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Wastewater Treatment of Mariout Lake Drains Using Combined Physical, Chemical, and Biological Methods in Microcosm Experiments

Hermine RZ Tadros

Professor and Head of Marine Chemistry, Marine Chemistry Department, Marine Environment Division, National Institute of Oceanography & Fisheries, Qayet Bay, Alexandria, Egypt

Samia Kh Hamdona

Professor of Marine Chemistry, Marine Chemistry Department, Marine Environment Division, National Institute of Oceanography & Fisheries, Qayet Bay, Alexandria, Egypt

Mary G Ghobrial

Professor of Aquatic Plants, Hydrobiology Department, Marine Environment Division, National Institute of Oceanography & Fisheries, Qayet Bay, Alexandria, Egypt

Email: mary_ghobrial@hotmail.com (Corresponding Author)

Mona F El-Naggar

Lecturer of Marine Chemistry, Marine Chemistry Department, Marine Environment Division, National Institute of Oceanography & Fisheries, Qayet Bay, Alexandria, Egypt

Omayma H Abd El-Hamid

Lecturer of Marine Chemistry, Marine Chemistry Department, Marine Environment Division, National Institute of Oceanography & Fisheries, Qayet Bay, Alexandria, Egypt

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Abstract

The treatment of wastewater is a must due to the decrease of clean water and the increase in the consumption of fresh water for domestic uses. This study discusses the physical, chemical, and biological treatments of water from different types of Mariout Lake drains. It also aims at a designation of appropriate wastewater treatment process for sewage water (El-Qalah drain), agriculture water (El-Umoum drain), and raw drinking water before treatment (Nubareya canal) so as to adopt an appropriate procedure to be applied as the drains discharge their wastewaters in Mariout Lake affecting its water quality as well as its fish productivity. Obtaining secure effluents for discharge in natural water bodies (El-Mex bay), or using treated effluents in agriculture or industrial purposes, is a target too, open for estimation. Alum, aeration beside two natural medicinal plants, piper *nigrum* (Black Pepper) and dry ginger (Zingiber officinalis), and the eukaryotic microorganism yeast, were used for treatment, in addition to the freshwater submerged macrophyte *Ceratophyllum demersum*.

The results of the physicochemical parameters revealed that the best material for treatment in El-Qalaa sewage drain was by Alum + Aeration + Ginger + *Ceratophylum demersum.*

The most preferable material for both the raw drinking water of Nubareya canal and El-Umoum agricultural wastewater was Alum + Aeration + Yeast + Ceratophylum demersum.

Regarding the four trace metals' (Zn, Pb, Fe, and Cu) concentration treatments, the best treatment in all cases was found to be Alum + Aeration + Yeast + *Ceratophylum demersum,* except for Zn in El-Qalaa sewage water which had to be treated by Alum + Aeration + Ginger + *Ceratophylum demersum*.

Keywords: sewage water, agricultural water, raw drinking water, treatment, Alum; Aeration, piper *nigrum*, ginger, yeast, *Ceratophylum demersum*

1. Introduction

Egypt has been listed among the top ten countries threatened with water scarcity by the year 2025 due to the rapidly increasing population. Such a situation of water shortage necessitates seeking new water supplies for agricultural activities, which consume about 86.3% of the water supply in Egypt (Abdel-Shafy and Raouf, 2002). Using waste water for irrigation purposes was one of the available alternatives that can be adopted. In this context, transitional water bodies in the country gain special relevance. Lake Mariout, for a long time, has been a source of fish production in Egypt. Nowadays, some parts of it are used in aquacultural activities. It became one of the most heavily populated urban areas in Egypt, and the Lake has been subjected to various anthropogenic activities (Mateo, 2009; Saad et al., 2017). Lake Mariout not only represents a possible future reservoir of treated waste waters, but could also become a much more important source of fish than it is today, a unique area for leisure, and a priceless natural environment for future generations to learn the importance of staying connected to nature.

The discharge of wastewater directly into water bodies resulted in a significant deterioration of water quality of such bodies. In addition, untreated wastewater (sewage), containing a large amount of organic matter, discharged into a river/stream will consume the dissolved oxygen needed to meet the biochemical oxygen demand (BOD) of wastewater, thus depleting the dissolved oxygen of the stream, and thereby causing fish to die, and other undesirable effects. Moreover, heavy metals pollution is one of the most relevant environmental problems nowadays (Bhatti & Latif, 2011).

Methods of wastewater treatment were first developed in response to the adverse conditions caused by the discharge of wastewater to the environment and the concern for public health.

Also, as populations grew, the quantity of wastewater generated rose rapidly and the deteriorating quality of this huge amount of wastewater exceeded the self-purification capacity of the streams and river bodies (Gray, 1989).

Wastewater treatment is a process used to convert wastewater into an effluent that can be returned to the water cycle with minimum impact on the environment, or directly reused (Zhou & Smith, 2002). Wastewater treatment involves the breakdown of complex organic compounds in wastewater into simpler compounds that are stable and nuisance-free, either physico-chemically and/or by using micro-organisms (biological treatment) (Grady et al., 1999 & Rehm & Reed 1986).

Studies on the treatment of effluent bearing heavy metals have revealed adsorption to be a highly effective technique. Chang Pan et al., (2018) suggested heavy metals remediation including physical, chemical, and bioremediation techniques, as well as joint techniques.

Adsorption involves the removal of specific compounds from wastewater on solid surfaces using the forces of attraction between bodies. Alum is mainly used in water treatment processes for the removal of suspended matters (Lai et al., 2015).

Based upon the reviewed literature (Lynette et al., 2007), several hypotheses can be generated regarding the use of alum in wetlands. First, it appears that alum will effectively sequester P in a municipal wastewater treatment wetland. Moreover, changes in the soil mineralogy will be evident due to the addition of alum. The author utilized both laboratory scale and field scale experiments.

On the other hand, medicinal plants such as dry ginger (Zingiber *officinalis*) and black pepper (Piper *nigrum*) have been used for the adsorption of heavy metals from the water samples (Juliana et al., 2016). Such absorbents also have an advantage of being a low cost material, user friendly, and locally available.

In the early 1990s, the Japanese Research Institute discovered the application of yeast wastewater treatment technology for the first time in the world (Yan Wang et al., 2018). Because of its fast growth and high metabolic efficiency, it has attracted much attention. The process of seeding inoculation of microorganisms, such as yeast (fungus), for degrading organic materials in wastewater treatment has rapidly become an increasing practice in many countries because it is economical and its application is uncomplicated.

Yeast, as a very valuable microbial resource, has a good enzyme system in the body and can adapt to a variety of special environments. Therefore, it plays an important role in the biological treatment of wastewater. The application of yeast in the field of wastewater treatment such as high concentration organic wastewater, heavy metal ion wastewater, and domestic sewage were investigated by Yan Wang et al., (2018). However, Karla et al., (2013) investigated the biosorption of zinc (Zn), copper (Cu), manganese (Mn), and iron (Fe) with immobilized yeast spp. Yeast can convert most of the organic matter into non-toxic, nutritious single cell protein, which is highly efficient with regards to wastewater treatment (Yang & Zheng, 2014).

Biological treatment is used primarily to remove the biodegradable organic substances (colloidal or dissolved) in wastewater. Plants can be used as low-cost extraction devices to purify polluted water. Biological remediation is perhaps the most important mechanism in removing pollutants in constructed wetlands. Wetland plants are widely recognized for their ability to capture and remove contaminants, particularly since some of the pollutants are essential nutrients, such as nitrate, ammonium, and phosphate which are easily taken up in such plants.

