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Future Perspective for Water Scarcity Challenges in Northern Nile Delta: Desalination Opportunities

Omnya A. El Batrawy[1], Rifaat Abdel Wahaab[2], Mahmoud S. Ibrahiem[1], Soliman Sorour Soliman[3] and Ahmed G. Yehia[3]

[1]Environmental Sciences Department, Faculty of Science, Damietta University, Egypt.
[2]Water pollution Department, National Research center, Giza, Egypt.
[3]Holding Company for Water and Wastewater (HCWW), Cornish El Nile, Rod El Farag, Cairo, Egypt.

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ABSTRACT

Egypt has reached a state where the quantity of water available is imposing limits on its national economic development. Governments all over the world pay more attention to freshwater resources as they become either increasingly scarce or at threat due to flooding. The study aims to give highlight on the situation and quality of water within the Rosetta branch and the quality of produced drinking water at the same study area with a proposal of the desalination of Northern Delta lakes water as alternative drinking water supply for Edku and Burullus area. Water quality investigation, water demand analysis and remote sensing study of the Edku and Burullus area have shown a great increase in the water demand concurrently with significant changes in land uses. The quality of drinking water pointed to deterioration regard to the WQI scale that attributes to increase in population, urbanization and industrialization. Discharges from domestic wastewater, agriculture drainage and fish cages along the Rosetta branch can lead to an excessive increase of pollutants concentration in the water bodies especially during the low water requirement period in winter. The average salinity of Edku and Burullus lakes are 3369 and 2918 mg/l, respectively, having such brackish water salinity could make it a possible potential source for domestic water supply by desalination with reasonable cost. Further research will be required to assess the economic aspects of this option.

***Keywords*: water quality; water demand; water management; desalination; remote sensing**

Introduction

Egypt is one of the countries faced with the possibility of chronic water shortages in the future (El Molla *et al.,* 2005). Water resources in Egypt are limited to the withdrawal share from the Nile water; the limited quantity of rainfall and groundwater. The non-traditional resources of water include reuse of treated wastewater and agricultural drainage water, as well as the desalination of seawater and brackish water (Allam and Allam, 2007). Rapid increase in population growth will threaten a severe shortage of drinking water supplies in nearest future and rapid deterioration is occurring in surface and groundwater quality (Shepl *et al.,* 2017).

Rosetta branch represents the main source of fresh water for the northern Nile Delta Region (Nada *et al*., 2014). Discharges from domestic wastewater, agriculture drainage and fish cages along Rosetta branch can lead to an excessive increase of pollutants concentration in the water bodies (El Bouraie *et al*., 2011). At Low-Flow period, the percentage of discharged water from the drains to the fresh water coming from Delta barrage is a maximum; hence; the pollution become a maximum (Ghodeif *et al.,* 2017). Consequently, the drinking water treatment plants along the water streams are oblige to increase the chlorine dose to face the increased level of pollution (Reemtsma and Jekel, 2006); resulting in health hazard and economical over burden (WHO, 2005).

Water resources management, water quality management, and environmental protection are the three main tools to effectively utilize the available water resources in achieving sustainable development (El Bedawy, 2014). The pollution overburden on Nile water together with the limited

Corresponding Author: Omnya A. ElBatrawy, Department of Environmental Sciences, Faculty of Science, Damietta University, New Damietta City, 34517, Damietta, Egypt.
E-mail: om_elbatrawy@du.edu.eg; om_elbatrawy@hotmail.com

fresh water resources make it is essential to increase water-use efficiency i.e. recycling and reusing available water resources to develop unconventional water resources. The integrated water resource management becomes necessary many available scenarios could be examined as water reuse, desalination, and recycling (El Gammal and El Shazely, 2008).

Desalination of seawater in Egypt, as a source of water, has been given low priority due, in part, to its high cost. Nevertheless, it may be feasible to use such method to produce and supply drinking water, particularly in remote areas where the cost of constructing pipelines to deliver Nile water is relatively high. It is expected that desalination plants for drinking water and industrial use in areas where no other cheaper resources are available, will be developed as the demands grow in the year 2050. However, if brackish water is nearby available in sufficient quantities, this may be the preferred sources for desalination, depending on the distance to source (HCWW, 2016).

Although desalination is expensive compared to conventional treatment of fresh water, the cost of desalination is decreasing, while the costs for developing new fresh water sources of potable supply are increasing or no longer possible (Batisha, 2007). In addition, as technological developments cause a reduction in the cost of equipment, the overall relative plant costs are expected to decline. This trend has made desalination, once a costly alternative to the provision of potable water, a viable solution and economically competitive with other options for water supply (Magdy *et al.,* 2008).

