Phycological and bacteriological assessment of drinking water in schools of Tanta city, Egypt

Mostafa M. El-Sheekh* and Mai M. Hamoud
Department of Botany, Faculty of Science, Tanta University, Tanta 31527, Egypt
*Corresponding author. E-mail: mostafaelsheikh@science.tanta.edu.eg

ABSTRACT

Frequent water analysis is required to discover pollutants, describe water characteristics, and create a database for the water type that must be cleansed and treated in order to generate healthy water and, as a result, determine the best treatment method. In this regard, the goal of this research was to evaluate the overall physicochemical, phycological, and bacteriological properties of tap water samples taken periodically from 12 different Tanta city schools. In total, 57 algal species were identified throughout the investigation, 33 species belonging to Chlorophyta, 13 species to Bacillariophyta, and 11 species to Cyanophyta. Phytoplankton species richness and diversity were relatively stable in each school all year round. *Chlorella*, *Cyclotella*, *Scenedesmus*, which are organically pollution-tolerant genera according to Palmer’s pollution index, were observed in the present study. Throughout the research seasons, total and fecal coliform bacteria were positively correlated \( r = 0.94 \) in all of the study area sites. The counts of pollution indicators were more in groundwater than treated water.

Key words: bacteria, environmental parameters, Palmer’s index, phytoplankton, pollution, water quality

HIGHLIGHTS

- Physicochemical, phycological, and bacteriological qualities of tap water.
- Phytoplankton species richness and diversity of schools.
- Total and fecal coliform bacteria were detected in drinking water.
- Pollution indicators were more in groundwater than treated water.

1. INTRODUCTION

Water is undoubtedly the most precious natural resource on our planet; it is the building block of life. The assessment of water quality is the first stage of any management, conservation, or restoration process of freshwater ecosystems, a complete water quality assessment of any water body is based on monitoring its hydrological, physical, chemical, and biological parameters (El Sayed et al. 2020). An adequate supply of safe drinking water is one of the major prerequisites for a healthy life, but the waterborne disease is still a major cause of death in many parts of the world (Ouf et al. 2018). Waterborne diseases are transmitted through the direct drinking of water contaminated with pathogenic microorganisms (Atta et al. 2019). Infants, young children who are disabled or who live in filthy surroundings, and the elderly are all at risk of contracting a waterborne disease (Moran 2018). Many developing regions either suffer from chronic freshwater shortages or the pollution of readily accessible water resources (McPeters 2013). Water resources in Egypt are limited mainly to the Nile River, rainfall, and groundwater in the Delta, Western deserts, and Sinai (Abdel-Shafy & Kamel 2016). The Nile River is the life artery of Egypt and represents the main freshwater resource needed for nearly all drinking and irrigation water demands, heavy metals are considered the main pollutant in the Nile River (Abdel-Satar et al. 2017). Shokr et al. (2016) observed in their studies a strong relationship between contaminated drinking water with heavy metals and chronic diseases such as renal failure. Egyptian farmers usually surfeit in chemical fertilizers, disturbing the nitrogen cycle, leading to the pollution of groundwater supplies with high nitrate concentrations (Atta et al. 2004). Nitrate plays a very important role in altering the phytoplankton quantity (AL-Shandah et al. 2017). Phytoplankton can be a good indicator of water quality changes, given its sensitivity and dynamic responses.
to changes in the surrounding environment. The World Health Organization has established an alert levels framework for drinking water supplies based on the cyanobacteria presence to determine water quality and human health risk (Katsiapi et al. 2011). Fecal indicator bacteria such as total coliform, fecal coliform, and fecal streptococci are used to detect fecal contamination in water. They are also likely to be present with other intestinal pathogenic bacteria such as Salmonella choleraesuis and Pseudomonas aeruginosa. The Egyptian Drinking Water Standards No. 458/2007 states that all drinking water samples should be free from any indicator microorganisms for fecal pollution. The present study aimed to assess the quality of drinking tap water in Tanta city schools and determine its compliance with Egyptian drinking water standards and WHO guidelines. This was achieved through physicochemical analyses [temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, total hardness, calcium, magnesium, heavy metals, nitrate, nitrite, and ammonia] of drinking tap water samples collected during the year seasons from 12 different schools in Tanta city. Determination of bacterial indicators of pollution [heterotrophic plate count bacteria (HPC), total coliforms (TC), fecal coliforms (FC) and fecal streptococci] in addition to pathogenic Gram-negative bacteria (Salmonella choleraesuis and Pseudomonas aeruginosa), enumeration and identifications of different divisions and genera of pollution-related algae and finding out co-relations between pollution-related algae and the other indicators.

2. MATERIALS AND METHODS

2.1. Study area and sampling stations

The study was carried out in Tanta city, the Gharbiya governorate’s capital, Egypt’s fifth-largest city, with an estimated 1,094,238 inhabitants. Tanta lies in the middle Delta of Egypt, 94 km (59 miles) north of Cairo and 130 km (81 miles) southeast of Alexandria. The study was intended to assess the overall physicochemical, phycological, and bacteriological qualities of tap water samples collected from 12 different schools in Tanta city based on Egyptian standards (EMHP 2007) and to World Health Organization guidelines for drinking water quality (WHO 2008) to gauge the safety of tap water for human consumption. The schools were selected randomly to cover the investigation area and to have different water-treated groundwater and mixed water. Six of these schools were selected at East Tanta city (E), and the other six schools were selected at West Tanta city (W) (Figure 1).

2.2. Physicochemical analysis

Temperature (°C), hydrogen ion concentration (pH), EC, and TDS of water were measured directly in the field during sampling using a Multimeter (Crisom MM40). The water samples were collected in 1 L clean glass bottles without air bubbles and transferred to the laboratory to determine their chemical parameters. Water turbidity in nephelometric turbidity units

![Figure 1](http://iwaponline.com/wst/article-pdf/84/10-11/3018/968780/wst084103018.pdf) | Location map of Tanta city showing sampling sites.
(NTU) was measured using a HACH ratio turbidimeter (Model 2100 AN, Co., USA). Total hardness was determined by the titration method using a standard ethylene-diaminetetraacetic acid (EDTA) solution (Diehl et al. 1950). The dissolved cations (Ca\(^{2+}\) and Mg\(^{2+}\)) and heavy metals (Pb\(^{2+}\), Cd\(^{2+}\), Cu\(^{2+}\), and Mn\(^{2+}\)) were determined directly by using an atomic absorption spectrophotometer ‘Perkin-Elmer model 2380’ equipped with a digital and direct readout, using standard solutions of each element under investigation. Nitrate was determined using sodium salicylate colorimetric technique (Akinsola & Godowoli 2005). Ammonia was determined using Manual Phenate Colorimetry Technique (Nollet 2000). Nitrite was determined using the colorimetric technique based on diazotization with sulfanilamide in an acid solution and coupling with N-(1-naphthyl)-ethylenediamine dihydrochloride to form a highly colored azo-dye for which its absorbance is proportional to the nitrite content (APHA 2005).

2.3. Phycological analyses:
The water samples were collected in 2 L dark polyethylene bottles, preserved immediately at the sampling site by adding acidified Lugol’s solution, and transported to the laboratory in an icebox (4 °C). The preserved well-mixed sample was allowed to stand undisturbed in the dark for 3 days. After sedimentation, most of the supernatant was carefully siphoned off using a siphon tube (0.5 mm in diameter) with a tight piece of phytoplankton net on its end to prevent the siphoning of any non-settled algae, mainly blue-green algae. The remainder known volume of the sample was mixed gently, ready for identification and enumeration (Hotzel & Croome 1998). Counting of phytoplankton was done using a Sedgwick-Rafter counting chamber using the light microscope, 100 fields were randomly counted, and the final result, expressed as cells per milliliter, was calculated using the following equation:

\[
\text{Cells mL}^{-1} = \frac{N \times 1000 \text{mm}^3}{A \times D \times F \times X}
\]

where \(N\) = number of cells counted, \(A\) = area of the field (mm\(^2\)), \(D\) = depth of a field (Sedgwick–Rafter chamber depth) (mm), \(F\) = number of fields counted, and \(X\) = sample concentration factor [\(X = S/C\) where \(S = \text{total collected tap water sample volume (2 L)}\) and \(C = \text{the concentrated subsample (40 ml)}\)].

The references used for the identification of the present algal taxa were Prescott (1975); Streble & Krauter (1978); Sykes (1981); Hindak (1984); Bellinger & Sigee (2010). The Species richness index (\(d\)), according to Margalef (1958), was used to evaluate the community structure. The equation below was applied, and results were recorded to two decimal places:

\[
d = (S-1)/\log_e N
\]

where \(d\) = Species richness index, \(S\) = Number of species in a population, and \(N\) = Total number of individuals in \(S\) species.

Shannon & Weaver (1949) diversity index (\(H'\)) given by the equation:

\[
H' = -\sum_{i=1}^{S} \left( \frac{n_i}{N} \right) \ln \left( \frac{n_i}{N} \right)
\]

where \(H'\) = Diversity Index, \(S\) = Total number of species in the sample, \(n_i\) = number of individuals per \(i\)th species, \(N\) = Total number of individuals in \(S\) species, and \(\ln\) = natural logarithm (\(\log_e\)).

Phytoplankton community’s maximum diversity occurs when all the species are equally abundant in numbers or contribute equally to the total number of individuals. Maximum diversity is given by:

\[
H'_{\text{max}} = \ln S
\]

where \(S\) is the total number of species observed in a sample.

Species equitability or evenness-index of the phytoplankton communities (Pielou 1975) was determined by the equation:

\[
j = \frac{H'}{H'_{\text{max}}}
\]

where \(j\) = Equitability index, \(H'\) = Shannon–Weaver diversity index, \(H'_{\text{max}}\) = maximum diversity.
The value of equitability \((j)\) is constrained between 0 and 1.0, with values near 1 indicating the most even distributions of species abundances and values near 0 indicating dominance by one or few species.

Palmer’s Algal Genus Pollution Index (Palmer 1969) was used to assess the water quality of the samples.

2.4. Bacteriological analysis

The water samples were collected in 2 L sterilized well stoppered autoclavable plastics (polypropylene) bottles, (3\%w/v) aqueous solution of sodium thiosulfate \(\text{(Na}_2\text{S}_2\text{O}_3)\) was added to the bottles before sampling to neutralize the bactericidal effect of any chlorine in the water. The sampling point was flamed and opened fully to let the water run to waste for a few minutes. All the samples were labeled and transported to the laboratory in an icebox (4 °C). The collected samples were examined directly upon arrival to the laboratory by membrane filtration technique (MF), using Sartorius sterile, gridded, 47 mm in diameter and 0.45 \(\mu\)m pore size, cellulose nitrate membrane filters, according to Standard Methods for the Examination of Water and Wastewater, 20th ed (APHA 1998) as presented in (Table 1).