One of the economic and rapid methods for element removal is displacement of metals by biosorption (Foroughi et al., 2010); therefore they concluded that the coontail *Ceratopyllum demersum* can be used for refining wastewater. Bo Jiang et al., (2018) evaluated the behavior of heavy metal uptake by 12 native aquatic macrophytes, including *C. demersum*, and found accumulation ability and high uptake capacity potential.

This research aims to designation of appropriate wastewater treatment process for sewage water (El-Qalah drain), agriculture water (El-Umoum drain), and raw drinking water before treatment (Nubareya canal) in order to adopt an appropriate treatment method to be applied. Obtaining secure effluents for discharge in natural water bodies (El-Mex bay), or using treated effluents in agriculture or industrial purposes is a target too, open to estimation.

2. Materials and Methods

2.1 Sampling Collection

Wastewater samples were collected from two main drains, and raw drinking water from a canal (El-Qalaa, El-Umoum and Nubareya). Each sample was collected in 20L polyethylene plastic bottle during spring. These different types of water are considered the main inflows to Lake Mariout (Fig. 1).

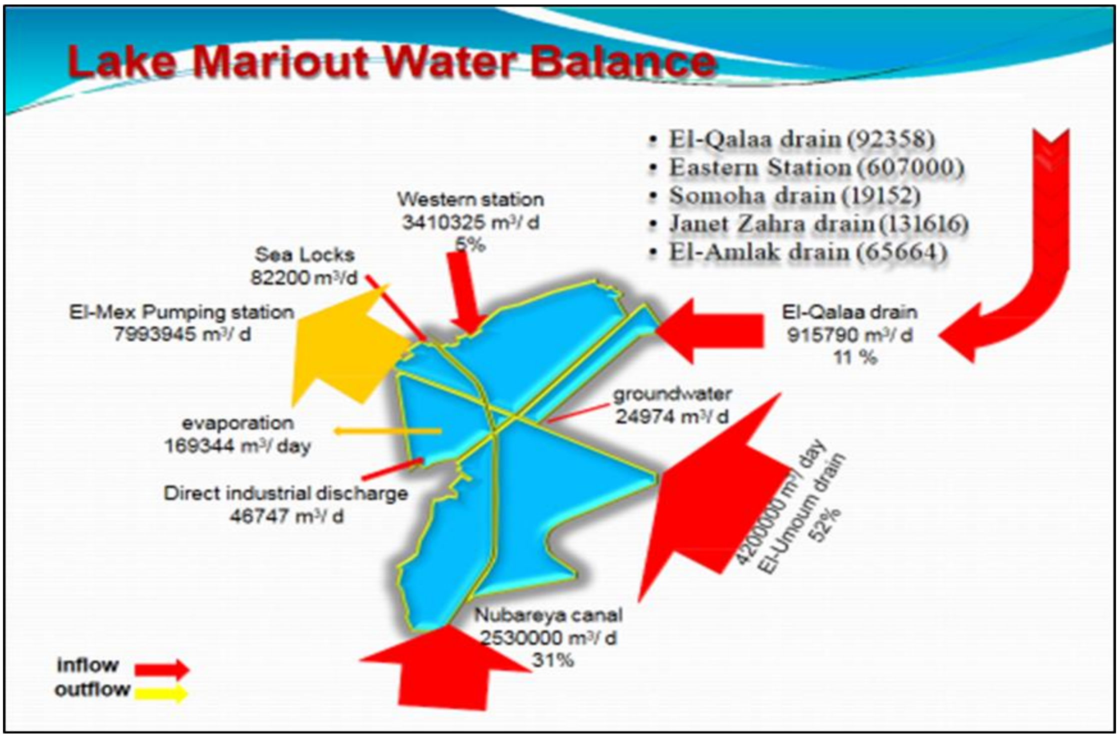

Figure 1. The three main wastewater drains inflow sources in Lake Mariout

2.2 Preparation and Treatment of Samples

Alum adsorption tests were performed in a batch of polyethylene bottles containing collected wastewater samples. Twenty gram Alum (Al_2O_3) (corundum) were added to 20L of drain wastewater. The pH was adjusted to 7.5 and left for sedimentation. After filtration, ventilation began by pumping, followed by addition and integration of different biological materials (natural plants) with or without a macrophyte for treatment, and all were accompanied by aeration. The experiment was established in microcosm glass basins (5L).

Two natural medicinal plants, piper *nigrum* ((Black Pepper) and dry ginger (Zingiber officinalis), and the eukaryotic microorganism yeast were used for treatment, in addition to the freshwater submerged macrophyte *Ceratophyllum demersum*. 0.2, 0.4, 0.8 and 1.0 g/100 ml wastewater of the biosorbent mentioned before, respectively, while 5g/L of the macrophyte were used. The key for treatment was as follows: I. Drain water before treatment, II. Drain water (Alum + Aeration), III. Drain water (Alum + Aeration) + 5g/l *Ceratophylum,* IV. Drain water (Alum + Aeration) + 10g/l piper nigrum, V. Drain water (Alum + Aeration) +10g/l piper nigrum +5g/l *Ceratophylum*, VI. Drain water (Alum + Aeration) + 10g/l ginger, VII. Drain water (Alum + Aeration) + 10g/l ginger + 5g/l *Ceratophylum*, VIII. Drain water (Alum + Aeration) + 10g/l yeast, and IX. Drain water (Alum + Aeration) + 10g/l yeast +5g/l *Ceratophylum* all at 24 h.

Treated water samples were tested at 15, 30, 60, 90, 120 min intervals, and overnight, during the biosorption experiments and analyzed for oxidizable organic matter (OOM), nitrite, nitrate, phosphate, silicate, and sulphate. Three sets of experiments for treatment of El-Qalaa, El-Umoum, and Nubareya polluted wastewater sources were carried out in duplicate, in spring season.

2.3 Determination of the Chemical Parameters

Oxidizable organic matter (OOM) was determined using permanganate values test (FAO, 1975). The nutrients parameters, nitrite, nitrate, phosphate, and silicate were determined colourimetrically according to the methods described by APHA (1995). The sulphate was measured turbidimetrically using a spectrophotometer at wave length 420nm (Rossum & Villarruz, 1961).

2.4 Determination of the Heavy Metals

Water samples were digested according to the method described in APHA (1995). The levels of iron (Fe), copper (Cu), zinc (Zn), and lead (Pb) in digests of water were determined using atomic absorption spectrophotometer model (SHIMADZU-AA-6800) equipped with different cathode lamps with air acetylene flame atomic absorption (FAA) technology (Thermal atomization) for Fe, Cu, Zn, and Pb at specific wavelengths appropriate for each metal.

3. Results

A study on the physicochemical parameters on Lake Mariout during 2014 showed that the range of some physicochemical parameters were 18-27.5 ℃ for Temperature; 0.28- 7.40‰ for Salinity; 7.84-8.84 for pH; 0.60-5.24meq/l for Total alkalinity; 0.14–10.71mg/l for DO;

3.2-134.4mg/l for OOM. The results of nutrient salts range (µM) were from 0.05 to 22.48 for Nitrite; from 0.14 to 66.67 for Nitrate; from 0.39 to 157.26 for ammonia; from 0.10 to 45.30 for reactive phosphate; from 2.14 to 226.16 (39.97 ±21.85) for silicate (Gehan et al., 2018).

