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Performance Efficiency of Bacterial Removal in Some Drinking Water Treatment Plants in Damietta Governorate, Egypt

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Abstract

Water supplied to consumers must meet safety standards and be free of pathogens and hazardous materials. Thus, this study aims to evaluate the efficiency of disinfectant process and microbial control for some drinking water treatment facilities. Water samples were collected from eleven treatment plants at River Nile. The investigation based on bacteriological analysis of two sampling point for each plant, the source catchment (inlet) and produced water (outlet). The subjected analysis included total plate count (TPC) using pour plate method, total coliform (TC), fecal coliform (FC) and fecal streptococcus (FS) which conducted by membrane filtration. The result showed that the mean value of total plate count, total coliform, fecal coliform and fecal streptococcus of plant inlets were 301.4±138.1, 152.3±95.4, 28 ± 12, 33 ± 10.7 CFU/100ml, respectively, while for plant outlets were <1 in all parameters except total plate count which was 24.72±6.47 CFU/100ml. It was indicated that the fecal coliform and fecal streptococcus of plant inlets and outlets was within the permissible limit according to WHO standard but total plate count and total coliform exceeded the standard limit in most plant inlets. According to the results of the examined River Nile water samples, there was microbial contamination in catchment point of each station. However, drinking water treatment plants efficiency for the investigated biological parameters varied between 88% and 100%. In conclusion, it's recommended to perform a temporal and spatial assessment of Nile River at consistent intervals to mitigate the potential impacts and sustain the main drinking water source.

Keywords: Drinking Water Treatment Plants; River Nile; Total Coliform; Fecal Streptococcus; Fecal Coliform.

Introduction

The Nile River provides the majority of Egypt's drinking water, unfortunately a lot of household, industrial, and agricultural waste are dumped into the Nile (Afifi *et al*., 2023). To ensure that the water given to the public is safe and free from dangerous substances and pathogenic microorganisms, drinking water must adhere to strict requirements and standards

(Sabae and Rabeh, 2023). A multi-barrier method is needed to acquire safe and clean water, which is crucial for human health. This technique involves protecting water source from pollution and appropriately treating raw water. Surface water treatment plants are establishments that undergo treatment to render water from lakes, rivers, and reservoirs suitable for human consumption and other purposes. (Afifi *et al*., 2021).

The population will be at risk of intestinal and other infectious disease outbreaks if proper protection and treatment are not provided (Fiksdal and Tryland, 2008). Easy diffusible assays are required for risk assessment of water supply systems, for example by monitoring of raw water quality, assessment of treatment efficiency, monitoring of finished water quality as well as aquatic recreation (Obasohan *et al*., (2010); Hasballah *et al*., (2019); EL-Emam, (2020); Hasballah *et al*., (2023)). The water sources must be protected from contamination by human and animal wastes, which contain a variety of bacterial, viral, protozoan pathogens, and parasitic organisms.

The main source of microbiological contamination, which affects humans through contaminated groundwater from wastewater, landfills, or wastewater treatment plants and can lead to major health issues, is microorganisms from human or animal excreta (Lugo Luis *et al*., 2021). Water-borne diseases such salmonellosis, typhoid, paratyphoid, cholera, amoebic dysentery, poliomyelitis, and infectious hepatitis can result from the presence of pathogenic bacteria in the water supply (Stupar *et al*., 2022). Total bacteria count, total coliform, and fecal coliform bacteria are examples of indicator species that are used to quantify the microbiological quality of water. (McFeters, 2013).

