Corresponding author.

Presented at AdaptToClimate Conference, 27–28 March 2014, Nicosia, Cyprus

1944-3994/1944-3986

Keywords: Microbiological content; *Salmonella*; *Candida*; Municipal water; Wastewater treatment plant monitoring; Egypt

1. Introduction

Today major uncertainties have been arisen about the implications of changing climate on wastewater treatment and effluent quality. Climate change is expected to bring a variety of new challenges in the area of wastewater treatment processes on middle and long-term timeline. Evidence of the impact of climate change on the transmission of waterborne diseases has become clear [1]. Climate change is expected to have a significant impact on land surface water availability, contributing to a 20% reduction according to Mariotti et al. [2]. The Mediterranean basin represents a "hot spot" area due to climate change, by an increase in the average annual temperature between +3.5 and +3.9°C [3]. According to the Intergovernmental Panel on Climate Change scenario, the average global air temperature should increase between 1.8 and 4.0°C [4] during the twenty-first century and this increase might affect wastewater treatment processes. Moreover, an increasing drying period in summer is expected, particularly in the subtropics, low latitudes and mid-latitudes, in addition to the increased appearance of extreme events on a worldwide scale. The vulnerability assessment of water resources in the Nile basin in Egypt due to climatic change has been already reported [5]. Irrigation of agricultural lands by wastewaters, following varying levels of treatment, is increasing around the world [6–9]; therefore, the availability of reclaimed wastewater of appropriate quality is of great importance.

Pollution from wastewater is currently the greatest threat to the sustainable use of surface and groundwater in megacities. Today, household, commercial, and industrial effluents and raw untreated sewage are often discharged into the surface freshwater sources, while untreated wastewaters from villages and rural areas in the most of developing countries are often discharged directly into the waterways. The wastewater eventually percolates or is washed into the water bodies by rainstorms. The stagnating pools of wastewater in the open gutters and on the roads often provide the breeding grounds for mosquitoes and habitat for several bacteria and viruses. In addition, wastewater pools contain hazardous contaminants such as oil and grease, pesticides, ammonia and heavy metals [10]. When point source pollution is reduced in many countries (even if wastewater treatment plants (WTPs) begin to reach their capacity limits), climate (global) change impacts could increase the diffuse pollution due to urban or agricultural run-off. The climate change parameters affecting water quality include mainly the ambient (air) temperature and the increase of extreme hydrological events; in addition, soil drying–rewetting cycles and solar radiation increase should be considered. By the end of the 21st century, projected future climate change would lead to an increased portion of treated wastewater in rivers due to reduced discharges during low-flow situations [11].

Waterborne pathogens could be spread within the freshwater after a contamination by animal or human waste due to heavy rainfall discharge in combined sewer systems (CSS). When the flow exceeds the CSS capacity, the sewers overflow directly into surface water body [12]. Coliform load in a tidal embayment was studied, and it was shown that storm water coming from the surrounding watershed represented a primary source of coliform [13]. Moreover, higher water temperatures will probably lead to a pathogen survival increase in the environment, although there is still no clear evidence [14]. Half of the waterborne disease outbreaks in the US during the last half century followed a period of extreme rainfall [15]. Even though the risk of diseases outbreak linked to mains drinking waters is low in developing countries, private supplies would be at risk [14], and even properly constructed onsite wastewater treatment systems may cause a waterborne outbreak [16]. In addition, an increase in temperature may worsen water quality with regard to waterborne diseases especially cholera disease in Asia, Africa and South America [14]. At last, it was shown that by increased UV radiation due to ozone layer depletion, natural organic substances might trap higher levels of UV energy resulting to their breakdown to more bioavailable organic compounds, minerals and micronutrients. All these processes could stimulate bacterial activity in aquatic ecosystems [17]. The prevalence of pathogenic microbes in treated wastewater has raised concerns about the capacities of existing treatment to remove theses microbes [18].

Recently, the average log removals rates in effluents by three different pilot-scale sand filters were 2.2–3.5 for pathogenic human noro- and adenoviruses and 4.3–5.2 and 4.6–5.4 log CFU/ml for indicator viruses and bacteria, respectively. The system that effectively removed microbes was also efficient for removing nutrients [19]. The aim of this study was to assess the performance of 17 WTPs, evaluate of seasonal variation and examine of the efficiency of various treatment steps in cold and hot climate over a one-year period from April 2012 to March 2013 in the province of Al-Sharqiya, Egypt. Additionally, the second aim of this study was to evaluate the quality of wastewater in drainages that discharges from these WTPs in order to demonstrate long-term benefits to the mitigation of climate change in the Mediterranean region.

2. Materials and methods

2.1. Study area

The target area is Al-Sharqiya governorate, Egypt (Fig. 1). This map was created by ArcGIS (geographic information system) that working with maps and geographic information. The Al-Sharqiya is located at latitude 30.7˚N and 31.63˚E longitudinal at an altitude of 10 m above the mean sea level. Treated wastewater from WTPs is discharged into the Masraf Bilbyas Drain and then into Bahr Al Baqar Drain (BEBD) (Fig. 1), which in turn drains to Lake Manzala, 170 km away from Cairo.