There is a continuous need to identify and develop an efficient, low cost adsorbent for facile, and an efficient removal process. Adsorption on low cost materials such as biomass has been performed by contemporary researchers and was found to be effective (Juliana, 2016), (Akar et al., 2009), (Orumwense, 1996). They are simple to handle and have a very low maintenance cost (Dubey & Gopal, 2007).

Alum has been used for phosphorus inactivation in lakes and for phosphorus removal in wastewater treatment plants for decades (Welch & Schrieve, 1994, Berkowitz et al., 2006). In the present research, alum and aeration considerably lowered OOM and SO_4^{2-}, while other nutrient loads decreased slightly, particularly PO_4^{3-} compared with Lynette results. The effect of combined physical, chemical, and biological treatments on the chemical parameters of the wastewater for El-Qalaa drain, El-Umoum drain, and Nubareya canal were studied as follows:

3.1 El-Qalaa Drain

3.1.1 The Effect of Different Treatments on the Chemical Parameters of the Sewage Wastewater of El-Qalaa Drain

Table (1) presents the oxidizable organic matter (OOM) recorded 34.8 mg O_2/l at Qalah before treatment. After treatment, the OOM fluctuated between 8.44mg O_2/l for the treatment by [II] and 2.56mgO_2/l for [VII] treatment. Phosphate concentration (PO_4^{3-}) recorded 16.4µM before treatment and fluctuated between 15.9µM for the treatment by [1I] and 3.05µM for [VIII] treatment, while silicate recorded 89.49µM before treatment and variation from 63.73µM for the treatment by [II] and 15.41µM for [VI] treatment. Nitrite recorded 2.25µM before treatment and variations from 1.13µM for the treatment by [II] to 0.15µM for [VII] treatment. Nitrate value recorded 5.33µM before treatment and fluctuated between 4.67µM for the treatment by [V] and 0.2µM for [VIII] treatment. Sulphate (SO_4^{--}) recorded 3.49 g/l before treatment and differed between 2.36 g/l at the treatment by [II] and 1.31 g/l for [IX] treatment.

It is noticed from the results shown in Table (1) and Fig. (2) that studies of the chemical parameters of El-Qalaa drain wastewater showed reduced concentrations of oxidizable organic matters and nutrient loads (PO_4^{3-}, SiO_3^{-}, NO_2^{-}, and NO_3^{-}) beside SO_4^{2-} after treatments. Afterwards, they were considerably reduced after using biological materials, with maximum reduction in ginger and the macrophyte *Ceratophylum demersum* integrated medium, recording nearly minimum concentrations of most parameters.

Table 1. The effect of different treatments on some chemical parameters in El-Qalaa Drain wastewater during spring 2014

El-Qalaa	OOM mgO_2/l	PO_4^{3-} µM	SiO_3^- µM	NO_2^- µM	NO_3^- µM	SO_4^{2-} g/l
I. El-Qalaa sewage	**34.8**	**16.4**	**89.49**	**2.25**	**5.33**	**3.49**
II. El-Qalaa sewage + Alum + aeration	**8.44**	**15.9**	**63.73**	**1.13**	**4.25**	**2.36**
III. El-Qalaa sewage + Alum + aeration + ***Ceratophyllum***	**5.76**	**10.3**	**29.99**	**0.62**	**4.24**	**2.34**
IV. El-Qalaa sewage + Alum + aeration + Piper ***nigrum***	**5.12**	**8.05**	**62.89**	**0.45**	**4.23**	**2.35**
V. El-Qalaa sewage + Piper ***nigrum*** **+ alum + aeration +** ***Ceratophyllum***	**3.52**	**7.03**	**42.48**	**0.38**	**4.67**	**2.31**
VI. El-Qalaa sewage + Ginger + alum + aeration	**3.2**	**3.15**	**15.41**	**0.68**	**4.25**	**2.31**
VII. El-Qalaa sewage + Ginger + alum + aeration + ***Ceratophyllum***	**2.56**	**3.9**	**17.07**	**0.15**	**2.04**	**2.12**
VIII. El-Qalaa sewage + Yeast + alum + aeration	**5.12**	**3.05**	**28.32**	**0.93**	**0.2**	**1.32**
IX. El-Qalaa sewage + alum + aeration + Yeast + ***Ceratophyllum***	**4.16**	**3.4**	**23.74**	**0.43**	**0.24**	**1.31**

Treatment with yeast in the medium with alum and aeration (VIII) showed a high decrease in PO_4^{3-} and NO_3^- concentrations, compared with the other treatments (Fig. 2). These results were supported by Nguyen & Ronald, (1973), whose results indicated that high removals of phosphorus, ammonia-N, and total N were achieved using yeast for treatment. Moreover, Takashi et al., (2008) suggested that yeasts would not only treat organic matter, but also remove and allow recovery of phosphorus.

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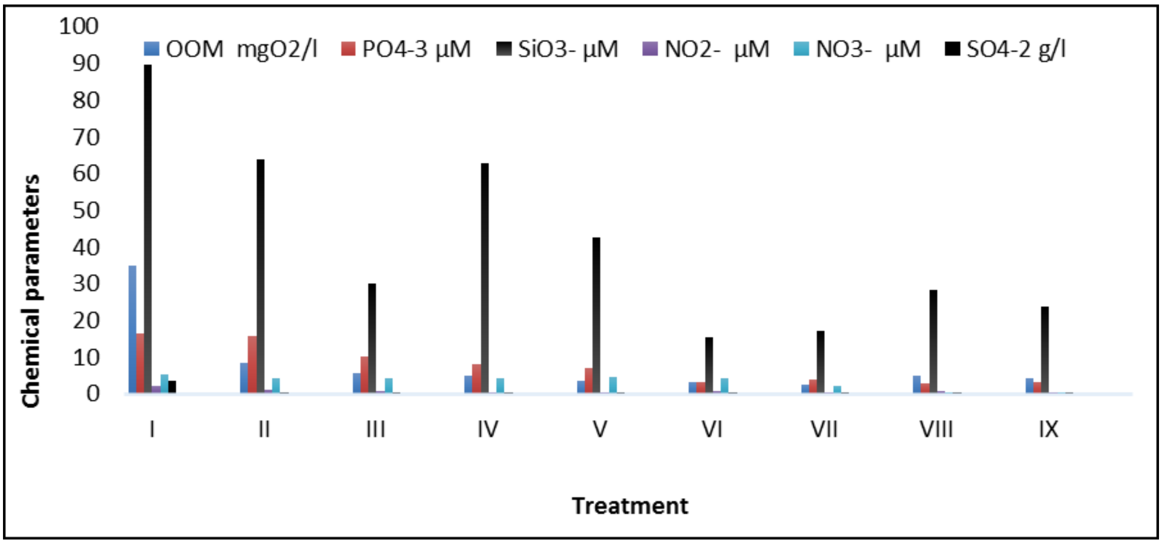

Figure 2. The effect of different treatments on the chemical parameters of El-Qalaa drain wastewater during spring 2014

3.1.2 The Effect of Different Treatments on the Trace Metals Concentrations of the Sewage Wastewater of El-Qalaa Drain

Heavy metal pollution is regarded as a severe problem because it injures the biological functions of the aquatic organisms and their accumulation in fish organs and flesh leading to serious health hazards to the consumers (Daoud et al., 1999).

Different treatments used affected the concentrations of Zn, Pb, Fe, and Cu present in wastewater of El-Qalaa drain. Table 2 shows considerable reduction of all the four metals; Zn, Pb, Fe, and Cu by using piper, ginger, and yeast. On the other hand, Pb, Fe, and Cu recorded the least decrease in their concentrations by using Alum + Aeration + Yeast + *Ceratophyllum* treatment, while Zn recorded the least decrease in its concentration by using Alum + Aeration + Ginger + *Ceratophyllum*.