Total coliform (TC) includes both non-fecal bacterial groupings and types of bacteria that originate in the feces. These microorganisms provide information about the overall sanitary condition of the water as well as any potential infectious disease risks. The TC indicator tests are carried out because the presence of these microorganisms suggests the existence of pathogenic groups of bacteria, which is neither cost-effective or practicable to test for every microorganism. If coliform bacteria are identified in treated water supplies, it indicates that either post-treatment contamination occurred, the treatment was insufficient, or the nutrients were too high. Therefore, TC bacteria testing is a useful tool for assessing the effectiveness of treatment as well as the systemic integrity of distribution. (Muhammad *et al*., 2009). Since fecal coliform (FC) bacteria are related to the digestive system, they are discharged into the environment through animal and human excrement feces. Although their existence suggests the presence of pathogenic bacteria originating from feces, they are not always harmful. Animal waste and untreated human sewage are two ways they can get into water bodies. Additionally, animal feces may flow into water bodies as a result of agricultural practices like applying fertilizers. People are more likely to have diarrhea-related illnesses and other infections when they drink water contaminated with feces. The majority of people who suffer from diarrhea belong to immunosuppressed individuals and children under five. This necessitates regularly checking the microbiological quality of drinking water sources (Kirianki, 2017). Disinfectant of drinking water by chlorination for microbial control had been investigated extensively. Pre- and post-chlorination are excessively employed to improve the performance efficiency of coagulation process, mitigate ammonia, and inactivate pathogenic microorganisms in drinking water (Swelam, et al., 2022). However, the formation of disinfection by-products should be carefully monitored because they form harmful disinfection byproducts which affects human health.

To the best of our knowledge, only a limited number of research have been focused on monitoring and evaluate the microbial quality for drinking water. Thus, the main target of the current study is to assess the performance efficiency of some water treatment plants located on River Nile, Damietta governorate, concerning bacteriological control.

Material and Methods

Study Area

The study area is situated in Damietta district and extend about 20 km of the Nile River Damietta Branch (Figure 1).

Triplicate seasonal water samples were collected from eleven conventional drinking water treatment plants (Table 1) over the

duration of one year (winter, spring, summer, and autumn 2022). Each plant had two sampling locations that represented the raw (inlet) and treated (outlet) water, respectively. The samples were gathered in 250 ml sterile glass tubes which were stored in an ice box before examination. The following method was adopted to get the inlet and outlet water samples: The bottle was held close to the river's base and lowered, neck down, to get the raw water directly while, treated water samples were collected from treatment plants tap through fully open the water tap and let the water run to waste for at least two minutes to get rid of any impurities. Water samples were subsequently collected to fill the sampling bottle without splashing when the water flow was reduced. Sample air was allowed to remain in the bottle (at least 2–5 cm) to facilitate shaking and mixing. Finally, the bottles were securely closed and brought to the lab in an ice box for a maximum of 24 hours. Bacteriological water quality was evaluated by the colony forming unit (CFU/100ml) approach (APHA, 2017).

Table 1: Samples locations in the study area

Site	GPS location	
St1	31°40'85"N	31°76'64.7"E
St2	31°39' 98"N	31°78' 30.1"E
St3	31°39' 79.9"N	31°77' 81.6"E
St4	31°39' 85.2"N	31°76' 75.1"E
St5	31°24'34.7"N	31°44'50.8"E
St6	31°27'64.2"N	31°64'97.5"E
St7	31°34.4' 61"N	31°70.2' 66"E
St8	31°33'79.5"N	31°74.5' 52"E
St9	31°40'80.5"N	31°74'72.90"E
St10	31° 28' 73.8"N	31°68' 47.1"E
St11	31° 27.3' 43"N	31°66' 69.1"E

Figure (1): Sampling sites along the study area

Analysis of Biological Parameter

According to APHA (2017), the total plate count (TPC) was recorded using the pour plate method. The petri dishes were filled with nutrient agar medium after adding sample, which was then allowed to become rigid. For twenty-four hours, the Petri dishes were inverted and incubated at 37°C. Additionally, negative control plates were incubated. Following the incubation times, a colony counter (Cook Electoromics LTD.) was used to count each dish and report the colony forming unit (CFU/100ml).

The membrane filtration technology method was used to count total coliform (TC) (Stuart, Bibby Scientific, UK). On top of a filter funnel was a sterile 0.45µm, 47mm membrane filter (Sartorius, Germany). Each water sample was added to a membrane in an amount of 10 mL, and the vacuum pump was then turned on. The water was kept under vacuum after it had gone through the filter until all of the liquid had passed. After that, the filter was moved to a 50mm disposable Petri dish filled with m –Endo agar media using sterile forceps, 20 milliliters of distilled water were used to rinse each funnel. All Petri dishes were incubated upside down in an incubator for 24 ± 2 hours at 37°C. All samples were analyzed by counting the blue and pink colonies under a colony counter (Acculite, Fisher, USA) and recorded as CFU/100mL.