2.2. Water sampling

Wastewater samples were collected from 17 WTPs which applying the same treatment process steps. These stations are located in the megacities in Al-Sharqiya, Egypt. They served about 6.884.000 inhabitants, receiving about 387.000 m^3/y of sewage water and indirect discharge of about 138.000 m^3/y. Monthly samples were collected from the target points, WTPs and BEBD, between 8 and 11 am in a sterile Schott glass bottle during different seasons of 2012–2013. Each sample was collected from a point of fast flow at a depth half that of the total height, in order to avoid debris and collecting exclusively surface water. The samples were placed in a container filled with ice, transported to the microbiological laboratory, Microbiology Department, Faculty of Agriculture, Zagazig University, and stored at 4˚C prior to analysis.

2.3. Microbiological analysis

Wastewater samples (10 ml) were aseptically pipetted into a sterile Erlenmeyer flask and diluted tenfold by adding 90 ml of sterile buffered peptone water (BPW: peptone 1 g/l, pH 7.4) followed by subsequent decimal dilution (up to 10^{-7}) using the BPW. Total bacterial counts (TBC) for wastewater samples were conducted in triplicate according to the American Public Health Association [20], using plate count agar, and incubated at 30°C for 48 h. Results are expressed as the mean ($\log_{10}$), while the calculated standard error is indicated. For total coliforms measurement, 1.0 ml from dilution sample was poured in sterile Petri dish and then poured 10 ml of Violet Red Bile Dextrose Agar (Biolife 402188). After solidifying media, a 10 ml overlay of the same molten medium was added. The incubation was carried out at 37˚C for 24 h. For *E. coli*, the detection was done using the selective Chromo Cult Coliform agar (Merck KGaA, Germany) according to the manufacturer's instructions and confirmed by Kovac's indole reagent. Total yeasts were detected onto Rose Bengal Chloramphenicol Agar (Lab M, 36, supplemented with chloramphenicol, X009) at 25˚C for 5 d;

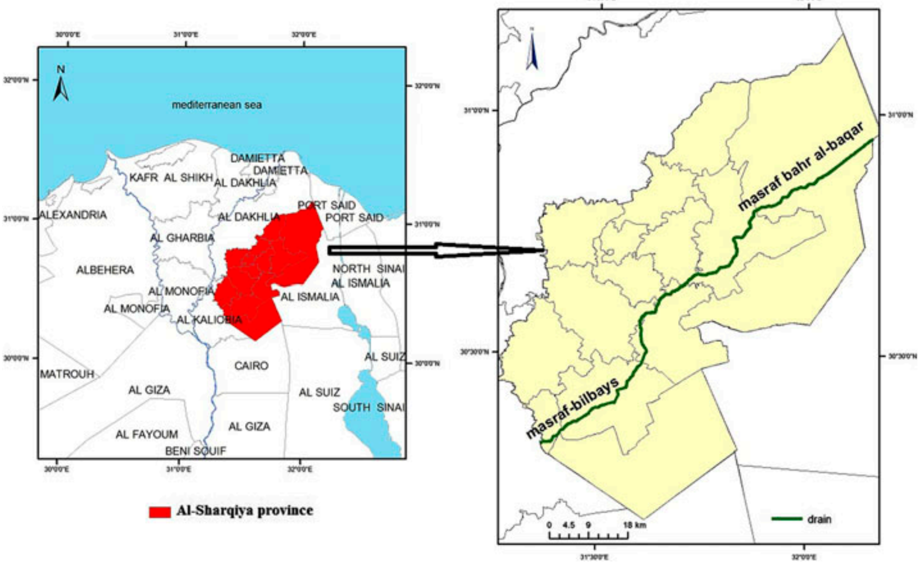

Fig. 1. Map of Delta Egypt explained Al-Sharqiya governorate (area of study), Egypt.

Candida counts were counted on *Candida* Agar (Biolife, 4012802, Milano, Italy) by spreading 0.1 ml of sample onto media and incubated at 37°C for 48 h. All plates were examined for typical colony types and morphological characteristics associated to each culture medium. *Salmonella* and *Shigella* were counted on *Salmonella* & *Shigella* Agar (SS Agar, LAB052, UK) after incubation for 24 h at 37°C.

2.4. Data collection and statistical analysis

In addition to microbiological data, physicochemical data were used that were routinely collected each week by the regional Holding Company of Water and Wastewater management, used to evaluate the treated wastewater quality. These parameters include the following: temperature, pH, total suspended solids (TSS), turbidity, total dissolved solids (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate (NO_3), sulphite (SO_4) and oil values [20]. Wastewater quality data interpretations of these stations and drains were conducted in a period of one year from April 2012 to March 2013. The removal efficiency of each treated wastewater sample in the WTPs was calculated as [(influent−effluent)/influent × 100]. All analyses were performed in three replicates. The results were expressed by the mean of the two samples plus the standard error. Data were statistically analysed using ANOVA through the general linear models procedure of the statistical analysis system software (SAS version 9.1, SAS Institute, Inc, 2003). Least significant differences were used to separate means at $p < 0.05$.