The study aims to stand on the status of water quality of fresh water represented in Rosetta Branch and the drinking water produced from the drinking water treatment plants located at the population in the domain of study area. Also, the quality of brackish water of Edku and Burrullus Lakes was investigated with a proposal of the desalination of Northern Delta lakes water as alternative drinking water supply for Edku and Burullus area.

Materials and Methods

Study Area

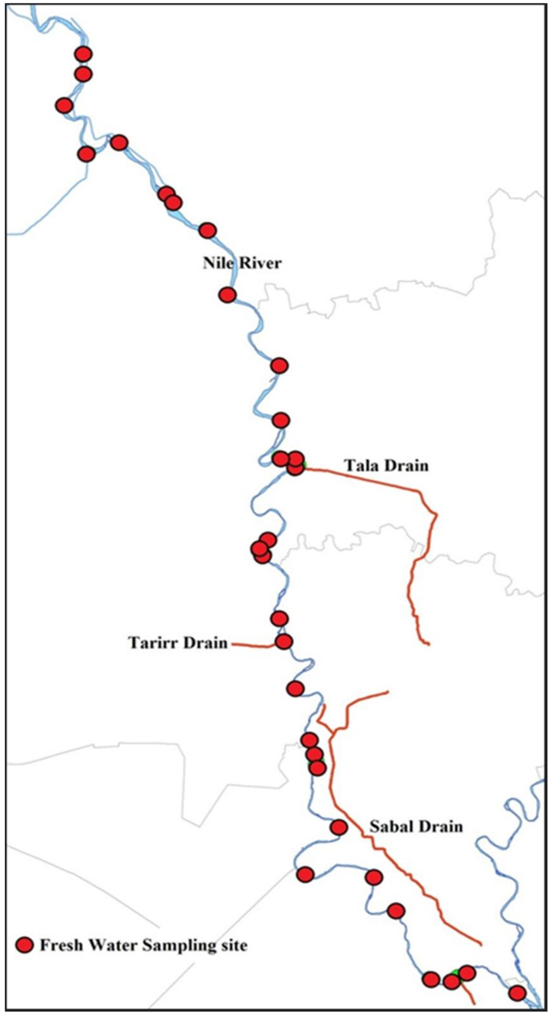
Sampling areas and samples locations at Rosetta Branch, Lake Edku area and Lake Burullus area are presented in Figure (1). Rosetta branch is the main raw surface water resources for the North Nile Delta Region. Edku and Burullus Lakes are of the northern lakes in Egypt. Lake Edku located at the western part of the Delta Nile while Lake Burullus is situated in a middle locus between the two branches of the Nile that form the Delta.

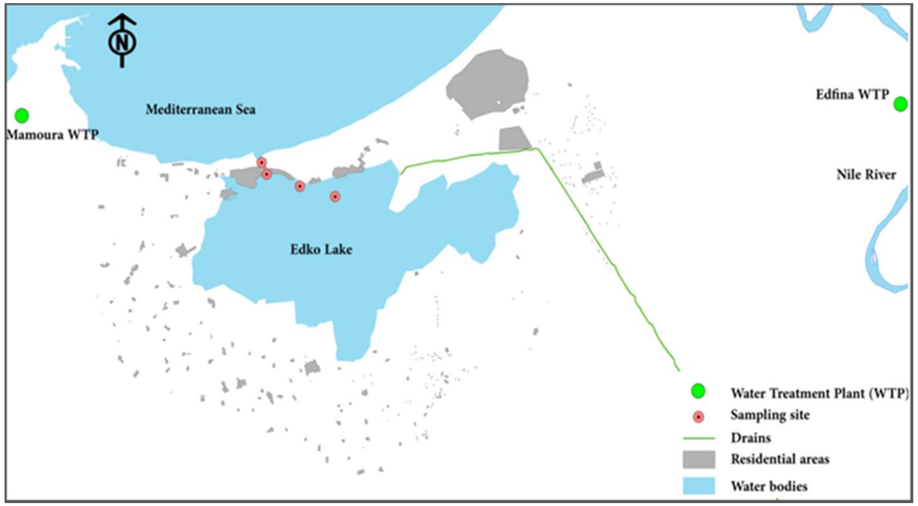
Sampling and Approach

A sampling campaign was delineated to illustrate the impact of the fresh water (from Rosetta Branch) on the quality of produced drinking water in the domain of investigated area, and to use the most common water pollution indicators in a comparison between the fresh water and brackish water. Coordination meeting among water stockholders was held to discuss challenges within the study area and the best available scenarios to mitigate the water deterioration consequences.