Fecal coliform (FC) and fecal streptococcus (FS) were measured by membrane filtration and m–Endo agar media described in the standard method for the examination of water and wastewater APHA (2017).

The overall efficiency of the treatment plant was calculated using the following formula:

Treatment Efficiency

$$\text{Treatment efficiency}\,(\%) = \frac{Ci - Ce}{Ci} \times 100$$

Where, *Ci* and *Ce* are the inlet and outlet content of the studied biological parameter.

Results

Biological parameters and the efficiency of all stations were detected in Tables (2, 3, 4 and 5) and Figure (2).

Total plate count (TPC)

The average value of TPC for station (St) inlets and outlets was 301.4±138.1 and 24.72±6.47 (CFUs/100 ml), respectively. The maximum value was 690 CFUs/100ml at St 2 inlet in summer and 39 at St 7 outlet in spring, while the minimum value was 123 at St 9 outlet in

summer and 15 at St 5 outlet in spring.

Total Coliforms (TC)

The averages of total coliform for St inlets were 152.3±95.4 and 0 CFUs/ml. The highest value was 420 (CFUs/100 ml) at St 10 inlet in summer, while the lowest value was 54 at St 11 inlet in summer. There was total coliform (<1) in the treated water (St outlets).

Fecal coliforms (FC)

The concentration of fecal coliform of plant inlets was 28 ± 12 CFUs/ml, while the maximum value was 52 CFUs/100 ml at St 2 inlet in autumn, and the minimum value was 14 CFUs/100 ml at St 4 inlet in summer. The Fecal coliform result for St outlet (<1 CFUs/100 ml) at all St outlets in all seasons.

Fecal streptococci (FS)

The annual value of fecal streptococcus for plant inlets during study period varied between 56 CFUs/ml at St 4 inlet in autumn and 13 CFUs/ml at St 8 inlet in winter with an average 33±10.7 CFUs/ml. The concentration of fecal streptococcus of St outlets was <1 CFUs/ml at all plant outlets in all seasons.

Drinking water treatment plants efficiency

The efficiency of the bacterial control by drinking water treatment plants (Table 5) ranged from 88 of TPC removal to 100 %, where the St 8 and St 10 showed the highest percentage (100%) of total coliform removal. Total plate count efficiency removal varied between 88% at St 7 and 95 % at St 2. The removal efficiency of total coliform was 99% at most stations but at St 8 and St 10 was 100%. The efficiency of fecal coliform removal ranged from 94% at St 1 to 97% at most stations as shown in table (5), while the highest removal efficiency of fecal streptococcus was 98% at St 4.

Table (2): Annual average of biological parameters of all plant inlets and outlets in the study area.

Biological parameters	**Plant inlets**				**Plant outlets**			
Unit (CFU/100 ml)	Min	Max	Mean	Standard deviation	Min	Max	Mean	Standard deviation
TC	54	420	152.3	95.4	<1	<1	<1	<1
FC	14	52	28	12	<1	<1	<1	<1
FS	13	56	33	10.7	<1	<1	<1	<1
TPC	123	690	301.4	132.1	15	39	6.5	24.7

Table (3): annual average of biological parameters for each plant inlet

plant inlets	**Total coli form CFU/100 ml**	**Fecal coli form CFU/100 ml**	**Fecal strept ococcus CFU/100 ml**	**Total plate count (CFU/ ml)**
inlet 1	120	18	39.5	332.25
inlet 2	170.75	24.75	28	445
inlet 3	112	24.5	34.25	385
inlet 4	101.25	16.25	42.75	277.5
inlet 5	93.75	21.5	32.75	377.5
inlet 6	116	23.75	25.25	277.5
inlet 7	140.75	34.75	25.25	212.25
inlet 8	255	41.25	39.5	258.25
inlet 9	176.25	37.25	24	230.75
inlet 10	231.25	35.5	34.75	275.5
inlet 11	158.5	30.25	36.5	244.25