3. Results and discussions

3.1. Influent, effluent characteristics and microbial indicators removal efficiency

The level of TBC, total yeasts and moulds count (TYC), total *Candida* count (TCC), total coliform count (TCFC), total *E. coli* (TEC) and total *Salmonella* and *Shigella* (TSSC) counts in wastewater samples collected from different treatment steps in 17 WTPs is presented in Figs. 2 and 3 and Tables 1 and 2. The pathogenic bacteria and microbial indicators are used to evaluate WTPs through a one-year period from April 2012 to March 2013. The results revealed that the influent in the WTPs was heavily contaminated with cultivable bacteria and yeasts. The TBC, TYC, TCC, TCFC, TEC and TSSC counts were significantly decreased ($p < 0.05$) in the TW during all periods of study. Among the various types of wastewater disinfection, chlorination has gained wide acceptance commercially, because of its simple application and moderate cost [21]. However, the TBC, TYC, TCC, TCFC, TEC and TSSC counts were varying from a minimum of 3.1 log CFU/ml to maximum 9.2 log/CFU/ml, from 2.1 to 5.76 log CFU/ml, from 1.0 to 4.47 log CFU/ml, from 1.2 to 5.86 log CFU/ml, from 1.2 to 5.1 log CFU/ml and from 1.5 to 5.71 log CFU/ml (Figs. 2 and 3), respectively. The average log removals of TBC, TYC, TCFC, TEC, TSSC and TCC counts after treated wastewater were 4.71 (58.08%), 2.87 (56%), 3.20 (57.87%), 2.33 (49.44%), 3.55 (66.03) and 1.97 (59.51%) log CFU/ml, respectively (Table 1). The maximum removal of TBC was (60%), TYC (59%), TCC (75%), TCFC (77%), TEC (75%) and TSSC (74%) of TW in August, September and October 2012. Coliforms, *E. coli* and *Salmonella* spp. have been accepted as contamination indicator bacteria in treated wastewater [22]. Moreover, seasonal conditions appear to have a clear effect on performance efficiencies, emphasizing the strongest role of microbial populations especially in hot climates [23,24]. However, the capacity of WTPs could not sufficient to counteract increased domestic wastewater. The reduction in microbial groups may have been influenced by the seasonal changes and the volume of receiving stream [25]. The average log removals after treated wastewater by three different pilot-scale sand filters were 4.6–5.4 log CFU/ml for bacteria. The system that effectively removed microbes was also efficient at removing nutrients. The coliform bacteria were correlated ($r = 0.83$) indicators of a reduction in concentrations of pathogenic bacteria during the wastewater treatment, but were not correlated ($r = -0.33$) to *Candida* contamination of wastewater (Table 2). Total coliforms load in a tidal embayment was studied and shown that storm water coming from the surrounding watershed is a primary source of coliform [13]. The presence of coliforms is usually assumed to indicate the potential presence of other faecal pathogens such as *Salmonella* spp., *Shigella* spp. or pathogenic strains of *E. coli* [26]. These organisms can cause gastroenteric illnesses via the faecal/oral route through the consumption of raw produce irrigated crops with contaminated water. Moreover, higher water temperatures will probably lead to a pathogen survival increase in the environment, although there is still no clear evidence [13]. Its logic is that after tertiary treatment, the pathogens could be absent, but in this study, the wastewater treatment received more domestic water than its capacity and the conventional tertiary treatment was not applied correctly. In Europe, *Salmonella* spp. was more rarely detected (16.3%) in the reclaimed wastewater and *Campylobacter* cells were only found in 2% of samples [27].

3.2. Microbial indicators in drainages

The average levels of bacterial indicators (TBC, TYC, TCC, TCFC, TEC and TSSC), in 10 sites on BEBD