2.4.1. Verification tests

Total coliforms were determined by the lactose fermentation test. Five typical colonies were randomly selected from each plate of m-Endo Agar LES and placed in lauryl tryptose broth (LTB) and cultured at 350.5 °C for 48 hours. Within 48 hours, gas developed in the LTB and was confirmed in brilliant green lactose bile broth (BGLB), confirming the colony as a coliform. Fecal coliform colonies were verified by the gas formation in LTB broth and EC broth within 48 hours at 35 °C. The fecal streptococci colonies were verified using brain heart infusion (BHI) agar incubated at 35 ± 0.5 °C for 24–48 h. The isolated colony was then transferred to glass slides, and a catalase reaction was conducted [3% hydrogen peroxide \((\text{H}_2\text{O}_2)\) was added] followed by a Gram stain. Catalase-negative and Gram-positive cocci confirmed the colony as a fecal streptococci group. Salmonella choleraesuis was verified using Triple Sugar Iron Agar incubated at 35 °C for 18–24 hours. Pseudomonas aeruginosa was verified using Milk Agar incubated at 35 ± 1 °C for 24 h; a yellowish to green diffusible pigment was produced. Determination of HPC was carried out according to the methods adopted by Gensberger et al. (2015).

2.5. Statistical analysis

Based on the software program SAS (Statistical Analysis System) for Windows version (6.12), the obtained results were statistically analyzed using analysis of variance (ANOVA-1 and ANOVA-2) to determine the degree of significance for the

---

**Table 1** Presumptive tests; media, incubation conditions, and typical colonies for indicator bacteria colonies using the membrane filtration method

| Bacteria               | Media                      | Incubation Conditions                  | Typical colonies                                                                 | Refs.           |
|------------------------|----------------------------|----------------------------------------|----------------------------------------------------------------------------------|-----------------|
| Heterotrophic plate    | m-HPC agar                 | 35.0° ± 0.5 °C for 48–72 hours         | Colonies were of different sizes and colors; most of them were white, cream, yellow or colorless. | APHA (1998)    |
| count (HPC)            | m-Endo Agar LES            | 35.0° ± 0.5 °C for 22–24 hours after incubation for 2 hours at 35.0° ± 0.5 °C on a pad saturated with Lauryl-Tryptose Broth | Pink to dark red colonies with a golden-green metallic sheen | USEPA (1992); APHA (1998) |
| Total coliforms (TC)   | m-FC agar                  | 44.5° ± 0.2 °C for 24 ± 2 hours        | Various shades of blue colonies                                                  | USEPA (1992); APHA (1998) |
| Fecal coliforms (FC)   | m-Enterococcus agar        | 35.0° ± 0.5 °C for 48 hours            | Light and dark red colonies                                                      | APHA (1998)    |
| Fecal streptococci (FS)| Bismuth sulphite agar      | 35.0° ± 0.5 °C for 24–48 hours         | Light-colored colonies with black to brown centers surrounded by a black zone with sheen (fish eye) | ISO 6540 (1995); APHA (1998) |
| Salmonella choleraesuis | Bismuth sulphite agar      | 35.0° ± 0.5 °C for 24–48 hours         | Light-colored colonies with black to brown centers surrounded by a black zone with sheen (fish eye) | ISO 6540 (1995); APHA (1998) |
| Pseudomonas aeruginosa (Ps.) | m-PA-C agar          | 41.5° ± 0.5 °C for 72 hours            | All colonies on the filter were counted                                        | APHA (1998)    |
variations between the different sites and seasons, in addition to performing Pearson correlation coefficient (r) analysis to assess the type of the relationship between physicochemical, phycological and bacteriological parameters (SAS 1985).

3. RESULTS AND DISCUSSION

School tap water is the most common drinking option in schools. The type and amount of drinking facilities available at school, their location, how well they are maintained, how appealing the water supply and facilities are to children, and when they are allowed access them, all influence how many children drink at school. The current research study has looked at schools’ tap water qualities in Tanta city and its potential health hazards for pupils. Tap water quality was examined in 12 schools over a four-season period from autumn to summer.

3.1. Physicochemical characteristics

In the present study, the average values of the physicochemical parameters of the 12 sampling sites, water temperature exhibited little variance among the schools in Tanta city and reflected the values of air temperature during the sampling time (Tables 2 and 3). It is parallel to the usual climate of Egypt (10–35°C); the lowest temperature value (15.9°C) was recorded during winter in the W4 School, while the highest value (31.4°C) was encountered during summer in W5 School. pH value affects the biological and chemical reactions, and also controls the metal ion solubility, and thus it affects the natural aquatic life and could control pathogenic microorganism growth (Rawway et al. 2016). The tested tap water’s pH values in Tanta city schools ranged between neutral (7.26–7.28) to slightly alkaline (7.81–7.92). There was a narrow variation in pH value (about 0.2) among schools within the same season, while pH variations within the same school ranged between 0.25 and 0.49 in the different seasons. The highest pH values were recorded during winter in all schools. Both W4 and W5 Schools that have treated water exhibited the maximum pH value (7.92).

Conversely, the minimum pH value (7.28) was recorded during summer in W1 School. In general, all the tested tap water samples had pH values within limits described by the Egyptian and WHO standards (6.5–8.5). Measurement of EC (25°C) provides sufficient information about the quantity of dissolved materials found in water. According to EC values of the tested tap water in Tanta city schools, the water of all schools can be classified as hard water during the autumn season with the range of (536–1,324 μS/cm). Water from E2 School, which is treated water mixed with groundwater, exhibited the highest conductivity values throughout the year compared to the other schools, sourced by either treated water or groundwater. TDS is a measure used to indicate an increase in one or more contaminants. Although high levels of TDS were detected, no sample was above the enforcement level for TDS standards. The turbidity of water samples ranged from 0.12–1.23 NTU for all the water samples, which means that none of the drinking water samples analyzed for turbidity exceeded the acceptable limit (less than 4 NTU). The values of the total hardness, calcium, and magnesium concentrations in the sampled water were recorded within the international permissible limits for drinking water. Lead is considered the number one health threat to children, and the effects of lead poisoning can last a lifetime. Not only does lead poisoning stunt a child’s growth, damage the nervous system, and cause learning disabilities, but also it is now linked to crime and anti-social behavior in children (USGAO 2000), Although lead concentration (Pb²⁺) of all the tested drinking tap water samples during autumn exceeded the maximum allowable concentration set by the Egyptian Ministry of Health and Population (0.05 mg/l) and the guideline limits recommended by the World Health Organization (WHO) 0.01 mg/l with mean concentration ranging from 0.086 to 0.181 mg/l, lead was present in the tested water samples at concentrations well within the recommendations within the rest of the study seasons. As for cadmium concentration (Cd²⁺), all the tested drinking water samples during autumn (0.014–0.039 mg/l) and most of them during summer (0.01, 0.02 mg/l) exceeded the acceptable limits and showed positive correlations with Pb²⁺ (r = 0.83). The values of Cu and Mn in drinking water of Tanta city schools were within the permissible limits of potable water.

In contrast, Cd and Pb exceeded the permissible limits, which may be attributed to using lead pipes in water lines. Seasonal variations in nitrate concentrations were 9.97: 19.09, 7.06: 18.29, 10.5: 26.8, and 3.18: 65.08 mg/l during autumn, winter, spring, and summer seasons, respectively. The results showed that all the tested drinking water samples collected from Tanta city schools were in compliance with the Egyptian standard (44 mg/l) and with WHO guidelines (50 mg/l) for nitrate (NO₃⁻) in drinking water except those samples collected from W1 School during the summer season which exceeded the regulations. Nitrate is used as an essential nutrient for phytoplankton growth. Accordingly, the maximum nitrate values in W1 School and most schools were when the algal counts had reached their minimum. Seasonal variations in ammonia concentrations fluctuated in the ranges of 0.0–0.12, 0.0–0.29, 0.0–1.4 and 0.0–0.26 mg/l during autumn, winter, spring and summer seasons,
Table 2 | Annual values of the physicochemical parameters of the tested tap water samples in Tanta city schools

| Sampling sites | Temp. (°C) | pH      | EC       | TDS     | NTU       | T. HARD   |
|----------------|-----------|---------|----------|---------|-----------|-----------|
| E1             | 24.2 ± 0.25 | 7.53 ± 0.07 | 766.25 ± 4 | 483 ± 3 | 0.29 ± 0.003 | 223 ± 2   |
| E2             | 24.43 ± 0.25 | 7.54 ± 0.07 | 1,155.25 ± 5 | 737 ± 4 | 0.27 ± 0.003 | 374.25 ± 2 |
| E3             | 23.28 ± 0.25 | 7.54 ± 0.07 | 462.25 ± 3 | 300.25 ± 2 | 0.44 ± 0.004 | 144.25 ± 2 |
| E4             | 23.78 ± 0.25 | 7.44 ± 0.07 | 532.25 ± 3 | 348.75 ± 2 | 0.71 ± 0.004 | 158.25 ± 2 |
| E5             | 24.13 ± 0.25 | 7.64 ± 0.07 | 454.75 ± 3 | 296.75 ± 2 | 0.49 ± 0.007 | 145.5 ± 1  |
| E6             | 21.83 ± 0.25 | 7.56 ± 0.07 | 763.5 ± 3 | 482.25 ± 3 | 0.31 ± 0.003 | 226.25 ± 2 |
| W1             | 23.65 ± 0.2  | 7.45 ± 0.07 | 866.5 ± 4 | 549.5 ± 3 | 0.29 ± 0.004 | 221.25 ± 2 |
| W2             | 22.8 ± 0.2   | 7.55 ± 0.07 | 824.25 ± 5 | 515 ± 5 | 0.27 ± 0.003 | 245.5 ± 2  |
| W3             | 23.15 ± 0.25 | 7.59 ± 0.07 | 424 ± 4 | 274.95 ± 2 | 0.44 ± 0.006 | 146.5 ± 2  |
| W4             | 23.43 ± 0.2  | 7.61 ± 0.07 | 424.75 ± 2 | 277.175 ± 2 | 0.71 ± 0.004 | 127 ± 1    |
| W5             | 24.18 ± 0.25 | 7.64 ± 0.07 | 426.25 ± 3 | 273.6 ± 2 | 0.49 ± 0.005 | 136.75 ± 1 |
| W6             | 24 ± 0.25    | 7.52 ± 0.07 | 533.25 ± 3 | 346.75 ± 2 | 0.31 ± 0.004 | 165 ± 2    |