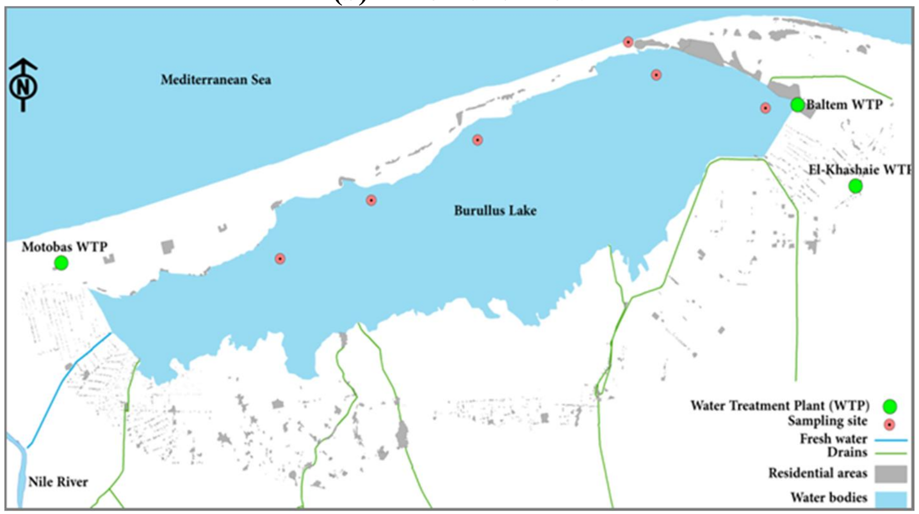
Water samples from Rosetta Branch, Edku and Burullus Lakes Drinking water treatment plants located adjoining to the Lakes area have been analyzed and investigated. Field measurements including pH, dissolved oxygen (DO), Salinity, and temperature done to avoid samples variation, while the other parameters were analyzed in the specialized laboratories and carried out according to Standard Methods for Water and Wastewater (Rice *et al.,* 2012). Table (1) listed types of water analyzed, number of samples, investigated parameters, sampling time, and the applied standards.

Due to large amount of data utilized from the sampling analysis, three techniques were used to express of such data. These techniques are (i) using the averages of the obtained results from all water types, (ii) using the compliance parentage to the applied standards if existing, and (iii) using the Water Quality Index (WQI) as a static tool to express the water quality.





(b) Lake Edku area.



a) Rosetta Branch.

(c) Lake Burullus area.

Fig. 1: Sampling areas and samples location (a) Rosetta Branch, (b) Lake Edku area and (c) Lake Burullus area

Table 1: Types of water analyzed, number of samples, investigated parameters, sampling time, and the applied standards.

Water Type	Number of Samples	Investigated parameters	Sampling Time	Applied Standards
Fresh Water	33 Sample along Rosetta Branch and Mahmudiya canal.	pH, TDS, Chlorides (Cl), Sulfates (SO_4^{-2}), Ammonia as (NH_3), Nitrites as (NO_2),Dissolved Oxygen (DO), Alumenium (Al), Copper (Cu), Cadmium (Cd), Nickel (Ni), Chromium (Cr), TOC (has no standard limit), COD, and BOD.	December 2016*.	law 48/1982 (**MPWWR, 1982**).
Drinking water	30 sample were collected from the DTPs	pH, TDS, Chlorides (Cl), Sulfates (SO_4^{-2}), Ammonia as (NH_3), Nitrites as (NO^{2-}), Dissolved Oxygen (DO), Alumenium (Al), Copper (Cu), Cadmium (Cd), Nickel (Ni), Chromium (Cr), COD, and BOD.	Samples were collected on monthly basis along 6 months from December 2016 to May 2017.	decree 458/2007 **(MoHP, 2007)**
Brackish water	4 samples from Edku Lake and 9 Samples from Burullus Lake	pH, TDS, Ammonia as (NH_3), Nitrites as (NO_2^-), Dissolved Oxygen (DO), COD, and BOD.	December 2016*.	No Standards Applied

*During the wintertime where winter damming is applied thus the flow is very low. This period represent the worst case for water quality in water streams.