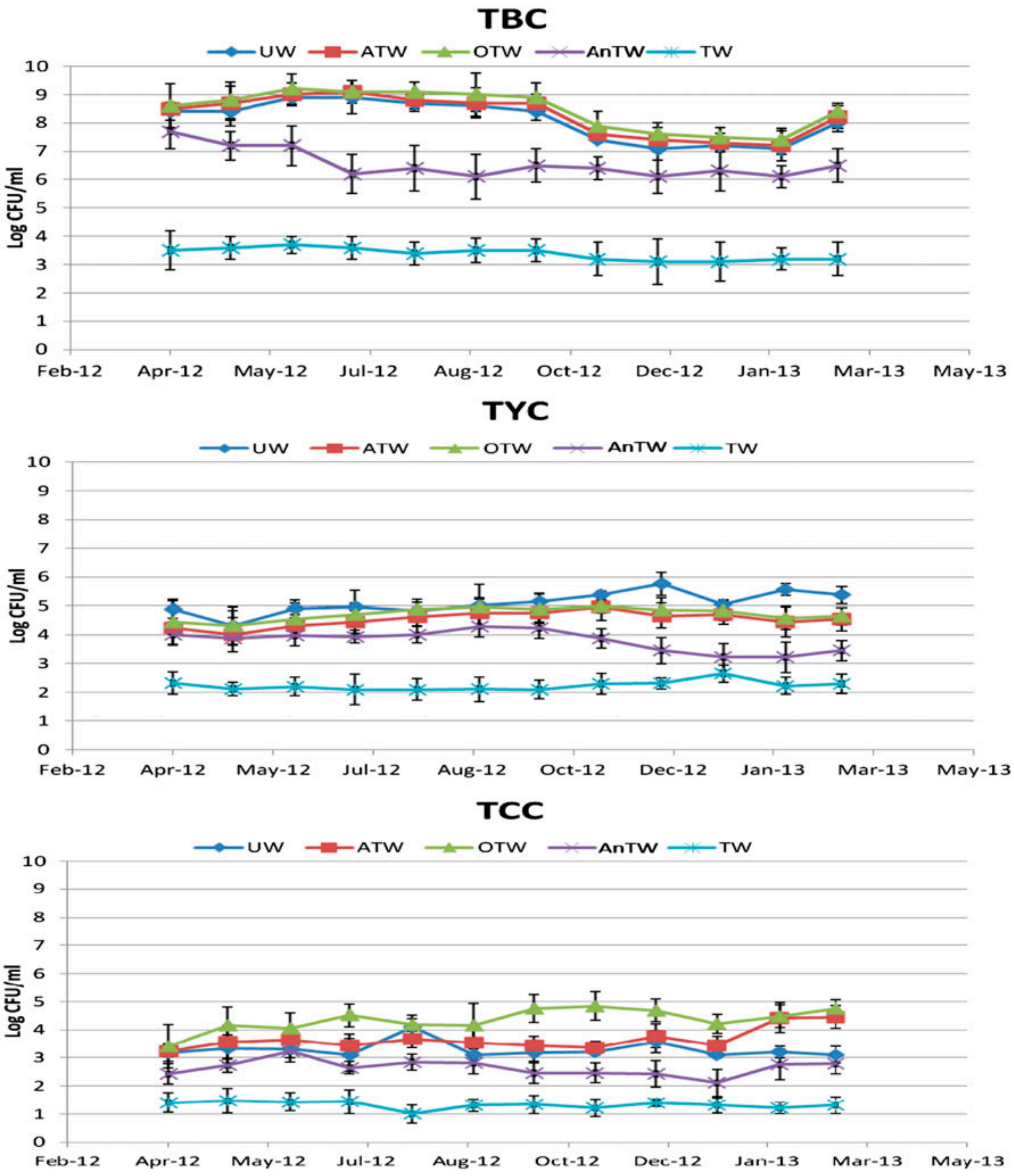

Fig. 2. The average levels of TBC, TYC and TCC in wastewater through treatment steps in 17 WTPs during the study period (April 2012 to March 2013).

located in Al-Sharqiya, were varying from a minimum of 6.8 log CFU/ml to maximum 9.7 log/CFU/ml, from 4.6 to 6.06 log CFU/ml, from 4.0 to 5.49 log CFU/ml, from 4.52 to 5.66 log CFU/ml, from 4.32 to 5.46 log CFU/ml and from 5.15 to 5.85 log CFU/ml, respectively (data not shown). These high levels of microbes resulted from the majority of villages and rural areas discharge their raw domestic wastewater directly into the waterways. The discharges are increasing year after year due to the population growth as well as the rapid implementation of water supply networks in many villages without the parallel construction of sewage systems. In Egypt, the increasing population, urbanization and industrialization resulted in a large proportion of mostly rural communities lacking adequate sanitation, waste disposal and