Source of variation | F value  | P value | F value  | P value | F value  | P value | F value  | P value | F value  | P value | F value  | P value |
|---------------------|----------|---------|----------|---------|----------|---------|----------|---------|----------|---------|----------|---------|
| Season              | 14,466.71 | 0.0001  | 189.27   | 0.0001  | 9,254.92 | 0.0001  | 9,247.31 | 0.0001  | 14,387.69 | 0.0001  | 1,286.75 | 0.0001  |
| Site                | 51.55     | 0.0001  | 9.21     | 0.0001  | 14,087.04 | 0.0001  | 15,394.38 | 0.0001  | 18,508.68 | 0.0001  | 14,591.56 | 0.0001  |
| Season * Site       | 57.09     | 0.0001  | 2.18     | 0.0018  | 300.84    | 0.0001  | 291.60    | 0.0001  | 2,502.83  | 0.0001  | 240.76   | 0.0001  |

Temp, temperature; EC, Electric conductivity; TDS, Total Dissolved Salts; NTU, Nephelometric Turbidity Unit; T. Hard, Total Hardness.
Table 3 | Annual values of the physicochemical parameters (mg/l) of the tested tap water samples in Tanta city schools

| Sampling sites | Ca       | Mg       | Pb       | Cd       | Cu      | Mn      | NO₃    | NO₂    | NH₃    |
|---------------|----------|----------|----------|----------|---------|---------|--------|--------|--------|
| E1            | 40.07 ± 0.4 | 35.0 ± 0.3 | 0.044    | 0.015    | 0.004   | 0.104   | 20.52  | 0.138  | 0.103  |
| E2            | 87.89 ± 0.8 | 61.2 ± 0.3 | 0.048    | 0.009    | 0.006   | 0.999   | 7.68   | 0.055  | 0.46   |
| E3            | 39.91 ± 0.4 | 23.9 ± 0.3 | 0.035    | 0.013    | 0.002   | 0.049   | 10.88  | 0.050  | 0.043  |
| E4            | 43.71 ± 0.6 | 25.4 ± 0.3 | 0.026    | 0.009    | 0.009   | 0.03    | 13.11  | 0.028  | 0.025  |
| E5            | 33.82 ± 0.3 | 22.9 ± 0.3 | 0.031    | 0.006    | 0.005   | 0.027   | 11.09  | 0.003  | 0.00   |
| E6            | 32.34 ± 0.4 | 35.7 ± 0.3 | 0.028    | 0.009    | 0.01    | 0.136   | 20.47  | 0.033  | 0.013  |
| W1            | 48.58 ± 0.6 | 42.8 ± 0.3 | 0.049    | 0.009    | 0.003   | 0.143   | 31.815 | 0.145  | 0.015  |
| W2            | 56.95 ± 0.6 | 39.9 ± 0.3 | 0.034    | 0.009    | 0.002   | 0.168   | 17.1875| 0.823  | 0.04   |
| W3            | 41.22 ± 0.5 | 27.8 ± 0.3 | 0.051    | 0.008    | 0.006   | 0.120   | 11.965 | 0.000  | 0.00   |
| W4            | 41.77 ± 0.5 | 23.7 ± 0.3 | 0.056    | 0.010    | 0.003   | 0.066   | 11.9425| 0.055  | 0.055  |
| W5            | 37.39 ± 0.3 | 23.2 ± 0.3 | 0.054    | 0.013    | 0.004   | 0.038   | 11.7075| 0.015  | 0.00   |
| W6            | 41.94 ± 0.4 | 25.5 ± 0.3 | 0.038    | 0.011    | 0.003   | 0.069   | 7.7025 | 0.053  | 0.07   |

Source of variation

| F     | P     | F     | P     | F     | P     | F     | P     | F     | P     | F     | P     | F     | P     | F     | P     | F     | P     |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Season| 11,351.3 | 0.0001 | 72,079.16 | 0.0001 | 99,999.99 | 0.0001 | 99,999.99 | 0.0001 | 99,999.99 | 0.0001 | 2,039.02 | 0.0001 | 2,166.21 | 0.0001 | 9,937.62 | 0.0001 | 28,314.93 | 0.0001 |
| Site  | 10,153.8 | 0.0001 | 11,144.17 | 0.0001 | 1,836.47 | 0.0001 | 3,310.47 | 0.0001 | 9,952.46 | 0.0001 | 84,589.38 | 0.0001 | 19,374.47 | 0.0001 | 50,380.67 | 0.0001 | 70,915.12 | 0.0001 |
| Season * Site | 1,798.69 | 0.0001 | 1,641.58 | 0.0001 | 1,022.65 | 0.0001 | 4,816.96 | 0.0001 | 13,416.64 | 0.0001 | 1,721.54 | 0.0001 | 4,738.54 | 0.0001 | 11,026.02 | 0.0001 | 40,907.09 | 0.0001 |
respectively. Samples from E2 School showed the highest values of ammonia. Concerning the nitrite content in tap waters of Tanta city schools, it ranged from 0.00 (W3) to maximum value 0.823 mg/l (W2).

Generally, the values of the most physicochemical parameters recorded in the tap drinking water samples collected from E2 School which is a mixture of treated surface water and untreated groundwater, were relatively higher than that recorded either in tap water samples of treated water or in tap water samples of underground water. The physicochemical parameter result of this study are in a close agreement with the findings of Abu Ouf (2007), Shehata (2008), and Atta et al. (2019). The correlation analysis (Table 4) indicated that water temperature correlated positively with Ca$^{2+}$ ($r = 0.51$), Cu$^{2+}$ ($r = 0.36$), Mg$^{2+}$ ($r = 0.51$) and Pb$^{2+}$ ($r = 0.30$), whereas it was negatively correlated with pH ($r = -0.66$) and showed a negative correlation for Mg$^{2+}$ ($r = -0.58$). There was a very high positive correlation between conductivity and TDS ($r = 0.98$). EC was also positively correlated with total hardness ($r = 0.83$), Mn$^{2+}$ ($r = 0.71$), Ca$^{2+}$ ($r = 0.44$), NH$_3$ ($r = 0.35$), Mg$^{2+}$ ($r = 0.34$), Pb$^{2+}$ ($r = 0.32$). TDS was correlated positively with total hardness ($r = 0.83$), Mn$^{2+}$ ($r = 0.72$), Ca$^{2+}$ ($r = 0.45$), NH$_3$ ($r = 0.36$), Mg$^{2+}$ ($r = 0.35$), and Pb$^{2+}$ ($r = 0.53$).

### 3.2. Phycological assessment of water quality

The qualitative and quantitative analysis of phytoplankton in treatment plants is important, not only for treatment efficiency, but also for monitoring water quality changes (Demir & Atay 2002). Algae removal from the water treatment process is difficult because of their small size and low specific gravity (Ma & Liu 2002). The composition of phytoplankton communities in drinking tap water can be influenced by the source of drinking water (either surface water or underground water), the removal efficiency of algae in the water treatment plant, the condition of the network of water pipelines, and the hygienic status of the drinking point of use. Analysis of the phytoplankton population density (Figure 2(a) and 2(b)) recorded in the tested tap water samples collected from Tanta city schools revealed that, of all the phytoplankton studied, members belonging to Chlorophyta recorded the highest population density followed by Bacillariophyta and then Cyanophyta. Chlorophyta emerged as a major algal group among the total phytoplankton and contributed as much as 57.38% to the total phytoplankton population. Fifty-seven algal species were identified by investigating these 33 species belonging to Chlorophyta, 13 species belonging to Bacillariophyta, and 11 species to Cyanophyta. The maximum number of phytoplankton taxa (species richness) were recorded in tap water samples collected from W3 School during spring and winter (37 and 36 species, respectively), followed by tap water samples collected during winter from both W5 School (31 species) and W4 School (30 species) It is worth mentioning that the water from three schools (W3, W4, and W5) were sourced during the study from underground water stations then they became sourced at a treated water station. Conversely, samples collected from E2 school had only one phytoplankton species during summer with the minimum algal count (4 Org./50 ml). Generally, phytoplankton densities were higher during spring in the samples collected from E3, E5, E6, W2, and W4 Schools with a distinguished peak in both E3 School (812 Org./50 ml) and E5 School (776 Org./50 ml) and during winter in E1, W1, W3, W5, W6 Schools with a distinguished peak in both W3 School (796 Org./50 ml) and W5 School (700 Org./50 ml).

The overall observation showed that the green algae were dominated by small planktonic Chlorococcales (Table 5), particularly Scenedesmaceae, mostly Scenedesmus obliquus, Scenedesmus bijuga, and Crucigenia rectangularis, and Oocystaceae mainly Tetraedron minimum. This finding agrees with Mahmoud et al. (2018), who demonstrated that Scenedesmus obliquus was the most dominant Chlorophyta in the Nile River around Gizert El-Warrak. The highest values of Scenedesmus obliquus (304 Org./50 ml) and Crucigenia rectangularis (52 Org./50 ml) were recorded during spring in the E3 School. While the highest values of Scenedesmus bijuga (212 Org./50 ml) and Tetraedron minimum (120 Org./50 ml) were recorded during the spring season in the E5 School. Some green algae species such as Coelosstrum microporum, Dictyosphaerium pulchellum, Scenedesmus quadricauda, and Sphaeocystis Schroeteri were frequently found during the study period, even if in low numbers and the remaining recorded Chlorophyta species were rarely recovered.

Cyclorella contorta was the most dominant among the diatoms throughout the study period. Cyclorella contorta was also recorded as the dominant species in Egyptian waters in other studies (Doma et al. 2018; El-Gamal et al. 2019). Another important dominated centric diatom was Melosira granulate. Pinnate diatoms were dominated by Diatoma elongatum. Other diatoms species such as Cocconies placenta and Synedra ulna were frequently recovered during the study period. In general terms, most diatoms are recorded as halophytic, that is they prefer alkaline waters (Wolf 1982), which correspond to the conditions of relatively high pH values in tested tap water samples in Tanta city schools.