Treatment of heavy metal ions in wastewater and domestic sewage were investigated by Yan Wang et al., (2018). Previous authors' suggestions in both chemical and trace metals concentrations support the results of the present research, as shown in Tables 1, 2, and Figs. 2, 3. Generally, Yeast treatment medium reduced all metals under investigation.

Although reduction of pollutants under consideration was achieved in all treatment media, but were more reduced in all media with the integration of the submerged macrophyte *Ceratophyllum demersum*, as shown in Table 2 and Fig. 3, all pollutants were minimized. However, Foroughi et al., (2010) proved that one of the economic and rapid methods for elements removal is displacement of metals by biosorption for the purpose of purifying wastewater by *Ceratophyllum demersum*. Bo Jiang et al., (2018) investigated Effective phytoremediation of low-level heavy metals by native macrophytes *C. demersum* in China.

Previous studies reported that Dry Ginger (Zingiber officinalis) and Black Pepper (Piper *nigrum*) were used as an adsorbent for heavy metals (Remigius et al., 2003).

Table 2. The effect of different treatments on the trace metals concentrations (µM) of El-Qalaa Drain sewage water

El-Qalaa	Zn	Pb	Fe	Cu
(I) El-Qalaa raw sewage	25.7	35	168	16
(II) El-Qalaa sewage +Alum + Aeration	17.8	22.3	120.3	13.8
(IV) El-Qalaa sewage +Alum + Aeration + Piper	16	19.1	97.4	10.2
(V) El-Qalaa sewage +Alum + Aeration + piper + *Ceratophyllum*	14.6	13.2	77.8	8.5
(VI) El-Qalaa sewage +Alum + Aeration + Ginger	11.8	14.8	117.7	6.6
(VII) El-Qalaa sewage +Alum + Aeration + Ginger + *Ceratophyllum*	9.6	10.3	103.2	4.8
(VIII) El-Qalaa sewage +Alum + Aeration + Yeast	14.6	5.6	80.2	1.5
(IX) El-Qalaa sewage +Alum + Aeration + Yeast + *Ceratophyllum*	11.7	2.9	66.9	1.1

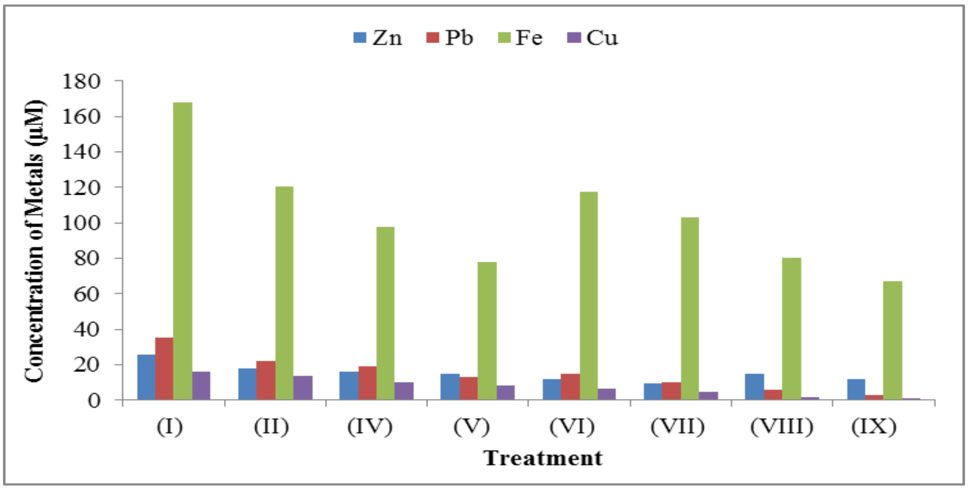

Figure 3. The effect of different treatments on the trace metals concentrations of El-Qalaa drain sewage during spring 2014

3.2 Nubareya Canal

It is the main source of drinking water in Alexandria City, Egypt. Nubareya's canal raw drinking water is treated before reaching houses and other domestic uses.

3.2.1 The Effect of Different Treatments on the Chemical Parameters of the Raw Drinking Water of Nubareya Canal

From Table (3) the oxidizable organic matter (OOM) recorded 18.26mgO_2/l at Nubareya before treatment (I). After treatment, (OOM) fluctuated between 13.12mg O_2/l for the treatment by (II) and 1.45mgO_2/l for (IX) treatment. Phosphate concentration (PO_4^{-3}) recorded 13.5µM before treatment and fluctuated between 3.14µM for the treatment by (III) and 0.35µM for (VIII) treatment. The silicate recorded 17.14µM before treatment and variation from 16.42µM for (III) and 5.53µM for (VI) treatment. Nitrite concentration recorded 0.08µM before treatment and variations from 0.08µM for the treatment by (II, III, and VII) to 0.04µM for (V) treatment. Nitrate value recorded 2.98µM before treatment and fluctuated between 2.79µM for the treatment by (III) and 1.86µM for (VIII) treatment. Sulphate (SO_4^{--}) recorded 3.5g/l before treatment and differed between 2.51g/l at (V) treatment and 1.56g/l for (IX) treatment.

As shown in Table 3 and Fig. 4; the best results obtained above all treatment media were observed in the alum, aeration integrated medium with yeast and also with both yeast and the macrophyte *Ceratophylum demersum*. Thus, OOM, PO_4^{3-}, SiO_3^-, and SO_4^{2-} concentrations were considerably reduced. On the other hand, alum and aeration integrated medium with both ginger and *C. demersum* recorded low values of OOM, PO_4^{3-}, SiO_3^-, and NO_2^-, but to a lesser degree than the previously mentioned medium, compared with the initials (raw drinking water from Nubareya).

Table 3. The effect of different treatments on some chemical parameters in Nubareya Canal water during spring 2014

Nubareya	OOM mgO_2/l	PO_4^{3-} µM	SiO_3^- µM	NO_2^- µM	NO_3^- µM	SO_4^{2-} g/l
I. Nubareya raw water	**18.26**	**13.5**	**17.14**	**0.08**	**2.98**	**3.5**
II. Nubareya raw water + Alum + aeration	**13.12**	**3.05**	**15.41**	**0.08**	**2.07**	**2.23**
III. Nubareya raw water + Alum + aeration + *Ceratophyllum*	**12.34**	**3.14**	**16.42**	**0.08**	**2.79**	**2.41**
IV. Nubareya raw water + Piper *nigrum* + (alum + aeration)	**13.05**	**2.55**	**15.32**	**0.05**	**2.57**	**2.27**
V. Nubareya raw water + Piper *nigrum* + (alum + aeration) + *Ceratophyllum*	**12.88**	**2.2**	**10.65**	**0.04**	**2.65**	**2.51**
VI. Nubareya raw water + Ginger + (alum + aeration)	**10.24**	**0.85**	**5.53**	**0.05**	**2.41**	**2.22**
VII. Nubareya raw water + Ginger + (alum + aeration) + *Ceratophyllum*	**6.08**	**0.75**	**5.69**	**0.08**	**2.7**	**2.2**
VIII. Nubareya raw water + Yeast + (alum + aeration)	**1.92**	**0.35**	**8.55**	**0.05**	**1.86**	**1.94**
IX. Nubareya raw water + Yeast + (alum + aeration) + *Ceratophyllum*	**1.45**	**0.41**	**8.52**	**0.05**	**1.95**	**1.56**