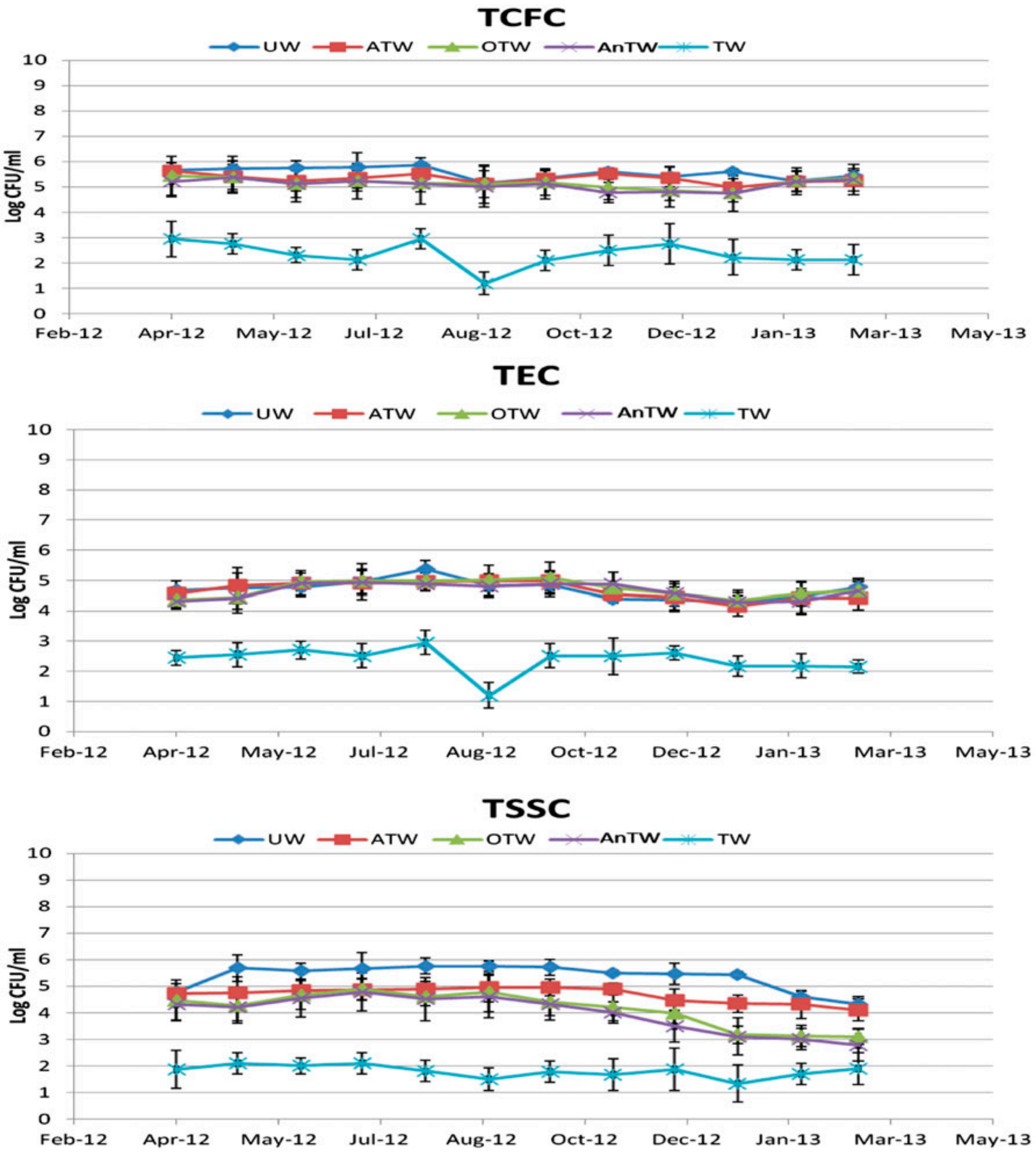

Fig. 3. The average levels of TCFC, TEC and TSSC in wastewater through treatment steps in 17 WTPS during the study period (April 2012 to March 2013).

access to safety wastewater. When the flow exceeds the CSS capacity, the sewers overflow directly into surface water body [11].

3.3. *Influent, effluent characteristics and nutrients removal efficiency*

The values of COD, BOD and TSS contents in the wastewater samples collected from different treatment processes in the WTPs are shown in Fig. 4. All targeted parameters were detected twice a month in influent and effluent samples throughout the year. They showed higher values in cold seasons than hot seasons. The treatment of aeration caused a dramatic ($p < 0.05$) reduction in COD and BOD contents between influent and effluent. The targeted parameters (minimum to maximum, mg/l: COD (441–541), BOD (367–421) and TSS (289–320) were detected in all

Table 1
RE of TBC, TYC, TCC, TCFC, TEC and TSSC of wastewater in 17 WTPs during the study period (April 2012 to March 2013)

Time (month)	RE-TBC	RE-TYC	RE-TCFC	RE-TEC	RE-TSSC	RE-TCC
Apr-12	58.33	52.46	47.88	47.65	60.96	55.66
May-12	57.14	51.27	51.75	46.11	63.09	55.86
Jun-12	58.43	55.19	59.83	43.31	64.09	56.80
Jul-12	59.55	57.66	63.26	49.40	62.79	53.70
Aug-12	60.92	56.52	49.66	44.96	68.75	75.61
Sep-12	59.30	57.97	76.70	75.21	73.91	57.88
Oct-12	58.33	59.14	60.63	48.25	68.83	57.86
Nov-12	56.76	57.33	55.26	43.05	69.58	62.31
Dec-12	56.34	59.90	48.98	40.27	65.81	60.50
Jan-13	56.94	47.52	60.43	49.30	75.37	57.88
Feb-13	54.93	59.89	59.46	51.12	63.20	62.19
Mar-13	60.00	57.17	60.59	54.72	55.92	57.88
Total mean of log removals CFU/ml	4.71	2.87	3.20	2.33	3.55	1.97
Total mean of [a]RE%	58.08	56.00	57.87	49.44	66.03	59.51

[a]RE, removal efficiency = [(influent−effluent)/influent × 100].

Table 2
Correlations between microbial groups (TBC, TYC, TCC, TCFC, TEC) and total *Salmonella* and *Shigella* counts (TSSC) in 17 WTPs during the study period (April 2012 to March 2013)

	TBC	TYC	TCFC	TEC	TSSC	TCC
TBC		0.020189*	0.188167*	0.283812*	−0.10849	0.19645*
TYMC			0.188741*	0.110162*	−0.19269	0.225603*
TCFC				0.833005*	0.341162*	−0.32795
EC					0.252595*	−0.19008
TSSC						0.243344*

*$p < 0.05$.