According to the frequency of abundance of Cyanophyta, Chroococcu turgidus, Gomphosphaeria naegeiania, and Merismopedia elegans were the most dominant species within the different sites. The maximum value of Chroococcu turgidus (68
Table 4 | Pearson correlation coefficient between different physicochemical parameters

|        | Temp | PH   | EC   | TDS  | NTU  | T.hard. | Ca    | Mg    | Pb    | Cd    | Cu    | Mn    | NO₃   | NO₂   |
|--------|------|------|------|------|------|---------|-------|-------|-------|-------|-------|-------|-------|-------|
| PH     |      | -0.66*** |      |      |      |         |       |       |       |       |       |       |       |       |
| EC     | -0.01 |       | -0.07 |      |      |         |       |       |       |       |       |       |       |       |
| TDS    |      |      |       | 1.00*** |      |         |       |       |       |       |       |       |       |       |
| NTU    | 0.03 | 0.09 |      |      | -0.21** | -0.21** |       |       |       |       |       |       |       |       |
| T.hard. |      |      |      |      |      |         |       |       |       |       |       |       |       |       |
| Ca     | -0.12 | 0.09 |      | -0.21** | -0.21** |         | -0.16* | 0.69** |       |       |       |       |       |       |
| Mg     | 0.31*** |      |      |      |      |         | 0.34*** | 0.35*** | -0.30*** | 0.60*** | 0.37*** |       |       |       |
| Pb     | 0.30*** |      |      |      |      |         | 0.32*** | 0.33*** | 0.39*** | -0.15 | -0.25** | -0.38*** |       |       |
| Cd     | 0.51*** |      |      |      |      |         | 0.20** | 0.21** | 0.22** | -0.17* | -0.35*** | -0.29*** | 0.83*** |       |
| Cu     | 0.36*** |      |      |      |      |         | -0.16 | -0.16* | -0.07 | 0.04 | 0.28*** | 0.26** | -0.25** | -0.22** |
| Mn     | 0.08 |      |      |      |      |         | 0.71*** | 0.72*** | -0.26*** | 0.83*** | 0.68*** | 0.51*** | 0.11 | 0.02 |
| NO₃    | 0.05 |      |      |      |      |         | -0.22** | 0.29*** | 0.28*** | -0.10 | 0.18* | -0.13 | 0.25** | -0.06 |
| NO₂    | -0.07 |      |      |      |      |         | 0.30*** | 0.29*** | 0.39*** | 0.26** | 0.14 | 0.20* | -0.01 | -0.18* |
| NH₃    | -0.08 |      |      |      |      |         | 0.35*** | 0.36*** | -0.17* | 0.45*** | 0.31*** | 0.40*** | -0.08 | -0.13 |

N.B.* P < 0.05, ** P < 0.01, *** P < 0.001.
Abbreviations: Temp, Temperature; pH, Hydrogen Ions Conc.; EC, Conductivity; TDS, Total dissolved solids; NTU, Turbidity; T.hard., Total hardness; Ca, Calcium; Mg, Magnesium; Pb, Lead; Cd, Cadmium; Cu, Copper; Mn, Manganese; NO₃, Nitrate; NO₂, Nitrite; NH₃, ammonia.
Org./50 ml) was found in W3 during summer. In comparison, the highest values of Merismopedia elegans (48 Org./50 ml) and Gomphosphaeria naegeliania (40 Org./50 ml) were recorded during winter in W5.

Species diversity implies both richness and evenness in the number of species and equitability for the distribution of individuals among the species (Vadrucci et al. 2007; Rajagopal et al. 2010). Species richness (d) had values fluctuating in the ranges of 0.31–4.93, 0.28–5.24, 0.80–5.70, and 0.0–4.75 during autumn, winter, spring, and summer seasons, respectively (Table 6). Since Margalef’s ‘d’ value is influenced by the number of species and individuals, the highest ‘d’ value was recorded as reflected with high species number and relatively low numbers of individuals during spring in water samples of W3 School. In contrast, the lowest values were recorded in E2 School during all the study period. The Shannon–Wiener and Evenness index values of phytoplankton in tap water samples collected from each school in Tanta city showed little variation among seasons, suggesting that overall phytoplankton species richness and diversity were quite stable in each school all year round. The highest mean value of Shannon’s index (H’) (2.91) was recorded during rainy seasons (autumn and winter) in W1 School, followed by (2.81) during autumn in W3 School. Dash (1996) reported that the higher the value of Shannon’s index (H’), the greater is the planktonic diversity.

Ankistrodesmus, Chlorella, Closterium, Cyclotella, Melosira, Navicula, Nitzschia, Oscillatoria, Scenedesmus, and Synedra, which are organically pollution tolerant genera according to Palmer’s pollution index (Table 7) were observed in the present study. The total score of W3 School samples during rainy seasons and W5 School samples during winter was greater than 20, indicating the confirmed high organic pollution. While the total scores of the remaining samples were less than 20, indicating probable high organic pollution in some schools and less organic pollution in others.
Table 5 | Phytoplankton species recorded in Tanta city schools and their seasonal appearance during our study

| Algal species | Sampling sites |
|---------------|----------------|
|               | E1  | E2  | E3  | E4  | E5  | E6  | W1  | W2  | W3  | W4  | W5  | W6  |
| Chlorophyta   |     |     |     |     |     |     |     |     |     |     |     |     |
| *Ankistrodesmus acicularis* (A. Br.) |     |     |     |     |     |     |     |     |     |     |     |     |
| *Ankistrodesmus falcatus* (Corda) Ralfs | F&S | –   | SP&S| F, SP&S| –   | –   | F&S | F, SP&S| F, SP&S| F, SP&S| F, SP&S| F&S |
| *Botryococcus braunii* Kütz. | –   | –   | F&SP| –   | –   | –   | –   | SP  | W   | –   |     |     |
| *Chlorella vulgaris* Beij. | –   | –   | F&S | A   | F   | –   | F&W | F&S | A   | F&SP| W   | A   |
| *Chodatella cillata* | –   | –   | F&SP| –   | –   | –   | –   | –   | W,  | W&SP| W&SP| –   |
| *Closterium pronum* | –   | SP  | F&W | F, W&S| –   | –   | –   | –   | SP&S| W&SP| S   | –   |
| *Coelastrum cambricum* Archer | –   | –   | –   | –   | –   | –   | W&SP| S   | –   | S   | –   | W&SP|
| *Coelostrum microporum* Näegeli | –   | –   | A   | A   | A   | A   | F&W | A   | F   | F   | F   | F   |
| *Cosmarium bioculatum* | SP&S| –   | –   | –   | F   | –   | –   | –   | F   | SP  | F&SP| F&SP|
| *Crucigenia rectangularis* (A. Br.) Gay | F   | SP&S| F, SP&S| F, SP&S| A   | –   | F, SP&S| F, SP&S| A   | A   | A   | F, SP&S|
| *Dictyosphaerium pulchellum* Wood | A   | –   | A   | F&W | F   | F   | F   | A   | F   | F   | F   | F   |
| *Golenkinia radiata* (Chod.) Wille | F&S | –   | F&S | F   | –   | –   | –   | –   | F   | W&SP| F&SP| F&SP|
| *Haematococcus pluvialis* (Girod.) Rostaf. | –   | –   | –   | –   | SP  | –   | –   | –   | W&SP| W&S | W&SP| –   |
| *Kirchneriella lunaris* (Kirch.) Moebius | –   | –   | –   | –   | –   | –   | –   | –   | –   | SP&S| W&SP| S   | SP&S| –   |
| *Nephrocytium lunatum* W.West | –   | –   | –   | –   | SP  | –   | –   | –   | –   | W&SP| –   | –   | –   | –   |
| *Oocystis lacustris* (Chod.) | –   | –   | S   | –   | –   | –   | –   | –   | –   | –   | –   | –   | –   | –   |
| *Oocystis parva* W.West | S   | –   | SP&S| SP  | F, W&S| –   | F   | W&SP| W   | SP&S| A   | F&W | A   | W&SP|
| *Oocystis solitaria* Wittrock | –   | –   | SP  | SP  | –   | SP  | W&SP| A   | W   | SP&S| W   | SP&S| W   | –   |
| *Pediastrum clathratum* Lemm. | F&S | –   | –   | SP&S| –   | –   | –   | –   | –   | –   | –   | –   | W   |     |
| *Pediastrum duplex* Meyen | W   | –   | –   | –   | –   | –   | –   | F&SP| –   | –   | –   | –   | –   | –   |
| *Pediastrum gracillium* W.West | –   | –   | W   | –   | –   | –   | –   | –   | –   | –   | –   | –   | –   | –   |
| *Pediastrum simplex* (Meyen) Lemm. | –   | –   | –   | F, SP&S| –   | –   | –   | –   | SP  | F&S | –   | F&SP|     |     |

(Continued.)
### Table 5

#### Algal species

| Algal species                                      | Sampling sites          | E1 | E2 | E3 | E4 | E5 | E6 | W1 | W2 | W3 | W4 | W5 | W6 |
|----------------------------------------------------|-------------------------|----|----|----|----|----|----|----|----|----|----|----|----|
| *Scenedesmus acuminatus* (Lagerh.) Chod.           |                         | –  | –  | F&S| W  | –  | –  | W  | –  | –  | SP | –  | W  |
| *Scenedesmus bijuga* (Turp.) Lagerh.               | A                       | A  | A  | A  | A  | A  | A  | A  | A  | A  | A  | A  | A  |
| *Scenedesmus obliquus* (Trup.) Küetz.              | A                       | –  | –  | A  | A  | A  | A  | A  | A  | A  | A  | A  | A  |
| *Scenedesmus platydiscus* (Trup.) Küetz.           | S                       | –  | S  | S  | F&SP| SP | –  | S  | SP&S| S  | –  | S  | –  |
| *Scenedesmus quadricauda* (Trup.) Brüb.            | F, W&SP                 | F  | W  | F  | F  | F&W| F  | F  | F&W| F  | F&SP|   |   |
| *Selenastrum gracile* Reinsch                      | W                       | –  | –  | –  | –  | –  | –  | –  | –  | –  | SP | –  | –  |
| *Sphaerocystis Schroeteri* (Chod.)                 | F&SP&SP                | F  | F  | F  | F  | F&W| F  | F  | F&W| F  | F, SP&S| A | –  |
| *Staurastrum paradoxum* Menegh.                    | W                       | –  | F&W| F&SP| –  | –  | –  | –  | –  | –  | SP | –  | –  |
| *Tetraedron minimum* (A. Br.) Hansg.               | A                       | A  | A  | F  | W  | A  | A  | A  | A  | A  | A  | A  | A  |
| *Tetraedron muticum* (A. Br.) Hansg.               | –                       | –  | –  | –  | –  | –  | W  | W  | F&W| –  | –  | –  | –  |
| *Ulothrix subtilissima* Rabenhorst                 | W                       | –  | –  | –  | –  | –  | –  | F&W| W  | W  | SP | –  | SP&S|
| **Cyanophyta:**                                    |                         |    |    |    |    |    |    |    |    |    |    |    |    |
| *Aphanizomenon gracile*                             |                         | –  | –  | –  | F&W| W&SP| –  | W  | F&W| W  | F&SP| W  | F&S|
| *Chroococcus turgidus* (Küetz.) Näegeli            | F, W&S                 | A  | A  | A  | A  | F&W| A  | A  | A  | A  | A  | A  | A  |
| *Chroococcus limneticus* Lemm.                     | –                       | –  | –  | –  | –  | –  | SP | –  | SP | W  | –  | –  | –  |
| *Coelosphaerium kuertzianum* Näegeli               | F&SP                   | A  | A  | F&SP| F  | A  | F  | A  | F  | –  | F&W| A  | –  |
| *Dactylocoleopsis raphidioides* Hansgirg           | F&W                    | SP | F&SP| F  | –  | –  | F&S| W  | W&SP| W&S| F&S| –  | –  |
| *Gomphosphaeria aponina* (Küetz.)                  | –                       | –  | S  | –  | –  | –  | SP | –  | –  | –  | –  | –  | –  |
| *Gomphosphaeria naegellana* Unger                   | F                      | W&S| A  | A  | A  | F, W&S| F | A  | F  | F  | F&W| A  | –  |
| *Merismopedia elegans* A. Braun                    | A                       | –  | A  | A  | A  | F&W| F  | A  | A  | A  | F  | W&S| A  |
| *Merismopedia glauca* (Ehrenb.) Näegeli            | –                       | SP&S| SP&S| –  | –  | –  | S  | –  | –  | –  | –  | –  | –  |
| *Oscillatoria chlorine* (Ehrenb.) Näegeli          | –                       | –  | –  | –  | F&W| –  | –  | W&SP| F  | W  | F&W| W  | SP&S|
| *Oscillatoria limnetica* Lemm.                     | F&W                    | F  | W&SP| W  | –  | –  | F  | F  | W  | W  | W  | W  | W  |