Water Quality Index (WQI)

WQI is a statically tool that simplifies the complex water quality data into one single number 100% means excellent water quality and 0% means bad water quality (Lumb *et al.,* 2006). In the present study, CCME-WQI serves as the basis for water quality assessment in relation to the characterization of pollution load and classification of water according to the national water quality standards for each water type (CCME, 2001).

Remote Sensing Analysis and GIS

Remote sensing applications provide qualitative and quantitative information about the change of land features. In this study, a land use analysis of the study area has been investigated for a period 2006 – 2016. This kind of analysis provides qualitative information about land features such as urbanization growth rate, land cultivation and fish cultivated areas. These land cover maps have been constructed using the Google earth historical images. This way provides daytime images. Also, the Geographical Information System (GIS) using ArcGIS (10.2) software was used to develop a digital map for the investigated areas including the boundary of the lakes, the residential areas, geographical location and spatial distribution for both the sampling sites and investigated parameters (Araya and Cabral, 2010).

Results and Discussion

Characterization of the Study Area

Rosetta Branch

Nile Delta is one of the oldest intensely cultivated areas on earth. Rosetta branch of river Nile extends northwards for about 239 km long on the western boundary of the Nile Delta from Egypt's Delta Barrage with waterfront about 60 km on both sides of the mouth of the Nile River on the Mediterranean Sea. The water level in the Rosetta Branch is controlled by two barrages; Delta Barrage in the south and Edfina Barrage which regulates the excess flow of the branch and regulate the releases water to the Mediterranean Sea during winter closure period. The Rosetta Branch water serves for domestic and industrial water supply, agricultural, fisheries and recreation to the Western and Middle Nile Delta regions (Ezzat *et al*., 2012).

The hydrological regime of Rosetta branch is characterized by low and high discharge rates which correspond to dry and flood seasons. The high discharge (High Flow period) is in summer season and is characterized by adequate water quantities that influxes into Rosetta branch. In a contrary way, the low discharge (Low flow period) is during the winter months and is associated with winter damming (MWRI, 2014). Along the Rosetta branch and its tributaries" the five drains", there are many settlements and anthropogenic activities which would, directly and indirectly, affects the water quality of the Rosetta Branch. In the same time, there are many populated areas were impacted by using the Rosetta branch's water in different domestic especially for drinking.

Edku Area

Lake Edku is situated about 30 km east of Alexandria, with a history of contraction from $28.5*10^3$ to about $12*10^3$ Feddans due to agricultural reclamation. Water depths in the lake vary from 10 to 140 cm, with maximum depths in the central and eastern parts (Magdy *et al.,* 2008). It has three basins; eastern, central and western. The lake is connected to the adjoining Abu Qir Bay through Boughaz El Maadiya (Nessim and El-Deek, 1995). It receives vast quantity of drainage water from four main drains, namely; Edku, El-Khairy, Bousaly and Berseek (Okbah and El-Gohary, 2002). The drainage water contains unspecified quantities of urban, industrial and agricultural chemicals from the Beheira Governorate and beyond. Lake Edku has been exposed to different sources of pollution from human activities. The maximum inflow from all drains is recorded during summer, while the minimum is in winter.

The main water supply for communities within Edku area comes from two conventional water treatment plants (WTPs); Al-Mamoura WTP (raw water resource from El-Mahmudiya canal) and Edfena WTP (raw water resource from Rosetta branch).The investigation of the study area concludes that there is a constrain in drinking water sustainability that attributed to rotation of the produced water with average service hours of 10 hours. The population in Edku area has increased by 28% with average rate of 2.8 per year in the last 10 years. Edku area population, drinking water source, and average service hours are included in table (2).

Table 2: Edku area population, drinking water source, and average service hours **(HCWW, 2016)**.

Residential area	Population 2006 (Capita)	Population 2016 (Capita)	Drinking water source	Average service hours (hr/day)
El-Nakhal El-Bahariya	15176	31106	Al-Mamoura and Edfena WTPs	10 hours
BirketGhetas	37250	43035		
El-Maḋiya	12588	30275		
Edku	114600	119952		
6th of October	4950	19263		
El-Tarh	32500	34750		
KopanietAboker	32250	39780		
Kom El- Tarfayia	11300	14500		
El-Kaniyes	12500	13378		
El-Aly	9750	10600		
MonshaaBolyin	4273	10146		
MonshaaBalbaa	6580	10200		
MonshaaBasiuoni	7200	8840		