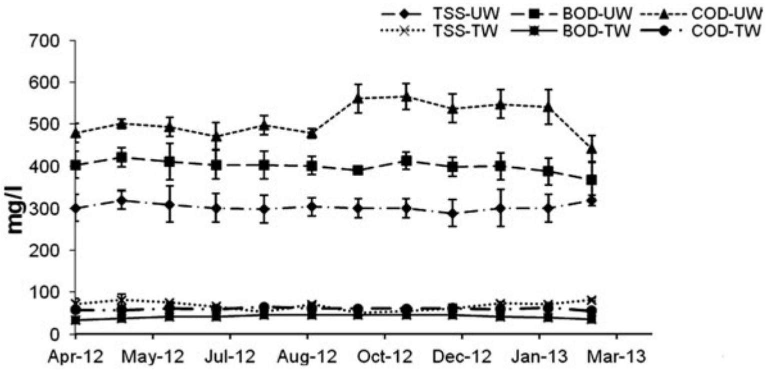

Fig. 4. The average levels of TSS, BOD, and COD of untreated wastewater (UW) and treated wastewater (TW)) in 17 WTPs during the study period (April 2012 to March 2013).

influent samples (Fig. 3). These targeted parameters were decreased significantly ($p < 0.05$) in all effluent samples, mg/l: COD (56–62), BOD (34–46) and TSS (52–82). The removal efficiency of COD was 86.95–89.22%, BOD was 88.83–91.56% and TSS was 74.83–82.73%. These results indicated that the removal efficiency of organic compounds in treated wastewater was incomplete by WTPs. From the literatures, it was

Table 3
Temperature, pH, total dissolved solids (TDS, mg/l), SO_4^-, NO_3^- and oil levels of untreated wastewater and treated wastewater in 17 WTPs during the study period (April 2012 to March 2013)

	Untreated wastewater						Treated wastewater					
Time (Month)	Temp.-UW	pH-UW	TDS-UW	SO_4^--UW	NO_3^--UW	Oil-UW	Temp.-TW	pH-TW	TDS-TW	SO^{4-}-TW	NO^{3-}-TW	Oil-TW
Apr-12	23 ± 3.1	7.6 ± 0.08	1,179 ± 31.2	71 ± 3.9	10 ± 1.5	66 ± 6.1	23 ± 3.5	7.4 ± 0.14	1,108 ± 37.2	6.7 ± 0.41	7.9 ± 0.77	7.3 ± 0.31
May-12	26 ± 3.2	7.6 ± 0.08	1,190 ± 32.3	75 ± 3.8	11 ± 1.9	62 ± 6.4	26 ± 3.5	7.5 ± 0.13	1,087 ± 33.1	6.7 ± 0.31	8.6 ± 0.72	7.2 ± 0.36
Jun-12	28 ± 3.3	7.7 ± 0.07	1,166 ± 34.1	66 ± 3.7	11 ± 1.8	69 ± 6.5	28 ± 3.3	7.5 ± 0.12	1,149 ± 43.1	6.7 ± 0.41	8.7 ± 0.73	7.4 ± 0.35
Jul-12	29 ± 3.5	7.7 ± 0.07	1,156 ± 23.9	67 ± 3.9	12 ± 1.3	70 ± 6.4	27 ± 3.2	7.4 ± 0.13	1,148 ± 34.3	6.8 ± 0.41	9.5 ± 0.76	7.4 ± 0.37
Aug-12	24 ± 3.2	7.8 ± 0.07	1,194 ± 23.7	70 ± 3.9	12 ± 1.5	55 ± 6.3	24 ± 3.3	7.5 ± 0.14	1,193 ± 43.3	7.8 ± 0.43	9.6 ± 0.75	7.3 ± 0.38
Sep-12	27 ± 3.2	7.8 ± 0.09	1,197 ± 31.5	77 ± 3.8	13 ± 1.4	75 ± 6.3	27 ± 3.2	7.4 ± 0.12	1,190 ± 34.3	7.3 ± 0.32	10.3 ± 0.71	7.4 ± 0.38
Oct-12	27 ± 3.6	7.9 ± 0.09	1,107 ± 34.1	75 ± 3.7	12 ± 1.6	70 ± 6.1	27 ± 3.2	7.6 ± 0.15	1,118 ± 32.1	7.8 ± 0.33	10.1 ± 0.74	7.7 ± 0.37
Nov-12	22 ± 3.4	7.7 ± 0.07	1,190 ± 23.7	75 ± 3.8	11 ± 1.7	74 ± 6.7	22 ± 3.2	7.4 ± 0.14	1,144 ± 34.3	7.8 ± 0.31	8.4 ± 0.77	7.8 ± 0.35
Dec-12	18 ± 3.2	7.7 ± 0.08	1,106 ± 32.9	75 ± 3.8	10 ± 1.7	74 ± 6.1	18 ± 3.6	7.5 ± 0.18	1,143 ± 34.1	7.6 ± 0.34	7.8 ± 0.74	8.1 ± 0.33
Jan-13	19 ± 3.4	7.7 ± 0.08	1,190 ± 22.8	75 ± 3.8	13 ± 1.4	77 ± 6.4	17 ± 3.6	7.6 ± 0.19	1,162 ± 32.1	7.7 ± 0.45	10.2 ± 0.75	7.5 ± 0.32
Feb-13	19 ± 3.3	7.8 ± 0.09	1,184 ± 34.6	75 ± 3.9	13 ± 1.4	70 ± 6.3	19 ± 3.7	7.4 ± 0.11	1,061 ± 33.4	7.7 ± 0.43	9.5 ± 0.77	6.6 ± 0.34
Mar-13	24 ± 3.2	7.7 ± 0.06	1,177 ± 32.7	70 ± 3.9	12 ± 1.3	71 ± 6.2	24 ± 3.1	7.4 ± 0.21	1,146 ± 34.2	7.8 ± 0.31	9.8 ± 0.72	7.2 ± 0.34
Average	23.67	7.73	1169.67	72.58	11.67	69.42	23.67	7.49	1137.42	7.37	9.19	7.41
[a]RE								3.02	2.76	89.85	2.00	89.33