(Continued.)
| Algal species | E1 | E2 | E3 | E4 | E5 | E6 | W1 | W2 | W3 | W4 | W5 | W6 |
|---------------|----|----|----|----|----|----|----|----|----|----|----|----|
| *Bacillariophyta:* |    |    |    |    |    |    |    |    |    |    |    |    |
| *Coccones placentula* Ehrenberg | F, W&S | – | F&W | A | F, SP&S | F&S | F&SP | – | A | A | – | – |
| *Cyclotella comta* Ehrenberg | A | F&W | A | A | F, W&S | F&W | F | A | A | A | A | F, W&S |
| *Cyclotella glomerata* Bochmann | A | – | – | – | – | – | W | W | – | – | – | – |
| *Diatoma elongatum* (Berkeley) Cleve. | F, W&S | – | F&W | A | F&W | – | F | F, W&S | F&W | F | F&W | – |
| *Fragilaria capucina* Desm. | F&W | – | – | S | – | – | – | – | – | – | W | – |
| *Fragilaria construens* Ehrenberg | F&SP | – | – | – | – | – | – | W | SP | W&S | – | – |
| *Melosira granulate* (Ehr.) Ralfs | A | – | – | A | F&W | – | F&SP | – | F, W&S | A | A | F&SP |
| *Melosira varians* C. Agardh | F&W | – | – | A | – | – | SP | – | W&SP | S | SP&S | – |
| *Navicula cryptcephala* Küetz. | – | – | – | – | – | – | F&W | – | F, SP&S | F, W&S | – | – |
| *Nitzschia linearis* W.Smith | W&S | – | – | F, W&S | – | – | W&SP | – | F, W&S | A | F&S | – |
| *Stephanodiscus dubius* Grun. | A | – | – | A | F, W&S | – | – | – | F&W | F&W | F&S | S |
| *Surirella ovalis* | W | – | – | – | – | – | – | – | – | – | F&W | – |
| *Synedra ulna* (Nitzsch) Ehr. | F&W | – | F&S | A | – | – | F, W&S | F&S | F, W&S | F&S | F&W | SP&S |

Species recorded during the autumn/fall (F), winter (W), spring (SP), summer (S), during all seasons (A) and absent (–).
Table 6 | Seasonal variations in the ecological indices of phytoplankton communities in the tested tap water samples collected from Tanta city schools

| Indices Seasons | Species richness (d) | Diversity (H') | Maximum diversity (H'max) | Species equitability (j) |
|-----------------|----------------------|----------------|--------------------------|-------------------------|
|                 | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring | Summer | Autumn | Winter | Spring | Summer |
| E1              | 4.19   | 4.25   | 2.59   | 3.80   | 2.72   | 2.77   | 2.17   | 2.69   | 3.22   | 3.26   | 2.64   | 3.09   | 0.84   | 0.85   | 0.82   | 0.87   |
| E2              | 0.31   | 0.28   | 0.80   | 0.00   | 0.69   | 0.69   | 1.10   | 0.00   | 0.69   | 0.69   | 1.10   | 0.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 1.00   | 0.00   |
| E3              | 4.13   | 2.75   | 2.99   | 3.39   | 2.68   | 2.29   | 2.14   | 2.34   | 3.22   | 2.71   | 3.04   | 3.04   | 0.85   | 0.85   | 0.70   | 0.77   |
| E4              | 4.30   | 3.57   | 4.27   | 3.69   | 2.70   | 2.55   | 2.57   | 2.30   | 3.33   | 3.18   | 3.33   | 3.22   | 0.81   | 0.80   | 0.77   | 0.71   |
| E5              | 3.33   | 2.57   | 2.40   | 2.61   | 2.56   | 2.43   | 1.94   | 1.98   | 3.04   | 2.77   | 2.83   | 2.77   | 0.84   | 0.88   | 0.69   | 0.71   |
| E6              | 2.39   | 1.75   | 1.72   | 1.85   | 2.14   | 1.86   | 1.67   | 1.97   | 2.48   | 2.20   | 2.20   | 2.08   | 0.86   | 0.85   | 0.76   | 0.95   |
| W1              | 0.08   | 0.81   | 3.72   | 1.53   | 2.91   | 2.91   | 2.61   | 1.83   | 3.14   | 3.14   | 3.04   | 2.08   | 0.93   | 0.93   | 0.86   | 0.88   |
| W2              | 3.63   | 3.61   | 3.45   | 3.87   | 2.62   | 2.79   | 2.41   | 2.40   | 3.09   | 3.04   | 3.09   | 3.14   | 0.85   | 0.92   | 0.78   | 0.76   |
| W3              | 4.93   | 5.24   | 5.70   | 3.18   | 2.63   | 2.81   | 2.65   | 2.27   | 3.40   | 3.58   | 3.61   | 3.00   | 0.77   | 0.78   | 0.73   | 0.76   |
| W4              | 4.13   | 4.51   | 3.67   | 4.75   | 2.56   | 2.63   | 2.27   | 2.72   | 3.22   | 3.40   | 3.22   | 3.37   | 0.79   | 0.77   | 0.70   | 0.81   |
| W5              | 3.93   | 4.58   | 3.47   | 3.37   | 2.54   | 2.76   | 2.32   | 2.50   | 3.18   | 3.43   | 3.14   | 3.09   | 0.80   | 0.80   | 0.74   | 0.81   |
| W6              | 3.33   | 2.73   | 3.32   | 2.60   | 2.49   | 2.33   | 2.42   | 2.18   | 3.00   | 2.83   | 3.00   | 2.71   | 0.83   | 0.82   | 0.81   | 0.80   |
There were statistically highly significant positive correlations between total phytoplankton and Chlorophyta ($r = 0.899$, $P = 0.0001$), Cyanophyta ($r = 0.777$, $P = 0.0001$) and turbidity ($r = 0.556$, $P = 0.0001$) (Table 8). Conversely, total phytoplankton showed a highly significant negative correlation with EC and TDS ($r = -0.64$, $P = 0.0001$), total hardness ($r = -0.681$, $P = 0.0001$) and manganese ($r = -0.51$, $P = 0.0001$). Chlorophyta were highly significant and positively correlated with Cyanophyta ($r = 0.73$, $P = 0.0001$), While they showed highly significant negative correlation with EC and TDS ($r = -0.59$, $P = 0.0001$).

### Table 7 | Algal genus pollution index for the tap water samples collected from Tanta city schools

| Sites | Seasons | Autumn | Winter | Spring | Summer |
|-------|---------|--------|--------|--------|--------|
| E1    |         | 6      | 6      | 6      | 8      |
| E2    |         | 5      | 5      | 0      | 0      |
| E3    |         | 5      | 5      | 5      | 5      |
| E4    |         | 14     | 15     | 11     | 13     |
| E5    |         | 6      | 11     | 4      | 5      |
| E6    |         | 5      | 5      | 4      | 4      |
| W1    |         | 9      | 8      | 6      | 6      |
| W2    |         | 12     | 5      | 7      | 5      |
| W3    |         | 22     | 21     | 16     | 5      |
| W4    |         | 10     | 18     | 11     | 5      |
| W5    |         | 12     | 21     | 12     | 5      |
| W6    |         | 6      | 10     | 8      | 5      |

### Table 8 | Pearson correlation coefficient between phytoplankton groups and different physicochemical parameters

|                | Chlorophyta | Cyanophyta | Bacillariophyta | Total phytoplankton |
|----------------|-------------|------------|-----------------|---------------------|
| Temp           | −0.156      | −0.325***  | −0.069          | −0.204**            |
| pH             | 0.113       | 0.525***   | 0.063           | 0.171*              |
| EC             | −0.598***   | −0.325***  | −0.219**        | −0.640***           |
| TDS            | −0.600***   | −0.530***  | −0.215**        | −0.641***           |
| NTU            | 0.458***    | 0.491***   | 0.293***        | 0.556***            |
| Total hardness | −0.605***   | −0.590***  | −0.279***       | −0.681***           |
| Ca             | −0.341***   | −0.245**   | −0.132          | −0.359***           |
| Mg             | −0.218**    | −0.448***  | −0.342***       | −0.382***           |
| Pb             | −0.077      | 0.017      | 0.038           | −0.041              |
| Cd             | −0.120      | −0.060     | 0.033           | −0.090              |
| Cu             | −0.197*     | −0.137     | 0.189*          | −0.099              |
| Mn             | −0.399***   | −0.487***  | −0.288***       | −0.507***           |
| NO$_3$         | −0.189**    | −0.221**   | −0.069          | −0.212*             |
| NO$_2$         | −0.010      | 0.017      | −0.085          | −0.039              |
| NH$_3$         | −0.278***   | −0.251**   | −0.082          | −0.291***           |
| Chlorophyta    | 1.000       | 0.730***   | 0.004           | 0.899***            |
| Cyanophyta     | 1.000       | 0.107      | 0.777***        |                     |
| Bacillariophyta| 1.000       |            | 0.425***        |                     |