Burullus Area

Burullus Lake is the second largest lake of the Egyptian northern lakes along the Mediterranean coast and is located in the Nile Delta between the two Nile River branches. It is a shallow brackish lagoon with an area of 410 km^2; a maximum length of 47 km and a maximum width of 14 km; and its depth varies between 40 and 200 cm (Shaltout and Khalil, 2005). In addition to its importance as fishing resources, it is a habitat for domestic fauna and a route for wintering migratory birds. The water bodies of the lake decreased by 44.97%, while the agriculture area increased by 45.52% during the period from 1984 to 2015. The statistical models indicated that the water bodies of the lake will be reduced by 58.95% in 2030 (Hossen and Negm 2016). Burullus Lake had changed due to the discharge of agriculture wastes and municipal wastes in the lake without adequate treatment. Six drains are discharging agricultural and municipal wastes and draining into the lagoon (EMI, 2012).

The main water supply for communities within Burullus area comes from three conventional WTPs; North Motobas WTP (raw water resource from Rosetta branch), El-Khashaie WTP and Baltem WTP (raw water resource from canals originated from Nile River). The investigation of the area concludes that there is a limitation in drinking water sustainability that attributed to rotation of the produced water with average service hours of 9 hours. The population in Burullus area has increased by 25% with average rate of 2.5 per year in the last 10 years. Burullus area population, drinking water source, and average service hours are included in table (3).

Table 3: Burullus area population, drinking water source, and average service hours (HCWW, 2016).

Residential area	Population 2006 (Capita)	Population 2016 (Capita)	Drinking water source	Average service hours (hr/day)
Tera village	4115	6182	Motobas, El-Khashaie, and Baltem WTPs	9 hours
BaniBakar	8116	9090		
El-KomuisonSharq	15256	18734		
Al-abassiya	14554	18000		
El-Bourg	46568	61351		
El-KhalijBahary	21958	26963		
El-Rouda	7574	9292		
El- FouqahaaBahary	7494	9193		
Kom El-Dahab	14317	17565		
Bar Bahary	11724	14455		
Al-Banaaen	12144	14973		
El-Sahel Bahary	3621	4465		
El-Sahel Qebly	16129	19889		
El-Rabaa	15473	19078		
El-Shiekh Mubarak	8143	10050		
Balttem	44780	49564		
El-Shehabiya	6579	8111		
El-Taftesh	79081	83110		

Water Quality

Surface Water Quality

Surface water quality compliance parameters percentage for Rosetta branch is presented in Figures 2. The results have demonstrated a great influence of discharges from the 5 drains; EL-Rahway, Sabal, El-Tahrir, Zawayt El Bahr and Tala, together with fish cages on the water quality of Rosetta branch. All samples are complying with the law 48/1982 (MPWWR, 1982) in pH, TDS, Alumenium (Al) and Chromium (Cr) while 25% of samples are not complying in Chlorides (Cl), Sulfates (SO_4^{-2}). On the other hand, all samples are not complying with the law 48/1982 in ammonia, nitrites, and DO, while 50% of samples are not complying in copper, cadmium, nickel, COD and BOD. Elevated TOC levels (6.1 mg/l as average) have been measured reflecting high organic pollution. Figure (2) clarify the deterioration of surface water quality in the Rosetta branch.

Previous studies carried out along the Rosetta Branch have the similar conclusions which prove that it remarkably influenced by the agricultural and domestic drainages from drains located on its banks regarding both physico-chemical and bacteriological characteristics (Ezzat *et al.,* 2012; El-Amier *et al.,* 2015). This increasing deterioration in Rosetta Branch water quality could attribute to the unprecedented expansion in the anthropogenic activities in the domain of Rosetta Branch. Selfpurification and dilution concepts plays and significant role in the alleviation of pollutants burden northward direction particular in high flow peak during summer time.