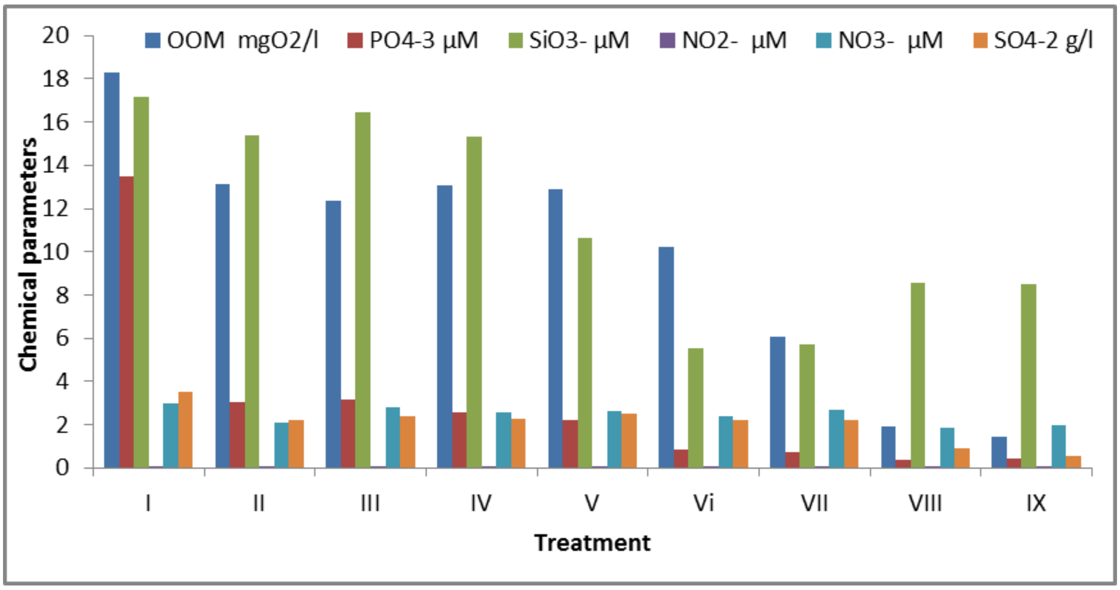

Figure 4. The effect of different treatments on the chemical parameters of Nubareya Canal water during spring 2014

3.2.2 The Effect of Different Treatments on the Trace Metals Concentrations of the Raw Drinking Water of Nubareya Canal

All treatments succeeded to reduce the concentrations of the trace metals concentrations (Zn, Pb, Fe, and Cu). The highest reduction in all trace metals concentrations was observed with the treatment by Alum + Aeration+ Yeast+ *Ceratophyllum* (Table 4 and Fig. 5). Besides reduction of all studied trace metals pollutants were more reduced in all media with the integration of the submerged macrophyte *Ceratophyllum demersum*. The treatment type most successful in reducing trace metals concentrations of Nubareya raw water was by using Yeast. Karla et al., (2013) in their studies using yeast demonstrated the biosorption capacity of heavy metals such as zinc, copper, lead, and iron.

Table 4. The effect of treatments on trace metals concentrations (μM) of Nubareya Canal water during spring 2014

Nubareya	Zn	Pb	Fe	Cu
(I) Nubareya raw water	18.8	14.6	65.8	9.9
(II) Nubareya raw water + Alum + Aeration	13.8	12.9	46.4	6.2
(IV) Nubareya raw water + Alum + Aeration +Piper	12.8	8.4	11.5	5.3
(V) Nubareya raw water + Alum + Aeration + piper + *Ceratophyllum*	10.4	4.8	9.8	3.9
(VI) Nubareya raw water + Alum + Aeration + Ginger	11.54	6.9	23.6	4.2
(VII) Nubareya raw water + Alum + Aeration +Ginger+ *Ceratophyllum*	8.9	4.7	21.3	2.8
(VIII) Nubareya raw water + Alum + Aeration +Yeast	8.2	3.4	12	0
(IX) Nubareya raw water + Alum + Aeration+ Yeast+ *Ceratophyllum*	6.4	2.1	9.6	0

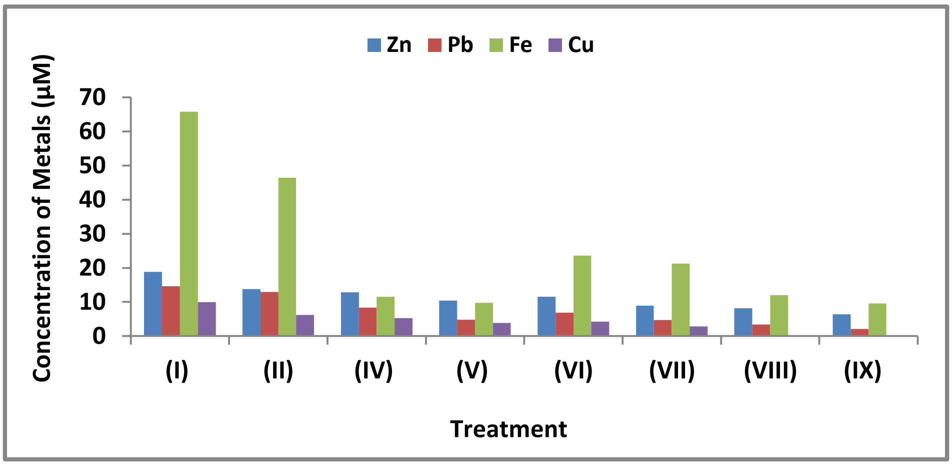

Figure 5. The effect of different treatments on the trace metals concentrations of Nubareya Canal water during spring 2014

Generally, yeast treatment showed the best results for OOM, PO_4^{3-}, NO_2^-, NO_3^-, SiO_3^-, and SO_4^{2-} as well as succeeding in reducing trace metals concentrations.

3.3 El-Umoum Drain

This drain is the main source of agricultural wastewater in Lake Mariout. Therefore, this study concentrates on the effect of treatments on the physicochemical parameters and trace metals concentrations in El-Umoum drain.

3.3.1 The Effect of Different Treatments on the Chemical Parameters of El-Umoum Agricultural Drain Water

From Table (5) it was noticed that the oxidizable organic matter (OOM) recorded 37.68 mg O_2/l at Umoum drain before treatment. After treatment, (OOM) fluctuated between 18.97 mg O_2/l for the treatment by (VIII) and 7.68 mgO_2/l for (IX) treatment. Phosphate concentration (PO_4^{-3}) recorded 10.95µM before treatment and fluctuated between 9.00µM for the treatment by (II) and 1.2µM for (V, IX) treatment. The silicate recorded 88.3µM before treatment and variation from 45.82µM for the treatment by (II) and 14.16µM for (VII) treatment. Nitrite concentration recorded 33.05µM before treatment and variations from 20.18µM for the treatment by (II) to 0.1µM for (VII) treatment. Nitrate value recorded 67.13µM before treatment and fluctuated between 52.33µM for the treatment by (II) and 0.04µM for (IX) treatment. Sulphate (SO_4^{--}) recorded 2.45 g/l before treatment and differed between 1.7 g/l at the treatment by (III) and 0.78 g/l for (IX).

As shown from Table 5 and Fig. 6, Alum + Aeration decreases the OOM, SiO_3^-, and SO_4^{2-} concentrations to nearly the half, and the best results obtained from all treatment media were observed in the alum, aeration integrated medium with yeast and the macrophyte *Ceratophylum demersum*. Thus, OOM, PO_4^{3-}, SiO_3^- , NO_2^-, NO_3^-, and SO_4^{2-} concentrations were considerably reduced.