N.B. *$P \leq 0.05$, **$P \leq 0.01$, ***$P \leq 0.001$.
Abbreviations: Temp, Temperature; pH, Hydrogen Ion Conc.; EC, Conductivity; TDS, Total dissolved solids; NTU, Nephelometric Turbidity Unit.
$P = 0.0001$) and total hardness ($r = -0.605$, $P = 0.0001$), Cyanophyta were highly significant and negatively correlated with EC ($r = -0.525$, $P = 0.0001$), TDS ($r = -0.530$, $P = 0.0001$) and total hardness ($r = -0.59$, $P = 0.0001$). Negative correlations were recorded between Bacillariophyta and EC ($r = -0.219$, $P = 0.008$), TDS ($r = -0.215$, $P = 0.009$), total hardness ($r = -0.279$, $P = 0.0007$), magnesium ($r = -0.34$, $P = 0.0001$) and manganese ($r = -0.288$, $P = 0.0005$). According to Codony et al. (2003), two different hypotheses on the origin of algae in drinking water can be considered. First, it can be assumed that water treatments are not 100% effective in removing algae. For this reason, some of them are capable of penetrating the drinking water systems. Since algae can travel from origin to the endpoint, the levels detected in tap water are exclusively from algae not removed by treatment. Secondly, some of these algae could proliferate or survive in the dark system, using the ability of some genera to develop heterotrophic metabolisms. In this study, it is logical to consider algae regrowth, probably into the biofilms. Two facts can support this hypothesis. First, the algae detected can grow in the dark using organic matter as a source of carbon. Second, the detected levels do not show a clear seasonal variability, indicating that the presence of algae is not affected by the seasonal changes occurring in the surface waters used for supply. But this does not preclude that the procedures used in water treatment plants to remove algae require frequent adjustment and attention.

### 3.3. Bacteriological assessment of water quality

The main goal of drinking water treatment is to remove or kill pathogenic microorganisms to reduce illness risk. Certain bacteriological testing, including quantitative analysis of total bacterial count (HPC bacteria), total coliform, fecal coliform, and fecal streptococci bacteria, are greatly recommended as efficient indicators for water quality and to make sure that drinking water is free from all pathogenic species (WHO 2004). HPC bacteria are just used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained is the water system (Rusin et al. 1997). The maximum values of heterotrophic plate count (Figure 3 photograph 1) detected in tested tap water samples collected from Tanta city schools (Table 9) were recorded in samples collected from West Tanta city schools, especially during winter from W5 School with 2,640 CFU/100 ml followed by W6 School with 2,490 CFU/100 ml and during summer from W2 School with 2,480 CFU/100 ml these three schools were sourced by three different groundwater stations followed by samples collected from East Tanta city schools 2,409 CFU/100 ml during spring in E2 School which was sourced by the station of treated water mixed with groundwater, followed by 2,260 and 2,199 CFU/100 ml during summer in schools which were sourced by the same groundwater station, E1 and E6 Schools, respectively. The differences between seasons of HPC were statistically significant ($F = 27,148.71$, $P = 0.0001$). Our results indicated that the total bacterial count of the tap water samples collected from Tanta city schools, which are sourced by groundwater stations (E1, E6, W1, W2, and W6 Schools), reached their maximum (2,260, 2,199, 2,040, 2,480 and 900 CFU/100 ml, respectively) in summer, and that the water samples which were collected from E2 School, which was sourced by station and composed of treated water mixed with groundwater were relatively higher than that recorded in samples of treated water or samples of groundwater, such findings are concurrent with those of Abdel-Monem (2000) and Abu Ouf (2007). Our results are also in accordance with those obtained by Shehata (2008), who reported in his study on the microbial pollution of drinking water in Tanta city that the water samples collected from water treatment plants after treatment supported high total bacterial count and also with the results obtained by Atta et al. (2019). It must be emphasized that if a water sample is positive for TC but does not contain FC, this water’s sanitary quality is still considered unacceptable (Bitton 2005). Our results indicated that TC bacteria (Figure 3 photograph 2) detected in water samples collected from Tanta city schools were higher than zero cells/100 ml, which is the maximum allowable limit set by the World Health Organization for drinking water quality (WHO 2008), during autumn in the tested water sample of W1 School, which is sourced by the groundwater station and which also exceeded the guideline limits during spring and summer seasons with 9 and 41 CFU/100 ml, respectively. These results are concomitant with Shehata (2008) who reported that pollution in the same groundwater station was found more frequently than the other groundwater stations and treatment plants in Tanta city. Total coliform bacteria also exceeded the permissible limits recommended by WHO (2008) for drinking water during winter in the tested tap water sample collected from W4 School, which was during this season sourced by the groundwater station while after winter, TC bacteria were completely absent from the water samples of W4 School after the school became sourced by the water treatment plant, during spring in tested tap water samples of E1, E2, E6 and W1 Schools with 17, 12, 18, 9 CFU/100 ml, respectively, and during summer in the water samples collected from E3, W1, W2 and W3 Schools with 20, 41, 15, 22 CFU/100 ml, respectively. Total coliform bacteria were not present throughout the study seasons in any of the examined water samples collected from E4 and W6 Schools sourced by the treatment plant and groundwater station.
Table 9 | Annual values of the bacteriological analysis of the tested tap water samples in Tanta city schools

| Sampling sites | HPC    | TC     | FC    | FS    | Sal.   | Ps     |
|----------------|--------|--------|-------|-------|--------|--------|
| E1             | 1,332.5 ± 8.3 | 4.75 ± 0.0 | 0.5 ± 0.0 | 17 ± 1.25 | 12.5 ± 1.5 | 1 ± 0.0 |
| E2             | 1,804.75 ± 10 | 4.75 ± 0.0 | 0.0 ± 0.0 | 12 ± 0.5 | 13 ± 0.75 | 0.0 ± 0.0 |
| E3             | 999 ± 5 | 5.25 ± 0.0 | 1 ± 0.0 | 0.0 ± 0.0 | 6.5 ± 0.75 | 0.0 ± 0.0 |
| E4             | 665.25 ± 3.3 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 3.5 ± 0.0 | 0.5 ± 0.0 |
| E5             | 171.25 ± 0.42 | 0.25 ± 0.0 | 0.0 ± 0.0 | 0.0 ± 0.0 | 3 ± 0.0 | 0.25 ± 0.0 |
| E6             | 1,444.75 ± 7.8 | 5.75 ± 0.0 | 0.5 ± 0.0 | 1.5 ± 0.0 | 11 ± 1 | 0.25 ± 0.0 |
| W1             | 1,097.25 ± 5.7 | 14.5 ± 0.75 | 2.5 ± 0.0 | 9.5 ± 0.75 | 9.25 ± 0.5 | 0.0 ± 0.0 |
| W2             | 1,553.25 ± 8.3 | 4 ± 0.0 | 1 ± 0.0 | 1.5 ± 0.0 | 21.5 ± 1.5 | 0.75 ± 0.0 |
| W3             | 787.5 ± 4 | 5.5 ± 0.0 | 0.5 ± 0.0 | 0.5 ± 0.0 | 0.5 ± 0.0 | 0.5 ± 0.0 |
| W4             | 1,653.75 ± 9 | 8.5 ± 0.0 | 1.75 ± 0.0 | 0.0 ± 0.0 | 13.75 ± 1 | 2.5 ± 0.0 |
| W5             | 1,543.75 ± 8.3 | 0.75 ± 0.0 | 0.0 ± 0.0 | 0.5 ± 0.0 | 1.25 ± 0.0 | 0.75 ± 0.0 |
| W6             | 635.5 ± 3 | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.5 ± 0.0 | 8.75 ± 0.5 | 0.5 ± 0.0 |

Source of variation  | F value | P value | F value | P value | F value | P value | F value | P value | F value | P value | F value | P value |
---------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
Season               | 27,148.71 | 0.0001 | 99,999.99 | 0.0001 | 99,999.99 | 0.0001 | 99,999.99 | 0.0001 | 26,578.00 | 0.0001 | 99,999.99 | 0.0001 |
Site                 | 19,236.91 | 0.0001 | 99,999.99 | 0.0001 | 99,999.99 | 0.0001 | 99,999.99 | 0.0001 | 10,864.91 | 0.0001 | 99,999.99 | 0.0001 |
Season*S Site        | 4,603.12 | 0.0001 | 99,999.99 | 0.0001 | 99,999.99 | 0.0001 | 99,999.99 | 0.0001 | 14,087.09 | 0.0001 | 99,999.99 | 0.0001 |

HPC, Heterotrophic plate count; TC, Total coliforms; FC, Fecal coliforms; FS, Fecal streptococci; Sal., Salmonella spp.; Ps, Pseudomonas aeruginosa.
According to Egyptian regulations for drinking water (1995), where 95% of the water samples taken in 1 year should be free from coliform bacteria, and no sample should contain more than three cells/100 cm³ in two consecutive samples of the same source, our results indicated that tap water of E1 and E6 Schools, which are sourced by the same groundwater station, W1 School, which is sourced by another groundwater station, and E2 School, which is sourced by water treatment plant (treated water mixed with groundwater) supported the pollution indicator.

Total and fecal coliform bacteria were highly substantially correlated in all research area locations during the study seasons ($r = 0.94$), as shown in Table 10. These, also, were positively correlated with nitrate NO₃ ($r = 0.56$, $P = 0.0001$). Fecal coliform (Figure 3 photograph 3) was completely absent throughout the study seasons from all the water samples collected from E2, E4, E5, W5, and W6 Schools. These results are in harmony with those obtained by El-Dib (1998). In addition, FC were slightly higher than zero cells/100 ml, which is the maximum allowable limit for drinking water (WHO 2008) in the tested tap water samples collected from E6 School during spring (2 CFU/100 ml), W1 School during spring (2 CFU/100 ml) and summer (8 CFU/100 ml), W2 School during summer (4 CFU/100 ml), and W4 School during winter (7 CFU/100 ml), which were sourced by four different groundwater stations. Fecal coliforms also exceeded the permissible limits in the tap water samples collected from E1 School during spring (2 CFU/100 ml), E3 School during summer (4 CFU/100 ml), and W3 School during summer (2 CFU/100 ml), which were sourced by the same water treatment plant.

In general, TC and FC bacteria were relatively higher in the groundwater samples than in treated water samples, this finding is concomitant with that recorded by Abu Ouf (2007), who reported that TC and FC of groundwater samples in the Gharbia region were high compared with those recommended for drinking water, and reported that the contamination of groundwater samples in Al-Gharbia with fecal indicator bacteria could be due to the rural regions having very closed pit-latrines and/or the bad state of sewer systems in most cities of the governorate. Also, our results are in agreement with those of Abdel-Monem (2000), who reported that all examined water samples produced by hand pump (groundwater) in Qalubia governorate were heavily polluted with coliform bacteria.