[a]RE, removal efficiency = [(influent-effluent)/influent × 100].

shown that with increased UV radiation due to ozone layer depletion, natural organic substance traps higher levels of UV energy and breaks down to more bioavailable organic compounds, minerals and micronutrients in water. All these processes could stimulate bacterial activity in aquatic ecosystems [16].

The values of temperature, pH, TDS, NO_3, SO_4 and oil levels in the wastewater samples collected from different treatment processes in the WTPs are shown in Table 3. These values were used to assess treated wastewater characteristics before discharge in waterways. Seasonal trends of TDS, NO_3, SO_4 and oil removals were observed twice monthly during the period of study. Monthly average of influent temperature and pH ranged from 18 to 29°C and from 7.6 to 7.9, while the average of effluent temperature ranged from 17 to 28°C and from 7.4 to 7.6, respectively (Table 3). There was no significant difference ($p > 0.05$) in the level of TDS and NO_3 in influent compared to the initial values recorded during the whole period of study. However, there is slight decrease in the NO_3 and TDS levels in effluent and this might be due to the lack of the efficiency of NO_3 and TDS removal during tertiary treatments in WTPs. The SO^{4-} and oil levels were significantly ($p < 0.05$) decreased in treated wastewater. The maximum removal of pH was 3.02%, TDS was 2.76%, NO_3 was 2% and SO_4 was 89.85% of treated wastewater compared to the initial values. Seasonal differences were observed in effluent NO_3 rates and COD, with the highest values in cold climate than hot climate. The targeted removal rate efficiencies greater than 75% were achieved for TSS, COD, BOD, SO_4 and oil levels. The efficiency of aeration on total carbon conversion rates depends on the bioavailability of easily degradable organic substances, on the abundance, composition and activity of microbial groups involved in degradation processes and on pre-existing environmental conditions such as oxygen supply, pH, temperature, water and nutrient values. A higher carbon conversion rate under aerated treatment than anaerobic conditions is attributed to aerobic microbial groups being able to convert semi-degradable and hardly degradable organic substances such as lignin which are resistant to anaerobic microbial breakdowns [28].

4. Conclusion

In this study, it was observed that almost all treated wastewater from the most of wastewater treatment plants were not above at the level of pollutants based on microbiological and physicochemical parameters. So, the treated wastewater from all stations satisfied the requirement for various agricultural purposes. On the contrary, the wastewater samples from Masraf Bahr Al Baqar drainage were highly polluted and unsafe for all purposes.

Acknowledgments

The authors are thankful to Zagazig University, Faculty of Agriculture, Microbiology Department and Holding Company of Water and Wastewater management at Zagazig, Egypt for facilities provided.

References

[1] J.B. Rose, P.R. Epstein, E.K. Lipp, B.H. Sherman, S.M. Bernard, J.A. Patz, Climate variability and change in the United States: Potential impacts on water- and foodborne diseases caused by microbiologic agent. Environ. Health Perspect. 109 (2001) 211–221.

[2] A. Mariotti, N. Zeng, J.-H. Yoon, V. Artale, A. Navarra, P. Alpert, L.Z.X. Li, Mediterranean water cycle changes: Transition to drier 21st century conditions in observations and CMIP3 simulations, Environ. Res. Lett. 3 (2008) 044001.

[3] F. Giorgi, Climate change hot-spots, Geophys. Res. Lett. 33 (2006) L08707.

[4] B.C. Bates, Z.W. Kundzewicz, S. Wu, J.P. Palutikof, Climate Change and Water Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 2008.

[5] M.S. Kenneth, N. David, D.E.D. El Quosy, Vulnerability assessment of water resources in Egypt to climatic change in the Nile Basin, Clim. Res. 6 (1996) 89–95.

[6] G. Barkle, R. Stenger, P. Singleteon, D. Painter, Effect of regular irrigation with dairy farm effluent on soil organic matter and soil microbial biomass, Aust. J. Soil Res. 38 (2000) 1087–1097.

[7] F. Papadopoulos, G. Parissopoulos, A. Papadopoulos, A. Zdragas, D. Ntanos, C. Prochaska, I. Metaxa, Assessment of reclaimed municipal wastewater application on rice cultivation, Environ. Manage. 43 (2009) 135–143.

[8] M. Arienzo, E.W. Christen, W. Quayle, A. Kumar, A review of the fate of potassium in the soil-plant system after land application of wastewaters, J. Hazard. Mater. 164 (2009) 415–422.

[9] K.P.M. Mosse, A.F. Patti, R.J. Smernik, E.W. Christen, T.R. Cavagnaro, Physicochemical and microbiological effects of long- and short-term winery waste wastewater application to soils, J. Hazard. Mater. 201–202(30) (2012) 219–228.