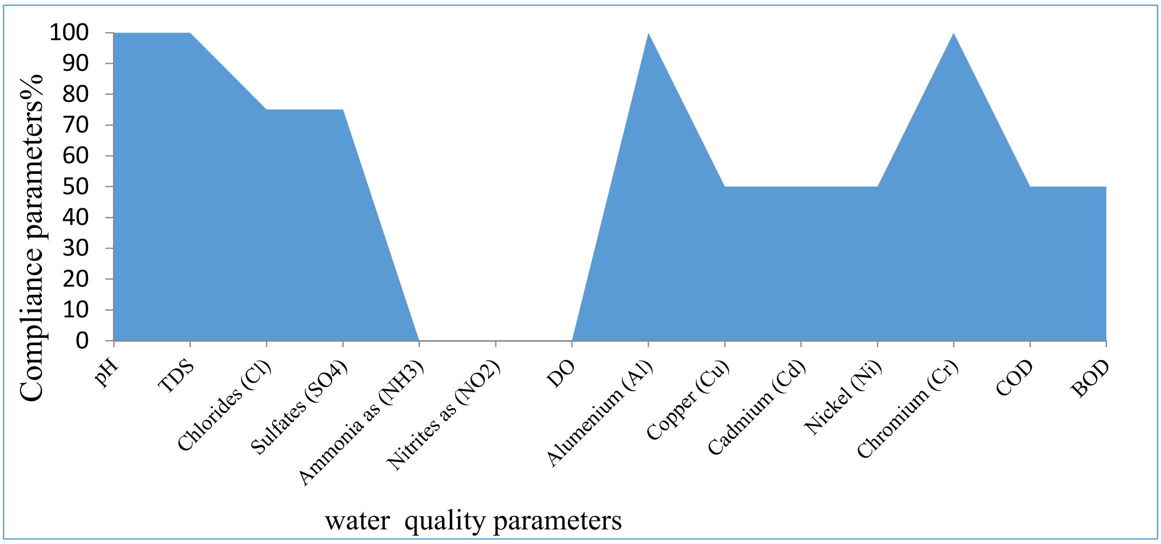


Fig. 2: Surface water quality in Rosetta branch.

Drinking Water Quality

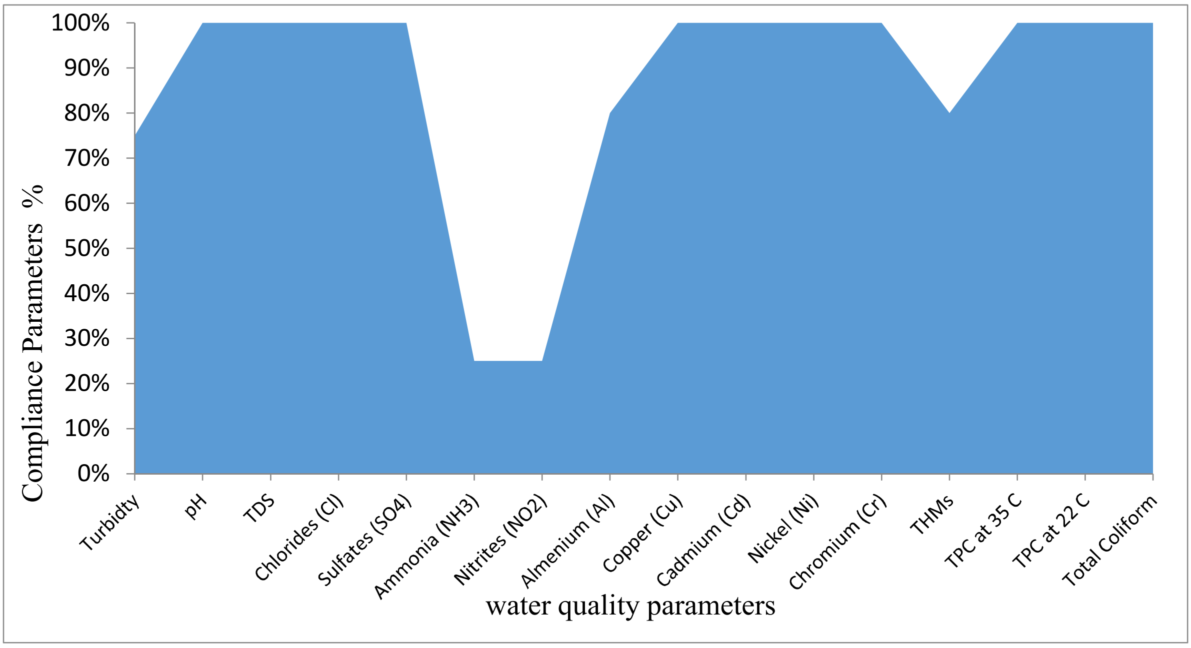
Figures 3 and 4 represent drinking water compliance parameters percentage for Edku area and Burullus area, respectively. All samples are complying with the decree 458/2007 (MoHP, 2007) in pH, TDS, Chlorides (Cl), Sulfates (SO_4^{-2}), copper, cadmium, nickel and Chromium (Cr). The elevated percentage in THMs could be attributed to that WTPs are enforced to increase the chlorine doses to overcome the elevated ammonia percentage at the raw water which cause customers vulnerable to possible carcinogenic disinfection byproducts (DBPs) (Hasan *et al.,* 2011).