The obtained results indicated that FS (Figure 3 photograph 4) were frequently detected and exceeded the permissible limit in the tap water samples of the same schools, which were polluted by TC, E1 with 10 and 58 CFU/100 ml during autumn and spring, respectively, and E6 with 2, 2 and 2 CFU/100 ml during autumn, spring, and summer, respectively, both schools were

Figure 3 | Bacteriological analysis. (Photograph 1) Heterotrophic plate count bacteria (HPC). (Photograph 2) Total coliforms (TC). (Photograph 3) Fecal coliforms (FC). (Photograph 4) Fecal streptococci (FS). (Photograph 5) Salmonella choleraesuis (Sal.).
sourced by the same groundwater station, E2 School which is sourced by a water treatment plant (treated water mixed with groundwater) with 4 and 44 CFU/100 ml during autumn and spring, respectively and W1 School which is sourced by another groundwater station with 8 and 30 CFU/100 ml during autumn and spring, respectively in addition to W2 which is sourced by a third groundwater station with 6 CFU/100 ml during summer.

Pathogenic microorganisms must not be present in drinking water because they are of public health significance, associated with gastrointestinal infections such as diarrhea, dysentery, typhoid fever, and other form of infections (Osaro & Oyaribhor 2013). *Salmonella choleraesuis* (Figure 3 photograph 5) was detected and exceeded the permissible limit for drinking water during all the study seasons with maximum values during the spring season in the tested tap water samples collected from the same schools, which were polluted by TC and FS. *Salmonella choleraesuis* was detected in E1 School and E6 School, which are sourced by the same groundwater station with the range of 3–27 CFU/100 ml and 1–25 CFU/100 ml, respectively, in E2 school which is sourced by water treatment plant (treated water mixed with groundwater) with the range of (1–45 CFU/100 ml), and in W1 School which is sourced by another groundwater station with the range of 1–30 CFU/100 ml.

*Salmonella choleraesuis* was also detected during the summer season with relatively high numbers in the tested tap water samples collected from E3, E4, E5, and W6 Schools with 26, 10, 12, and 30 CFU/100 ml, respectively, and from W2 School with 62 CFU/100 ml, in addition to 45 CFU/100 ml during winter in W4 School, which was during this season sourced by the groundwater station. There were highly significant positive correlations between *Salmonella choleraesuis* and heterotrophic

---

### Table 10 | Pearson correlation coefficient physicochemical, biological and bacteriological parameters

|               | HPC   | TC    | FC    | FS    | Sal.  | Ps    |
|---------------|-------|-------|-------|-------|-------|-------|
| Temp          | 0.03  | 0.08  | 0.04  | −0.05 | 0.11  | 0.05  |
| PH            | 0.02  | −0.13 | −0.12 | −0.18 | −0.19 | 0.12  |
| EC            | 0.19  | 0.08  | 0.03  | 0.29***| 0.08  | −0.05 |
| TDS           | 0.19  | 0.07  | 0.03  | 0.29***| 0.07  | −0.04 |
| NTU           | 0.00  | −0.07 | −0.04 | −0.27***| −0.04 | 0.53***|
| Total hardness| 0.40***| 0.13  | 0.06  | 0.29***| 0.20* | −0.25**|
| Ca            | 0.40***| 0.04  | −0.01 | 0.09  | 0.17* | −0.08 |
| Mg            | 0.46***| 0.30***| 0.26**| 0.40***| 0.43***| −0.26**|
| Pb            | −0.29***| −0.15 | −0.19*| −0.10 | −0.21**| 0.48***|
| Cd            | −0.20  | −0.07 | −0.07 | 0.00  | −0.05 | 0.37***|
| Cu            | 0.23** | 0.03  | −0.01 | −0.14 | 0.03  | −0.19*|
| Mn            | 0.33***| 0.04  | −0.07 | 0.23***| 0.10  | −0.08 |
| NO₃           | 0.23** | 0.56***| 0.62***| 0.16  | 0.03  | −0.05 |
| NO₂           | 0.15  | −0.01 | 0.04  | 0.03  | 0.29***| 0.10  |
| NH₃           | 0.29***| 0.10  | −0.06 | 0.49***| 0.36***| −0.04 |
| Chlorophyta    | −0.10 | −0.15 | −0.08 | −0.29***| −0.16* | 0.18* |
| Cyanophyta     | −0.09 | −0.18*| −0.15 | −0.27***| −0.19* | 0.23**|
| Bacillariophyta| −0.15 | −0.19*| −0.15 | −0.09 | −0.17* | 0.15  |
| T.phytoplankton| −0.15 | −0.22**| −0.15 | −0.31***| −0.23**| 0.24* |
| HPC            | 1.00  | 0.35***| 0.34***| 0.19* | 0.45***| 0.13  |
| TC             | 1.00  | 0.94***| 0.26***| 0.49***| 0.49***| −0.10 |
| FC             | 1.00  | 0.22** | 0.50***| 0.10  |
| FS             | 1.00  | 0.48***| −0.09 |
| Sal.           | 1.00  | 0.01  |

N.B. * − P < 0.05; ** − P < 0.01; *** − P < 0.001.

Abbreviations: Temp, Temperature; pH, Hydrogen Ions Conc.; EC, Conductivity; TDS, Total dissolved solids; NTU, Turbidity; Ca, Calcium; Mg, Magnesium; Pb, Lead; Cd, Cadmium; Cu, Copper; Mn, Manganese; NO₃, Nitrate; NO₂, Nitrite; NH₃, ammonia; HPC, Heterotrophic plate counts; TC, Total coliforms; FC, Fecal coliforms; FS, Fecal streptococci; Sal., *Salmonella choleraesuis*; Ps., *Pseudomonas aeruginosa*.
The distribution system to control the hygienic quality of the water supply.

carry out frequent and regular bacteriological examination for the water entering the distribution system and the water in

the dry seasons. The total Palmer of Bacillariophyta exceeded that of the other groups; ranking third were the Cyanophyta, which were least abundant during

phytoplankton groups shows that Chlorophyta dominated the phytoplankton of all the samples collected from Tanta city (0.71 mg/l) seasons, exceeded the permissible limits of drinking water. The total percentage composition of the three main

calcium (Ca\(^{2+}\)), magnesium (Mg\(^{2+}\)), copper (Cu\(^{2+}\)) and manganese (Mn\(^{2+}\)) are compatible with the recommended standards by the Egyptian regulation (2007) and WHO guidelines (2008). The only exception is that lead (Pb\(^{2+}\)) in all the tested samples during autumn (0.086 to 0.181 mg/l), cadmium (Cd\(^{2+}\)) in all the tested samples during autumn (0.014–0.039 mg/l) and most of them during summer, nitrate (NO\(_3^–\)) in the samples collected from W1 during summer season (63.08 mg/l) and nitrite (NO\(_2^-\)) in samples of E1 during winter (0.29 mg/l) and W2 during autumn (0.86 mg/l), spring (1.7 mg/l) and summer (0.71 mg/l) seasons, exceeded the permissible limits of drinking water. The total percentage composition of the three main phytoplankton groups shows that Chlorophyta dominated the phytoplankton of all the samples collected from Tanta city schools throughout the study period except for the samples collected from both E1 and E4 where the percentage composition of Bacillariophyta exceeded that of the other groups; ranking third were the Cyanophyta, which were least abundant during dry seasons. The total Palmer’s pollution index score of W3 samples during rainy seasons and samples from W5 during winter was greater than 20, indicating the presence of organic pollution. Conversely, the total scores of the remaining samples were less than 20, indicating probable high organic pollution in some schools and less organic pollution in others. Our results indicated that the total bacterial count of the tap water samples collected from Tanta city schools, which are sourced by groundwater stations, reached their maximum in summer, and that total bacterial count detected in the water samples collected from E2 which were composed of treated water mixed with groundwater were relatively higher than that recorded in samples of treated water or samples of groundwater. Total and fecal coliform bacteria were relatively higher in the groundwater samples than that in treated water samples.

4. CONCLUSION

The results of the physicochemical analysis of the potable water samples collected from schools under investigation established the fact that all values of the various parameters tested [hydrogen ion concentration (pH), TDS, total hardness, calcium (Ca\(^{2+}\)), magnesium (Mg\(^{2+}\)), copper (Cu\(^{2+}\)) and manganese (Mn\(^{2+}\))] are compatible with the recommended standards by Abu Ouf (2007), who reported that tap water of the Gharbia region was heavily polluted with pathogenic Gram-negative bacteria and that Salmonella choleraesuis was from the most predominant pathogenic bacteria detected in all tap water samples with different frequencies, and indicted that tap water was non-potable for human consumption.

Pseudomonas aeruginosa was more detected more during wet seasons, as during autumn (1 CFU/100 ml) was recorded in the tested tap water samples of E4, E5, E6, W2, W3, W5, and W6 Schools (3 CFU/100 ml) in E1 School and (7 CFU/100 ml) in W4 School. During winter 1 CFU/100 ml was recorded in the water samples of E4, W5, and W4 Schools and 2 CFU/100 ml in W5 School. Pseudomonas aeruginosa was also recorded during dry seasons (1 CFU/100 ml) during spring and summer in water samples of W2 and W4 Schools and during summer only in E1 and W6 Schools samples. Pseudomonas aeruginosa was completely absent throughout the study seasons from all the water samples collected from W1 School this explained the negative correlations between Pseudomonas aeruginosa and TC (r = −0.1), FC (r = −0.1) and FS (r = −0.09), but there were highly significant positive correlations between Pseudomonas aeruginosa and water turbidity (r = 0.53, P = 0.0001) and lead Pb\(^{2+}\) (r = 0.48, P = 0.0001).

Generally, microbiological analysis of the tap water samples collected from schools of Tanta city indicated that the counts of pollution indicators were more in ground water than treated water.

In Egypt, the availability of safe and clean water is a serious problem. The deterioration of operation efficiency of water treatment plants and using one fixed system for the water treatment plants all over the country, which is not compatible with the types of pollution in different places, are major problems of potable water in Egypt. The detection of microbial groups in this study could be attributed to the inefficiency of the treatment method, contamination during the distribution, or the presence of internal microbial contamination in the pipes of the distribution system, so it is highly recommended to carry out frequent and regular bacteriological examination for the water entering the distribution system and the water in the distribution system to control the hygienic quality of the water supply.