[10] J.K. Saliu, O.J. Eruteya, Biodiversity of gutters in Lagos Metropolis, Nigeria, J. Biol. Sci. 6(5) (2006) 936–940.

[11] M.P. Schlüsener, P. Hardenbicker, E. Nilson, M. Schulz, C. Viergutz, T.A. Ternes, Occurrence of venlafaxine, other antidepressants and selected metabolites in the Rhine catchment in the face of climate change, Environ. Pollut. 196 (2015) 247–256.

[12] D.F. Charron, M.K. Thomas, D. Waltner-Toews, J.J. Aramini, T. Edge, R.A. Kent, A.R. Maarouf, J. Wilson, Vulnerability of waterborne diseases to climate change in canada: A review, J. Toxicol. Environ. Health Part A 67 (2004) 1667–1677.

[13] A.M. Pednekar, S.B. Grant, Y. Jeong, Y. Poon, C. Oancea, Influence of climate change, tidal mixing, and watershed urbanization on historical water quality in newport bay, a saltwater wetland and tidal embayment in southern California, Environ. Sci. Technol. 39 (2005) 9071–9082.

[14] P.R. Hunter, Climate change and waterborne and vector-borne disease, J. Appl. Microbiol. 94 (2003) 37S–46S.

[15] F.C. Curriero, J.A. Patz, J.B. Rose, S. Lele, The association between extreme precipitation and waterborne disease outbreaks in the united states, 1948–1994, Am. J. Public Health 91 (2001) 1194–1199.

[16] M.A. Borchardt, K.R. Bradbury, E.C. Alexander, R.J. Kolberg, S.C. Alexander, J.R. Archer, L.A. Braatz, B.M. Forest, J.A. Green, S.K. Spencer, Norovirus outbreak caused by a new septic system in a dolomite aquifer, Ground Water 49 (2011) 85–97.

[17] Y.C. Soh, F. Roddick, J. van Leeuwen, The future of water in Australia: The potential effects of climate change and ozone depletion on Australian water quality, quantity and treatability, Environmentalist 28 (2008) 158–165.

[18] L. Maunula, P. Klemola, A. Kauppinen, K. Soderberg, T. Ngujen, T. Pitkänen, S. Kaijalainen, M.L. Simonen, I.T. Miettinen, M. Lappalainen, J. Laine, R. Vuento, M. Kuusi, M. Roivainen, Enteric viruses in a large waterborne outbreak of acute gastroenteritis in Finland, Food Environ. Virol. 1 (2009) 31–36.

[19] A. Kauppinen, K. Martikainen, V. Matikka, A.-M. Veijalainen, T. Pitkänen, H. Heinonen-Tanski, I.T. Miettinen, Sand filters for removal of microbes and nutrients from wastewater during a one-year pilot study in a cold temperate climate, J. Environ. Manage. 133 (2014) 206–213.

[20] APHA, American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 21st ed., APHA, Washington, DC, 2005.

[21] P. Rusin, C. Gerba, Association of chlorination and UV irradiation to increasing antibiotic resistance in bacteria, Rev. Environ. Cont. Toxicol. 171 (2001) 1–52.

[22] L.A. Marcos, P. Yi, A. Machicado, R. Andrade, S. Samalvides, J. Sánchez, A. Terashima, Hepatic fibrosis and Fasciola hepatica infection in cattle, J. Helminthol. 81 (2007) 381–386.

[23] S. Mahgoub, H. Abdelbasit, H. Abdelfattah, S. Hamed, Monitoring phenol degrading *Candida* and bacterial pathogens in sewage treatment plant, Desalin. Water Treat. (2014) 1–8, doi:10.1080/19443994.2014.933627.

[24] S. Mahgoub, H. Abdelbasit, H. Abdelfattah, Removal of phenol and zinc by *Candida* isolated from wastewater for integrated biological treatment, Desalin. Water Treat. 53(12) (2014) 3381–3387, doi: 10.1080/19443994.2014.934113.

[25] S. George, V. Raju, M.R.V. Krishnan, T.V. Subramanian, K. Jayaraman, Production of protease by Bacillus amyloliquefaciensin solid-state fermentation [and its application in the unhairing of hides and skins, Process Biochem. 30 (1995) 457–462.

[26] A. Maimon, A. Tal, F. Friedler, A. Gross, Safe on-site reuse of greywater for irrigation—A critical review of current guidelines. Environ. Sci. Technol. 44 (2010) 3213–3220.

[27] C. Levantesi, R. La Mantia, C. Masciopinto, U. Böckelmann, M.N. Ayuso-Gabella, M. Salgot, V. Tandoi, E. Van Houtte, T. Wintgens, E. Grohmann, Quantification of pathogenic microorganisms and microbial indicators in three wastewater reclamation and managed aquifer recharge facilities in Europe, Sci. Total Environ. 408 (2010) 4923–4930.

[28] M. Ritzkowski, R. Stegmann, Emission behaviour of aerated landfills: Results of laboratory scale investigations, in: Proceedings of Sardinia 2003 Ninth Waste Management and Landfill Symposium, Cagliari, Italy, 2003.