The formation of THMs during chlorination can be reduced by removing precursors prior to contact with chlorine, for example, by installing or enhancing coagulation. This may involve using higher coagulant doses and/or lower coagulation pH than are applied conventionally (WHO, 2006). Accompanying to the former measures, the splitting the chlorine dose to pre-chlorine, mid-chlorine, and post-chlorine would have an effective impact in dealing with high ammonia concentrations. The same findings has been observed in similar areas in order to reach the breakpoint to be ensure the existing of free chlorine in produced drinking water (Ghodeif *et al.,* 2017).

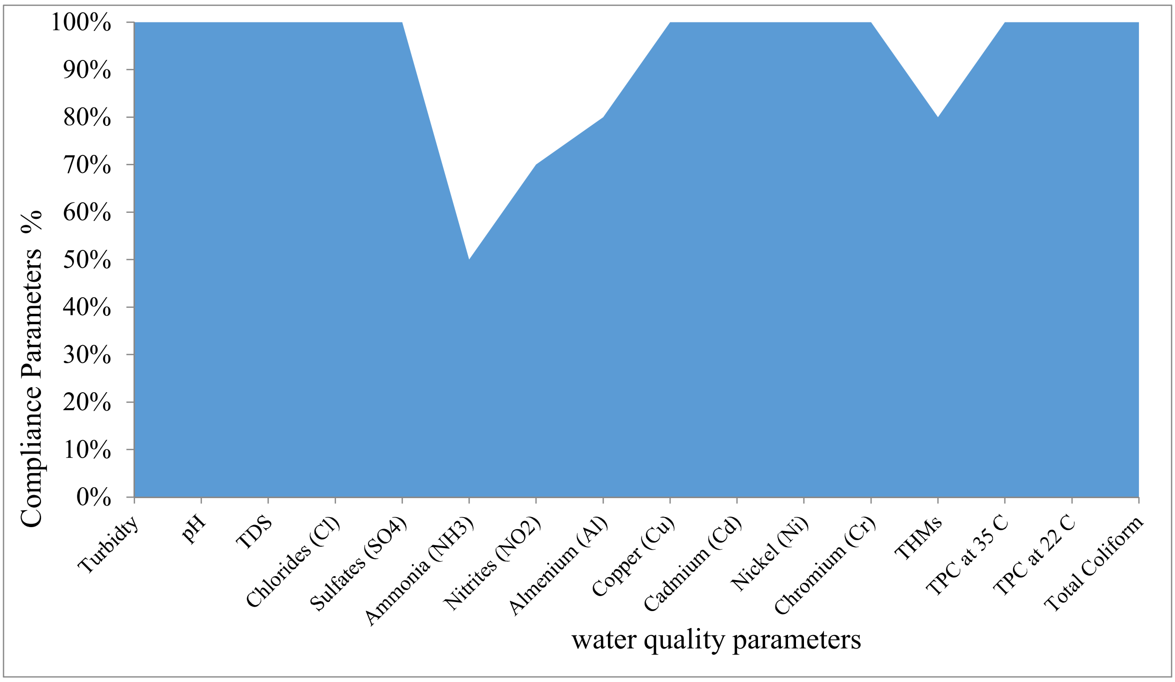
The drinking water quality was expressed by means of WQI. The drinking water resources for Edku area investigation have shown that Al-Mamoura and Edfena WTPs have WQI of 76.93% and 65.3%, respectively, with fair drinking water quality. The drinking water resources for Burullus area investigation has shown that North Motobas, El-Khashaie, and Baltem WTPs have WQI of 55%, 70.3%, and 80 % respectively, with average fair drinking water quality. The deterioration of drinking water quality is due to non-compliance of the drinking water in some parameters specially ammonia and nitrites as shown in Figure 3 and 4 for for Edku area and Burullus area, respectively. This could be attributed to elevated pollution percentage in the raw water resources.

The results obtained from Lakes water showed that Edku Lake has a higher average salinity of (3369 mg/l) than Burullus Lake (2918 mg/l). The two lakes water is classified as brackish water with salinity ranges between 1800-3500 mg/l.