Table (4): Annual average of biological parameters for each plant outlets

Plant outlets	**Total coliform CFU/100 ml**	**Fecal coliform CFU/100 ml**	**Fecal streptococcus CFU/100 ml**	**Total plate count CFU/ml**
Outlet 1	<1	<1	<1	25
Outlet 2	<1	<1	<1	24.25
Outlet 3	<1	<1	<1	23
Outlet 4	<1	<1	<1	26
Outlet 5	<1	<1	<1	25.75
Outlet 6	<1	<1	<1	20.75
Outlet 7	<1	<1	<1	26
Outlet 8	<1	<1	<1	25.25
Outlet 9	<1	<1	<1	24.5
Outlet 10	<1	<1	<1	27.25
Outlet 11	<1	<1	<1	24.25

Table (5): Removal efficiency of biological parameters of drinking water treatment plants

Stations	Total coliform CFU/100 ml	Fecal coliform CFU/100 ml	Fecal streptococcus CFU/100 ml	Total plate count CFU/ml
St 1	99%	94%	97%	92%
St 2	99%	96%	96%	95%
St 3	99%	96%	97%	94%
St 4	99%	94%	98%	91%
St 5	99%	95%	97%	93%
St 6	99%	96%	96%	93%
St 7	99%	97%	96%	88%
St 8	100%	98%	97%	90%
St 9	99%	97%	96%	89%
St 10	100%	97%	97%	90%
St 11	99%	97%	97%	90%

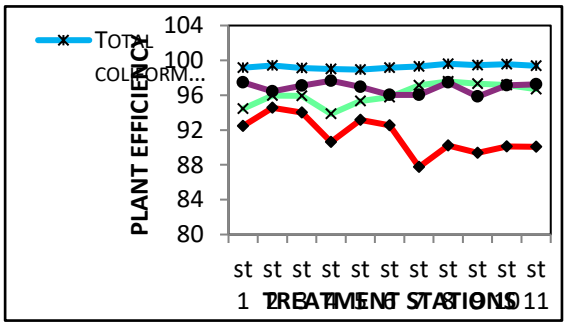

Figure (2): Drinking water treatment plants efficiency of TPC, TC, FC, FS

Discussion

Total plate count (TPC)

Total plate count represents the aerobic and facultative anaerobic bacteria that derive their carbon and energy from organic compounds. The number of recovered bacteria depends on medium composition, period and temperature of incubation. TPC count is useful for evaluating the efficiency of treatment processes as well as monitoring the bacterial re-growth potential and biofilm development within the distribution systems (Reasoner, 1990). The total plate count value (01.4±138.1 and 24.72±6.47 CFUs/100 ml) of inlets and outlets, respectively in this study disagrees with the result detected (52×10^2 CFUs⁄ ml and 2 - 27 CFU⁄ml at 37°C) by Ezzat *et al*. (2017) for samples collected from inlets and outlets, respectively. Kirianki (2017) documented 0.47 to 1.76 CFU/1mL in water sources. Hasballah *et al*. (2023) measured $34.75\times10^3\pm500$ and 44.25±4.35 CFU/ml for raw and treated water samples, respectively. Moreover, Abou-Dobara *et al*. (2023) reported 824 CFU/100 ml in Bahr Mowees water (raw water) in summer and 179, 180, 161, 312 and 290 CFU/100 ml for treated water respectively. TPC count is helpful for monitoring the formation of biofilms in distribution systems and the possibility for bacterial regrowth, in addition to assessing the effectiveness of treatment procedures (Reasoner, 1990).