ACKNOWLEDGEMENT

The authors would like to acknowledge the support from Tanta University through the project TU-09-31-2009.
DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

REFERENCES

Abdel-Monem, M. O. 2000 Bacteriological and Chemical evaluation of drinking water in Qalubya, Egypt. Egypt. J. Microbiol. 35, 343–354.
Abdel-Satar, A. M., Ali, M. H. & Goher, M. E. 2017 Indices of water quality and metal pollution of Nile River. Egypt. Egyptian Journal of Aquatic Research 43, 21–29.
Abdel-Shafy, H. I. & Kamel, A. H. 2016 Groundwater in Egypt issue: resources, location, amount, contamination, protection, renewal, future overview. Egypt. J. Chem. 59, 3.
Abu Ouf, H. A. H. 2007 Bioremediation of Pathogenic Gram-Negative Bacteria in Different Water Sources in Gharibia, Egypt. M.Sc. Thesis, Faculty of Science, Tanta University.
Akinsola, R. O. & Godowoli, I. A. 2005 Determination of nitrate content in drinking water: a survey of Bama Local Government Area, Borno State, Nigeria. Chem. Class Journal 2, 5–9.
AL-Postah, R. A., Abd Al-Jabar, R. A. & Farkha, T. J. 2017 Qualitative and quantitative study of algae in three drinking water plants and springs in sulaymaniyah province-Kurdistan region of Iraq. Tikrit Journal of Pure Science 22 (6), 8–24.
American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF). 1998 Standard Methods for the Examination of Water and Wastewater, 20th edn. Washington, DC: American Public Health Association, American Water Works Association, Water Environment Federation.
American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF). 2005 Standard Methods for the Examination of Water and Wastewater, 21st edn. Washington, DC: American Public Health Association, American Water Works Association, Water Environment Federation.
Atta, M. B., El-Hawary, F. I., Fouda, A. M. & Moustafa, H. E. 2004 Evaluation of Potable Water Quality in Tanta City: Some Chemical Characteristics of Drinking Water.
Atta, M. F., Amer, W. H., Ali, G. M. & Zamzam, A. S. 2019 Relation between drinking water contamination and gastroenteritis. Egyptian Journal of Medical Microbiology 28 (3), 17–24.
Bellinger, E. G. & Sigee, D. C. 2010 Freshwater Algae: Identification and Use as Bioindicators. Wiley-Blackwell, Chichester, West Sussex, UK. 284pp.
Bitton, G. 2005 Microbiological Indicators of Fecal Contamination: Application to Microbial Source Tracking. University of Florida, USA.
Codony, F., Miranda, A. & Mas, J. 2003 Persistence and proliferation of some unicellular algae in drinking water systems as result of their heterotrophic metabolism. Water SA 29 (1), 113–116.
Dash, M. C. 1996 Fundamentals of Ecology. Tata McGraw Hill Publishing Company Limited, New Delhi.
Demir, N. & Atay, D. 2002 The treatment efficiency of plankton in the Ivedik drinking water treatment plant, Ankara. Turk J Biol. 26, 229–234.
Diehl, H., Goetz, C. & Hash, C. C. 1950 Soil and water analysis. Am. Water Works Assoc. J. 40, 42.
Doma, H. S., Abdou, S. M., Hemdan, B. A. & Ali, G. H. 2018 Enhancing biomass, energy and value-added compounds yield from pilot scale pond system. J. Environ. Sci. Technol. 11 (4), 199–208.
Egyptian Ministry of Health 1995 Decree of Minister of Health No. (108) and (301)/1995 for Drinking-Water Source Protection.
El-Dib, M. A. 1998 Evaluation of Water Treatment Plants for Removal of Organic, Inorganic and Parasites Pollutants. A Final Report of Project Sponsored by Academy of Science and Technology, Egypt.
El-Gamal, A. D., Barakat, I. M. M., Hassan, H. A. S. & Salah El Din, R. A. 2019 Dynamic case study of phytoplankton as a result of the non-biological characteristics of water at embaba drinking water station, giza. Egypt. J. Phycol. 20, 155–182.
El Sayed, S. M., Hegab, M. H., Mola, H. R., Ahmed, N. M. & Goher, M. E. 2020 An integrated water quality assessment of Damietta and Rosetta branches (Nile River, Egypt) using chemical and biological indices. Environ Monit. Assess 192, 228.
EMHP (Egyptian Ministry of Health and Population) 2007 Decree No. 458/2007 for Drinking-water Source protection.
Gensberger, E. T., Gossl, E.-M., Antonielli, L., Sessitsch, A. & Kostic, T. 2015 Effect of different heterotrophic plate count methods on the estimation of the composition of the culturable microbial community. Peer J. 3, e862.
Hindak, F. M. 1984 Studies on the Chlorococal Alga (Chlorophyceae), Vol. IV. VEDA, publishing house of the Slovak Academy of Science, Bratislava.
Hotzel, G. & Croome, R. 1998 A Phytoplankton Methods Manual for Australian Rivers. Land and Water Resources and Development Corporation, Canberra.
ISO (International Standards Organization). 1995 (ISO 6340), Water Quality – Detection of Salmonella Species, 1st edn. International Federation of the National Standardizing Associations, Geneva, Switzerland.
Katsiapi, M., Moustaka-Gouni, M., Michaloudi, M. & Kormas, K. 2011 Phytoplankton and water quality in a Mediterranean drinking-water reservoir (Marathonas Reservoir, Greece). Environ Monit. Assess 181 (1–4), 563–575.
Ma, J. & Liu, W. 2002 Effectiveness and mechanism of potassium ferrate (VI) preoxidation for algae removal removal by coagulation. Water Research 36 (4), 871–878.
Mahmoud, K. M. A., Sayed, S. S. M. & Habib, M. R. 2018 Ecological assessment of the river Nile status around Gizert El-Warrak using phytoplankton and macroinvertebrates assemblages. *Egyptian Journal of Aquatic Biology & Fisheries*. 22 (4), 13–24.

Margalef, R. 1958 Temporal succession and spatial heterogeneity in phytoplankton. In: *Perspectives in Marine Biology* (Buzzati-Traverso, A. A. ed.). University of California, Berkeley, pp. 323–349.

McFeters, G. A. 2013 *Drinking Water Microbiology*. Springer-Verlag New York Inc, New York, USA.

Moran, S. 2018 *Clean Water Characterization and Treatment Objectives*. Elsevier BV, Berlin, Heidelberg.

Nollet, L. M. L. 2000 *Handbook of Water Analysis*. Hogeschool Gent, Ghent, Belgium.

Ouf, S. A., Yehia, R. S. & Abdul-Rahim, R. F. 2018 Bacterial contamination and health risks of drinking water from the municipal non-government managed water treatment plants. *Environ Monit. Assess.* 190, 685.

Palmer, C. M. 1969 A composite rating of algae tolerating organic pollution. *J. Phycol.* 5, 78–92.

Pielou, E. C. 1975 *Ecological Diversity*. Wiley-Interscience, New York, p. 165.

Prescott, G. W. 1975 *Algae of the Western Great Lakes Area: With An Illustrated key to the Genera of Desmids and Freshwater Diatoms*. WM. C. Brown Company Publishers: Dubuque, Iowa, USA.

Rajagopal, T., Thangamani, A., Sevarkodyione, S. P., Sekar, M. & Archunan, G. 2010 Zooplankton diversity and physicochemical conditions in three perennial ponds of Virudhunagar district, Tamilnadu. *J. Environ. Biol.* 31, 265–272.

Rawway, M., Kamel, M. S. & Abdul-Raouf, U. M. 2016 Microbial and physico-chemical assessment of water quality of the river Nile at Assiut governorate (Upper Egypt). *J. Eco. Heal.* 4 (1), 7–14.

Rusin, P. A., Rose, J. B., Haas, C. N. & Gerba, C. P. 1997 Risk assessment of opportunistic bacterial pathogens in drinking water. *Rev. Environ. Contam. Toxicol.* 152, 57–83.

SAS Institute Inc. 1985 *SAS User's Guide: Statistics*, 5th edn. SAS Inst. Inc, Cary, NC, p. 956.

Shannon, C. E. & Weaver, W. 1949 *A Mathematical Theory of Communication*. University of Illinois Press, Illinois: Urbana, p. 125.

Shehata, A. A. 2008 Studies on the Microbial Pollution of Drinking Water in Tanta City. M.Sc. Thesis, Faculty of Science, Tanta University.

Shokr, E. A. M., Alhazemi1, A., Naser, T., Zuhair, T. A., Zuhair, A. A., Alshamary, A. N., Alanazi, T. A. & Alanazi, H. A. 2016 Chronic renal failure associated with heavy metal contamination of drinking water in Hail, KSA. *Merit Research Journal of Medicine and Medical Sciences* 5 (1), 6–13.

Streble, H. & Krauter, D. 1978 *Das Leben im Wassertropfen Mikroflora und Mikrofauna des Sübwassers, Ein Bestimmungsbuch mit 1700 Abbildungen Stuttart.*

Sykes, J. B. 1981 An illustrated guide to the diatoms of British coastal plankton. Field studies council. *AIDGAP Project somerset*. 5, 425–468.

USEPA (US Environmental Protection Agency) 1992 *Manual for the Certification of Laboratories Analyzing Drinking Water*. EPA-814B-92-002. Office of Ground Water and Technical Support Division, USEPA, Cincinnati, Ohio.

USGAO (United states General Accounting Office) 2000 *Health Effect of Lead in Drinking Water*. US General Accounting Office reports 2000.

Vadrucci, M. R., Sabetta, L., Fiocca, A., Mazziotti, C., Silvestri, C., Cabrini, M., Guardiani, B., Konjka, E., Evangelopoulos, A., Koutsoubas, D. & Basset, A. 2007 Statistical evaluation of differences in phytoplankton richness and abundance as constrained by environmental divers in transitional water of the Mediterranean basin. *Aquat. Cons. Mar. Freshwat. Ecosyst.* 18, 88–104.

Wolf, H. 1982 Methods of coding of ecological data from diatoms for computer utilization. *Model Rijks. Geol. Dienst* 36 (2), 95–110.

World Health Organization (WHO) 2004 *Water Treatment and Pathogen Control: Process Efficiency in Achieving Safe Drinking Water* (Le Chevallier, M. W. & Au, K.-K. eds.). Published by IWA Publishing, London, UK. ISBN: 1 84359 069 8.

World Health Organization (WHO) 2008 *Guidelines for Drinking-Water Quality*, 3rd edn, Incorporating the First and the Second Addenda, Volume 1: Recommendations. WHO, Geneva.

First received 14 June 2021; accepted in revised form 16 July 2021. Available online 2 August 2021