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Table 5. The effect of treatments on the physicochemical parameters in El-Umoum drain water during spring 2014

El-Umoum	OOM mgO_2/l	PO_4^{3-} µM	SiO_3^- µM	NO_2^- µM	NO_3^- µM	SO_4^{2-} g/l
I. El-Umoum agricultural waste water	37.68	10.95	88.3	33.05	67.13	2.45
II. El-Umoum agricultural waste water + Alum + aeration	18.56	9.00	45.82	20.18	52.33	1.64
III. El-Umoum agricultural waste water + Alum + aeration + *Ceratophyllum*	15.04	1.95	29.16	0.15	17.65	1.7
IV. El-Umoum agricultural waste water + Piper *nigrum*+ alum + aeration	18.23	2.75	40.82	5.83	0.92	1.43
V. El-Umoum agricultural waste water + Piper *nigrum* + alum + aeration + *Ceratophyllum*	14.72	1.2	16.66	1.5	0.07	1.52
VI. El-Umoum agricultural waste water + Ginger + alum + aeration	11.52	1.9	37.49	14.08	12.44	1.38
VII. El-Umoum agricultural waste water + Ginger + alum + aeration + *Ceratophyllum*	10.24	1.7	14.16	0.1	5.24	1.56
VIII. El-Umoum agricultural waste water + Yeast + alum + aeration	18.97	1.35	42.07	7.95	0.07	1.35
IX. El-Umoum agricultural waste water + Yeast + alum + aeration + *Ceratophyllum*	7.68	1.2	41.06	0.18	0.04	0.78

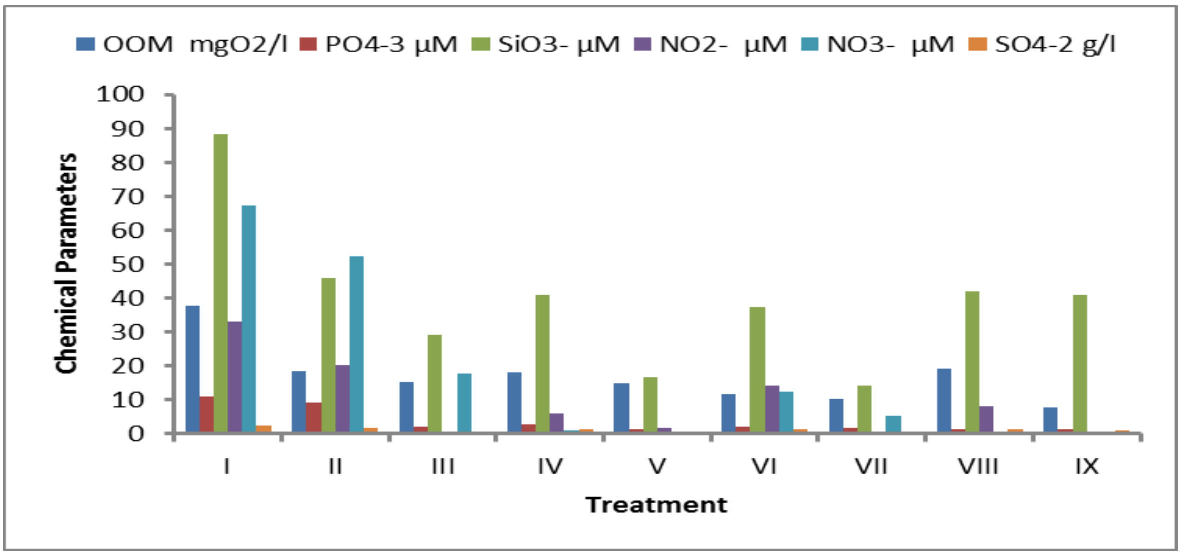

Figure 6. The effect of different treatments on the chemical parameters of El-Umoum drain water during spring 2014

Generally, yeast and the macrophyte *Ceratophylum demersum* with Alum + Aeration showed noticeable decrease in OOM, PO_4^{3-}, SiO_3^- , NO_2^-, NO_3^- and SO_4^{2-} concentrations indicating that these treatments were the best for agricultural wastewater at El-Umoum drain during this study.

3.3.2 The Effect of Different Treatments on the Trace Metals Concentrations of El-Umoum Agricultural Drain

All treatments succeeded to reduce the concentrations of the trace metals concentrations (Zn, Pb, Fe, and Cu) beginning from using Alum + Aeration till adding the piper *nigrum*, dry ginger, and yeast for treatment, in addition to the freshwater submerged macrophyte *Ceratophyllum demersum*.

The highest reduction in trace metals concentrations was observed with the treatment by Alum + Aeration+ Yeast+ *Ceratophyllum* (Table 6 and Fig. 7). The reduction of trace metals was observed in all media in the presence of the submerged macrophyte *Ceratophyllum demersum*. The treatment type most successful in reducing trace metals concentrations of El-Umoum agricultural drain was by using Yeast.

Table 6. The effect of treatments on trace metals concentrations (µM) of El-Umoum drain water during spring 2014

El-Umoum	Zn	Pb	Fe	Cu
(1) El-Umoum agricultural drain	19.8	27	168.9	18.3
(II) El-Umoum agricultural drain + Alum + Aeration	15.7	19.5	114.1	11.6
(IV) El-Umoum agricultural drain + Alum + Aeration + Piper	13.1	12.9	86.4	9
(V) El-Umoum agricultural drain + Alum + Aeration + Piper + *Ceratophyllum*	11.2	9.5	80.3	6.9
(VI) El-Umoum agricultural drain + Alum + Aeration + Ginger	11.8	14.3	100.9	7.4
(VII) El-Umoum agricultural drain + Alum + Aeration + Ginger + *Ceratophyllum*	8.7	10.1	89.2	5.8
(VIII) El-Umoum agricultural drain + Alum + Aeration + Yeast	8.3	4.9	68.5	2.6
(IX) El-Umoum agricultural drain + Alum + Aeration + Yeast + *Ceratophyllum*	7.5	2.3	59.1	1.9

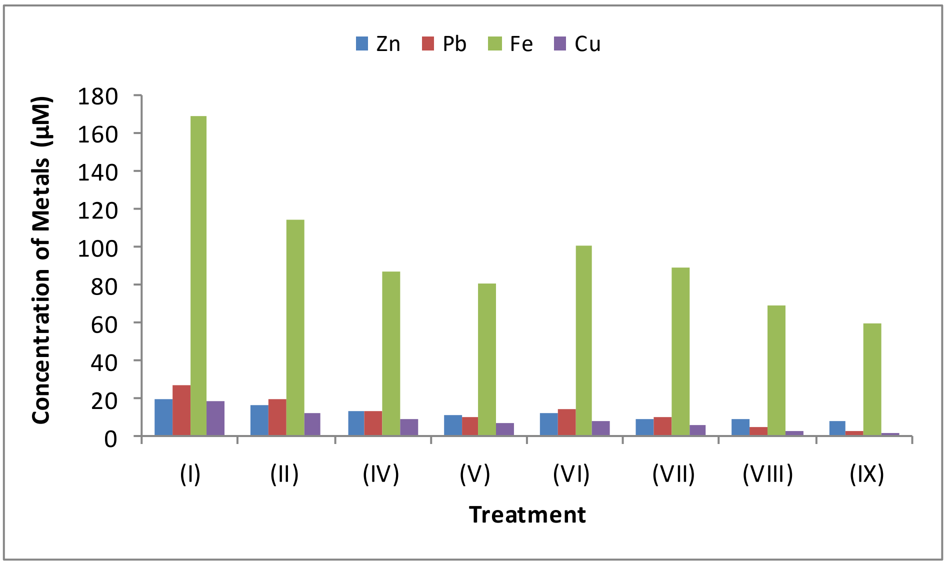

Figure 7. The effect of different treatments on the trace metals concentrations of El-Umoum agricultural drain water during spring 2014

Generally, the results obtained for trace metals treatment for agricultural waste water were similar to that of the raw water treatment by using Alum + Aeration + Yeast + *Ceratophyllum*.