Total Coliforms (TC)

According to (Al-Afify et al., 2019), total coliforms are bacteria which indicate whether there is human or animal waste in the water. This current value of station outlets(<1) agree with the result recorded (<1.1 CFUs/100 ml) by Abdel-Shafy (2018) and disagree with Ezzat *et al*. (2017) who reported that (120 - 100×103 CFU⁄ 100 ml) for water samples collected from plant inlets (River Nile), while TC bacteria in water samples collected from outlets (treatment station at Cairo) were undetectable and that determined (0.30 to 1.89CFU/100mL) in water sources in kenya by Kirianki (2017) and that reported ($46.5\times102\pm100$ and < 1 TC/100 ml) by Hasballah *et al*. (2023) for raw and treated water, respectively. Al-Jaberi and Al-Abbawy (2023) detected (900 MPN/100ml) for raw water samples and 170 MPN/100 ml for treated water. In addition, Abou-Dobara *et al*. (2023) recorded 180 CFU/100 ml in Bahr Mowees water in summer and 50, 70, 80, 120 and 110 CFU/100 ml for treated water, respectively**.**

Fecal coliforms (FC)

Fecal coliforms are rod-shaped, gram-negative, facultative anaerobic bacteria that do not generate spores which are oxidase negative, able to grow in the presence of bile salts or comparable surface agents, and within 48 hours at 44±0.5ºC, they can create gas and acid from lactose (Doyle and Erickson, 2006). It was found that fecal coliform (<1 CFUs/100 ml) at all St outlets in all seasons was higher than that recorded (Nil) by Abdel-Shafy (2018) and disagree with that obtained (50 – 40×10^3 CFU/100ml) for entries (River Nile) while in exits FC bacteria were undetectable by Ezzat *et al*. (2017), that measured (1.1 to 3.1 of intakes MPN-index/100 ml) by Osman *et al*. (2011), that determined (0.10 to 1.68 CFU/100mL) in source waterin kenya by Kirianki (2017) and

that reported (23.5×102±57.7 and < 1 FC/100ml) for raw water of River Nile and treated water, respectively by Hasballah *et al*. (2023). Besides, Abou-Dobara *et al*. (2023) detected 70 CFU/100 ml in Bahr Mowees water in summer and 3 CFU/100 ml for treated water. Nogueira et al. (2003) reported that untreated water sources had higher levels of total and fecal coliform contamination than treated water sources, which is consistent with our findings. Omari and Yeboah-Manu (2012) indicated that fecal coliform, or E. coli, was found in surface water samples that were analyzed.

Fecal streptococci (FS)

The genus Streptococcus, which includes S.faecalis, S.faceium, S.bovis, S.equines, S.avium, and S.gallinarum, is commonly found in the feces and digestive tracts of warm-blooded mammals. These species are together referred to as the fecal streptococcus group, they are Gram positive and typically survive longer in water than fecal coliforms, in contrast to coliform bacteria (Ezzat *et al*., 2017).

In this study fecal streptococcus average differs from that documented by Ezzat *et al*. (2017) which was 16 - 6×10^3 CFU/100ml for entries while in exits they were undetectable. In addition, Osman *et al*. (2011) indicated (1.1 to 2.5 MPN-index/100 ml) and Hasballah *et al*. (2023) detected 102±22.05 and < 1 FS/100ml for raw water and treated water, respectively**.**

The results revealed that all of raw source water (plant inlets) were contaminated and treated samples (plant outlets)were in allowed limits of the Egyptian standards for drinking water and free from any sewage pollution. drinkable water must be free from total coliforms; fecal coliforms, as well as fecal Streptococci besides total bacterial counts must be less than 50 CFU/ml, similar results were observed by **(**Hasballah *et al*. (2023; El-Salam et al., 2017 ; El-Deeb, 1997).

The obtained results for the microbial characteristics in Nile River, Damietta branch, revealed that major raw water sources were contaminated. The high concentrations of TPC and TC are indication of contamination load in water otherwise meant for drinking purposes. This indicated that the water from sources catchments did not match the microbial quality guidelines by WHO to be qualifying for drinking purposes. The decrease in TPC, TC and FC levels in plant outlets was probably due to the application of treatment methods such as coagulation, flocculation, sedimentation and chlorination. Therefore, the increased concentration values of TPC, TC and FC may lead to rise in diarrheal episodes among the local communities. The children, elderly and immunosuppressed people are most affected from diarrhea because of low immunity (Kirianki, 2017).