4. Discussion

4.1 Percentage Reduction of the OOM, Nutrients and Sulphate Concentrations

Reduction percentage of OOM sustained high performance, recording 75.6%, 50.74%, and 28.2% for raw wastewater from El-Qalaa, El-Umoum drains, and Nubareya canal, respectively, when treated with alum and aeration (Table 7). When using combined physical, chemical, and biological treatments, OOM was profoundly reduced, and recorded between 83.5% using *Ceratophyllum* beside (alum + aeration) and 92.6% reduction in ginger treatment media beside *Ceratophyllum* + (alum + aeration) using sewage water from El-Qalaa. OOM from Umoum and Nubareya drains reduction percentages were 79.62% and 92.06%, respectively, recorded when treated with combined yeast + (alum + aeration) + *Ceratophyllum*.

The least reduction percentage for PO_4^{3-} was in treatment with alum + aeration only (3.0%) for El-Qalaa sewage water, and it increased with treatments using combination of physical, chemical, and biological media, recording the highest value 81.4% of reduction in combined yeast and (alum + aeration). Concerning El-Umoum agricultural wastewater, PO_4^{3-} was slightly reduced with alum + aeration treatment (17.81%), while high reduction percentages were sustained in combined treatments, recording a maximum of 89.04% in piper *nigrum* and yeast combined with alum + aeration + *Ceratophyllum* treatment media. For Nubareya raw drinking water, alum + aeration reduced PO_4^{3-} by 77.41%, which is considerably high compared with that of El-Qalaa sewage water. On the other hand, combined treatments exhibited high reduction performance, particularly in piper *nigrum*, ginger, and yeast media, the highest of which was 97.41% in yeast + alum + aeration treatment, whether accompanied by the macrophyte *Ceratophyllum* or not.

SiO_3^- was highly reduced from El-Qalaa sewage water in ginger combined treatment media (82.8% and 80.9%), followed by yeast combined treatment media (73.5% and 68.4%). In El-Umoum wastewater, SiO_3^- was reduced considerably in piper *nigrum* and ginger combined treatment media recording 81.1% and 83.96%, respectively, but decreasing reduction capacity was obvious in other treatments. For Nubareya raw drinking water, SiO_3^- was highly reduced in ginger followed by yeast combined treatment media, but to less extent compared with the results obtained in El-Qalaa sewage water's case (Table 7).

About 50% of NO_2^- in El-Qalaa wastewater was reduced in alum + aeration treatment media, and was further reduced in other combined treatments media -ginger + alum + aeration + *Ceratophyllum* (93.3%)- but to less extent in other treatments. A 38.9 % reduction was noticed for treatment by alum + aeration in El-Umoum drain. The highest removal percentage was observed to be between 99.5 and 99.7 in combined treatments yeast + (alum + aeration) + *Ceratophyllum*, followed by alum + aeration + *Ceratophyllum*, then ginger + alum + aeration + *Ceratophyllum.* NO_2^- concentration in Nubareya raw drinking water was low (0.08 µM) (Table 3), but about 50% was reduced in combined treatment (piper + alum + aeration + *Ceratophyllum*).

From 5.33 µM NO_3^- initial concentration in El-Qalaa Drain water (Table 1), slight reduction ranging from 12.4% to 20.6% was recorded in treatments with combined piper *nigrum* + alum + aeration + *Ceratophyllum* and piper *nigrum* + alum + aeration, respectively. Maximum reduction was found to be 96.3%, and to less extent 95.5%, and 61.7% in combined treatments with yeast + alum + aeration, followed by yeast + alum + aeration + *Ceratophyllum*, then ginger + alum + aeration + *Ceratophyllum*, respectively. Reduction percentage of NO_3^- in El-Umoum agricultural drain fluctuated between 73.7% for treatment by alum + aeration + *Ceratophyllum*, and 99.9% in combined treatments by piper *nigrum* + alum + aeration + *Ceratophyllum* and for yeast treatment with alum + aeration with/without *Ceratophyllum.* In Nubareya raw water, the nitrate removal percentage differed from 6.39% in treatment using alum + aeration + *Ceratophyllum* and 37.6% in treatment by yeast + alum + aeration. Sulphate removal percentage was 32.4% in treatment by alum + aeration for sewage seawater of El-Qalaa drain. This removal percentage value increased to 62.2% followed by 62.5% with yeast treatment combined with alum + aeration, followed by yeast + alum + aeration + *Ceratophyllum*, respectively. The lowest sulphate removal percentage in El-Umoum drain and Nubareya raw water were 30.61% and 31.14%, respectively, for treatment by alum + aeration + *Ceratophyllum*, while the highest sulphate removal percentage for both El-Umoum drain and Nubareya raw water was 68.16% and 55.43%, respectively, for the treatment by yeast + alum + aeration + *Ceratophyllum*.

Table 7. Percentage removal of the OOM, nutrients and sulphate concentrations after different treatments for Mariout Lake drains water

Drain	OOM % Removal	PO_4^{3-} % Removal	SiO_3^- % Removal	NO_2^- % Removal	NO_3^- % Removal	SO_4^{2-} % Removal
II. El-Qalaa sewage + Alum + aeration	75.6	3.00	28.8	49.8	20.3	32.4
II. El-Umoum agricultural waste water + Alum + aeration	50.74	17.81	48.1	38.9	22.1	33.06
II. Nubareya raw water + Alum + aeration	28.2	77.41	10.1	0.0	30.5	36.3
III. El-Qalaa sewage + Alum + aeration + *Ceratophyllum*	83.5	37.2	66.5	72.4	20.4	33
IV. El-Qalaa sewage + Alum + aeration + Piper *nigrum*	85.3	50.9	29.7	80	20.6	32.7
V. El-Qalaa sewage + Piper *nigrum* + alum + aeration + *Ceratophyllum*	89.9	57.1	52.5	83.1	12.4	33.8
VI. El-Qalaa sewage + Ginger + alum + aeration	90.8	80.5	82.8	69.8	20.3	33.8
VII. El-Qalaa sewage + Ginger + alum + aeration + *Ceratophyllum*	92.6	76.2	80.9	93.3	61.7	39.3
VIII. El-Qalaa sewage + Yeast + alum + aeration	85.3	81.4	68.4	58.7	96.3	62.2
IX. El-Qalaa sewage + alum + aeration + Yeast + *Ceratophyllum*	88	79.3	73.5	80.9	95.5	62.5
III. El-Umoum agricultural waste water + Alum + aeration + *Ceratophyllum*	60.1	82.19	67.0	99.6	73.7	30.61
IV. El-Umoum agricultural waste water + Piper *nigrum*+ alum + aeration	51.6	74.89	53.8	82.4	98.6	41.63
V. El-Umoum agricultural waste water + Piper *nigrum* + alum + aeration + *Ceratophyllum*	60.9	89.04	81.1	95.5	99.9	37.96
VI. El-Umoum agricultural waste water + Ginger + alum + aeration	69.4	82.65	57.5	57.4	96.4	43.67
VII. El-Umoum agricultural waste water + Ginger + alum + aeration + *Ceratophyllum*	72.8	74.48	83.96	99.7	92.2	36.33
VIII. El-Umoum agricultural waste water + Yeast + alum + aeration	49.7	87.76	52.4	76.0	99.9	44.9
IX. El-Umoum agricultural waste water + Yeast + alum + aeration + Ceratophyllum	79.62	89.04	53.5	99.5	99.9	68.16
III. Nubareya raw water + Alum + aeration + *Ceratophyllum*	32.4	76.74	4.2	0.00	6.39	31.14
IV. Nubareya raw water + Piper *nigrum* + (alum + aeration)	28.5	81.11	10.6	37.5	13.8	35.14
V. Nubareya raw water + Piper *nigrum* + (alum + aeration) + *Ceratophyllum*	29.5	83.07	37.9	50.0	11.1	28.3
VI. Nubareya raw water + Ginger + (alum + aeration)	43.9	93.7	67.7	37.5	19.1	36.57
VII. Nubareya raw water + Ginger + (alum + aeration) + *Ceratophyllum*	66.7	94.44	66.8	0.00	9.4	37.14
VIII. Nubareya raw water + Yeast + (alum + aeration)	89.5	97.41	50.1	37.5	37.6	44.57
IX. Nubareya raw water + Yeast + (alum + aeration) + *Ceratophyllum*	92.06	96.96	50.3	37.5	34.6	55.43

4.2 Reduction Percentage of the Trace Metals after Different Treatments for Mariout Lake Drains

The lowest percentage of metals removal for El-Qalaa sewage drain, El-Umoum agricultural drain, and Nubareya raw water canal was recorded for the treatment using alum + aeration only (Table 8). For El-Qalaa sewage drain, the highest Pb, Fe, and Cu removals (91.71%, 60.48% and 93.13%) respectively were found with the treatment with yeast + alum + aeration + *Ceratophyllum*, while the highest Zn removal (62.65%) was observed with the treatment with ginger + alum + aeration + *Ceratophyllum*, followed by the treatment with yeast + alum + aeration + *Ceratophyllum* (54.47%). Regarding El-Umoum agricultural drain, it was observed that all metals' removal percentages (62.12%, 91.48%, 65.01%, and 89.62%), respectively for Zn, Pb, Fe, and Cu were recorded for the treatment with yeast + alum + aeration + *Ceratophyllum.* For Nubareya raw water, the highest metals' (Zn, Pb, Fe, and Cu) removals (65.96%, 85.62%, 85.41%, and 100%) respectively were for the treatment with yeast + alum + aeration + *Ceratophyllum*.

It was generally noticed that the best treatment for metals' removal was with (yeast + alum + aeration + *Ceratophyllum*), and it could be applied for different sources of polluted waters like sewage water (El-Qalaa drain), agricultural water (El-Umoum drain), and raw drinking water (Nubareya Canal).

Table 8. Percentage removal of the trace metals after different treatments for Mariout Lake drains

Drain waters with different treatments	Zn % Removal	Pb % Removal	Fe % Removal	Cu % Removal
(II) El-Qalaa sewage +Alum + Aeration	30.74	36.29	28.39	13.75
(IV) El-Qalaa sewage +Alum + Aeration + Piper *nigrum*	37.74	45.43	42.02	36.25
(V) El-Qalaa sewage +Alum + Aeration + Piper *nigrum* + *Ceratophyllum*	43.19	62.29	53.69	46.88
(VI) El-Qalaa sewage +Alum + Aeration + Ginger	54.09	57.71	29.94	58.75
(VII) El-Qalaa sewage +Alum + Aeration + Ginger + *Ceratophyllum*	62.65	70.57	38.57	70
(VIII) El-Qalaa sewage +Alum + Aeration + Yeast	43.19	84	52.26	90.63
(IX) El-Qalaa sewage +Alum + Aeration + Yeast + *Ceratophyllum*	54.47	91.71	60.18	93.13
(II) El-Umoum agricultural drain + Alum + Aeration	20.7	27.78	32.45	36.61
(IV) El-Umoum agricultural drain + Alum + Aeration + Piper *nigrum*	33.84	52.22	48.85	50.82
(V) El-Umoum agricultural drain + Alum + Aeration + Piper *nigrum* + *Ceratophyllum*	43.43	64.48	52.46	62.3
(VI) El-Umoum agricultural drain + Alum + Aeration + Ginger	40.4	47.04	40.26	59.56
(VII) El-Umoum agricultural drain + Alum + Aeration + Ginger + *Ceratophyllum*	56.06	62.59	47.19	68.31
(VIII) El-Umoum agricultural drain + Alum + Aeration + Yeast	58.08	81.85	59.44	85.79
(IX) El-Umoum agricultural drain + Alum + Aeration + Yeast + *Ceratophyllum*	62.12	91.48	65.01	89.62
(II) Nubareya raw water + Alum + Aeration	26.6	11.64	29.48	37.37
(IV) Nubareya raw water + Alum + Aeration +Piper *nigrum*	31.91	42.47	82.52	46.46
(V) Nubareya raw water + Alum + Aeration + piper *nigrum* + *Ceratophyllum*	44.68	67.12	85.11	60.6
(VI) Nubareya raw water + Alum + Aeration + Ginger	38.62	52.74	64.13	57.57
(VII) Nubareya raw water + Alum + Aeration +Ginger+ *Ceratophyllum*	52.66	67.81	67.63	71.71
(VIII) Nubareya raw water + Alum + Aeration +Yeast	56.38	76.71	81.76	100
(IX) Nubareya raw water + Alum + Aeration+ Yeast+ *Ceratophyllum*	65.96	85.62	85.41	100

5. Conclusions

The physicochemical parameters are considered the most important principles in the identification of the nature, quality, and type of water (fresh, brackish, saline) for any aquatic ecosystem.

The results of the physicochemical parameters present in Tables 1, 3, and 5 reveal that the best material for treatment in El-Qalaa sewage drain was with (Alum + Aeration + ginger + *Ceratophylum demersum*). This treatment reduced the parameters causing pollution (OOM, PO_4^{3-}, and NO_2^-) with up to 92%, 76.2%, and 93.3% reduction for El-Qalaa drain. These results indicate that good water quality was obtained after treatment, and if this treated water reaches the Lake, it would not pollute the Lake's water.

The most preferable treatment for the raw drinking water of Nubareya canal was by using Alum + Aeration + yeast + *Ceratophylum demersum*. For the El-Umoum agricultural wastewater, the best treatment was the same as that of the raw drinking water of Nubareya canal (Alum + Aeration + yeast + *C. demersum).*

With regards the four trace metals' treatments, the best treatment in all cases was by using, Alum + Aeration + Yeast + *Ceratophylum demersum* except for Zn, in El-Qalaa sewage water, which had to be treated by using Alum + Aeration + Ginger + *Ceratophylum demersum*, followed by Alum + Aeration + Yeast + *Ceratophylum demersum*.

Treating the different types of waste water should be taken into consideration by the decision makers before the waste water reaches Mariout Lake, so as to improve the lake's water quality, and therefore increase its fish productivity, and for good quality water to reach the Mediterranean Sea through El-Mex Bay.

The different types of treatments used in this study are of low cost and environmentally safe.

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