We suggested that urgent tasks for relevant bodies should include proper chlorination of the drinking water system, routine water quality monitoring, the provision of toilets and waste disposal systems, as well as intensive health education and sanitation practices for the community **(**Sitotaw et al., 2021).

Drinking water treatment plants efficiency

The efficiency of the bacterial control by drinking water treatment plants (Table 5) ranged from 88 of TPC removal to 100 %, where the St 8 and St 10 showed the highest percentage (100%) of total coliform removal. This may be because these stations used a standard dose of chlorine that impacted bacteria compared with the other treatment plants. The resulted data is nearly close to that documented (92.1-99.7%) by Al-Jaberi and Al-Abbawy (2023) and less than that reported (99%) by Hasballah *et al*. (2023).

Conclusion

The studied drinking water treatment plants in Damietta governorate varied between good and excellent efficiency for bacterial removal. The absence of bacterial indicators in treated water samples illustrates good efficiency of drinking water treatment plants as the use of reasonable amounts of chlorine according to WHO standard for disinfections. The contamination of water sources by feces was caused by the release of wastewater that was enhanced with organic matter from cities. All the bacteriological parameters of treated water were within the permissible limit according to WHO standard. However, there was microbial contamination in the source water of each station inlet which can avoid by applying strict laws against discharging wastewater into the

Nile River, as it is considered the lifeline in Egypt and the main source of drinking water.

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الملخص العربي

عنوان البحث: كفاءة أداء إزالة البكتيريا في بعض محطات معالجة مياه الشرب بمحافظة دمياط، مصر

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يجب أن تستوفي مياه الشرب معايير قياسية محددة لضمان سلامتها، وخلوها من مسببات الأمراض والمواد الخطرة عند توفيرها للمستهلكين. ومع ذلك، يمكن أن تنشأ أمراض الجهاز الهضمي من الملوثات البرازية الموجودة في الماء. وبالتالي فإن الهدف من هذه الدراسة هو تقييم كفاءة عملية التطهير وإزالة البكتيريا لبعض مرافق معالجة مياه الشرب. تم أخذ عينات المياه من أحد عشر محطة معالجة على نهر النيل. اعتمد البحث على التحليل البكتريولوجي لنقطتي أخذ العينات لكل محطة، الاولى من المصدر (المأخذ) و الاخرى المياه الناتجة او المعالجة (الطرد). شملت التحاليل العد البيكتيري الكلي والذي أجري بطريقة الصب والمجموعية القولونية الكلية والمجموعة القولونية البرازية ، المجموعة السبحية، القولونيات البرازية التي أجريت عن طريق الترشيح الغشائي. أظهرت النتيجة أن متوسط قيمة العد البيكتري الكلي والقولونيات الكلية والقولونيات البرازية والمجموعة السبحية لمآخذ المحطات كانت كما يلي ٣٠١,٤ ±١٣٨,١، ١٥٢,٣±٩٥,٤، ٢٨ ±١٢. ٣٣ ±١٠,٧علي التوالي. بينما بالنسبة لطرد المحطات (مياه الشرب) كانت <١ في جميع المحطات باستثناء العد البيكتري الكلي الذي كان ٢٤,٧٢ ± ٦,٤ وأشير إلى أن القولونيات البرازية والقولونية السبحية في مآخذ وطرد المحطات كانت ضمن الحد المسموح به وفقاً لمعايير منظمة الصحة العالمية ولكن العد البيكتيري الكلي والبكتيريا القولونية الكلية تجاوز الحد القياسي في معظم مآخذ المحطات. وفقا لنتائج عينات مياه نهر النيل التي تم فحصها، فقد وجد تلوث ميكروبي في نقطة تجمع كل محطة. ومع ذلك، تراوحت كفاءة محطات معالجة مياه الشرب للعوامل البيولوجية التي تم فحصها بين ٨٨٪ و١٠٠٪. ختاما، يوصى بإجراء تقييم زماني ومكاني لنهر النيل على فترات متساوية للتخفيف من الآثار المحتملة والحفاظ على المصدر الرئيسي لمياه الشرب.