Figure 5 represents the water quality parameters for Edku Lake and Burullus Lake. The results reveal that the ammonia concentration is 0.3 and 0.4 mg/l for Edku Lake and Burullus Lake, respectively. The COD and BOD results indicate that the Edku Lake is slightly less loaded than the Burullus Lake where COD and BOD concentration in Edku were 19 and 9.8 mg/l, respectively, while in Burullus Lake were 27 mg/l for COD and 12.2 mg/l BOD. This is because the retention time of water in Edku Lake is less than Burulles Lake which could has an impact of the accumulation and/or increasing their concentrations. Moreover, from the satellite images, the residential areas which riparian to the Burullus Lake is more than that at the Edku Lake. Such residential areas are unnerved by the sanitation services and the direct discharge of sewage into the Lake could increase COD and BOD concentrations.

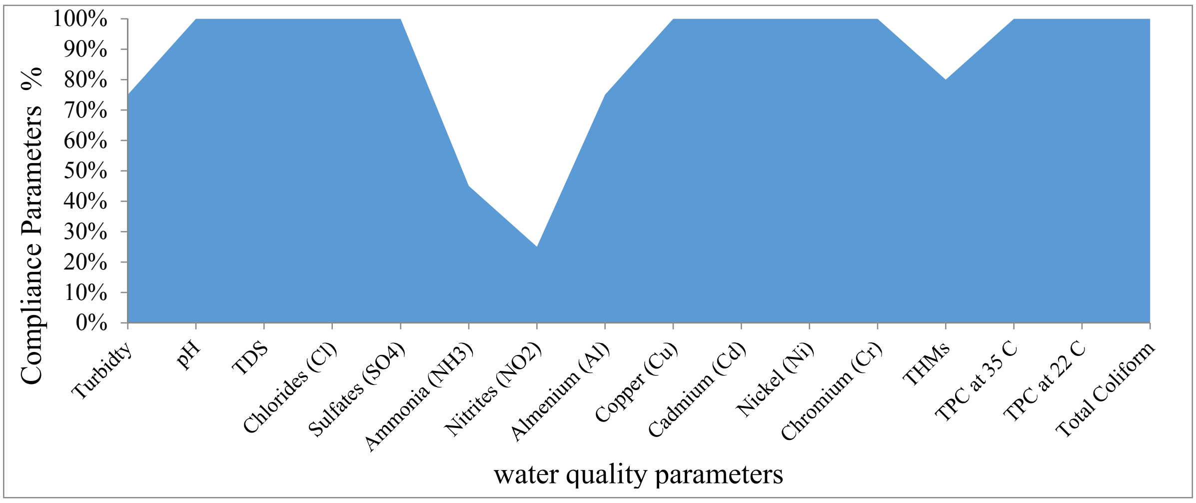


(a) Al-Mamoura WTP.

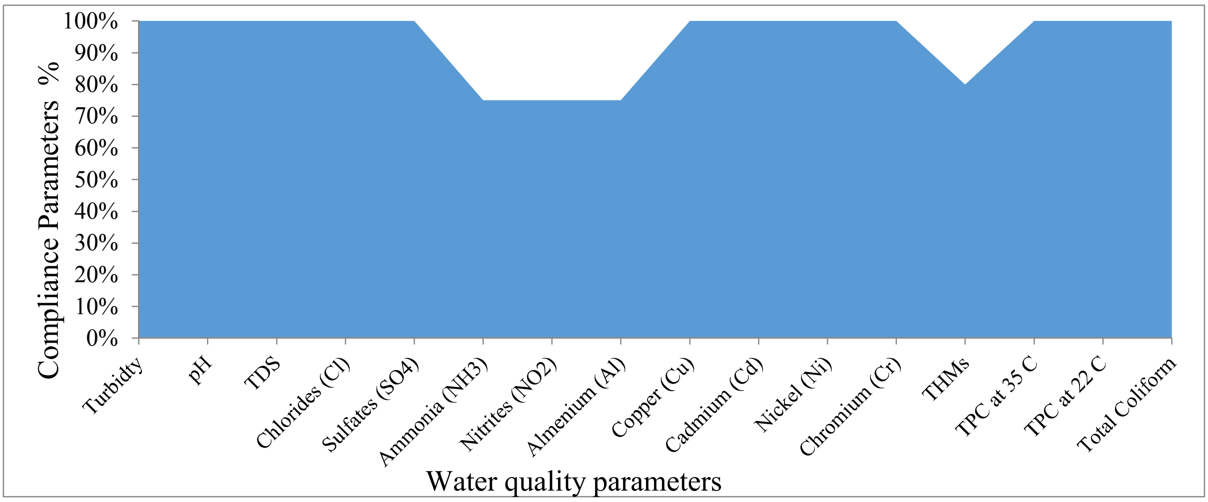


(b) EdfenaWTP.

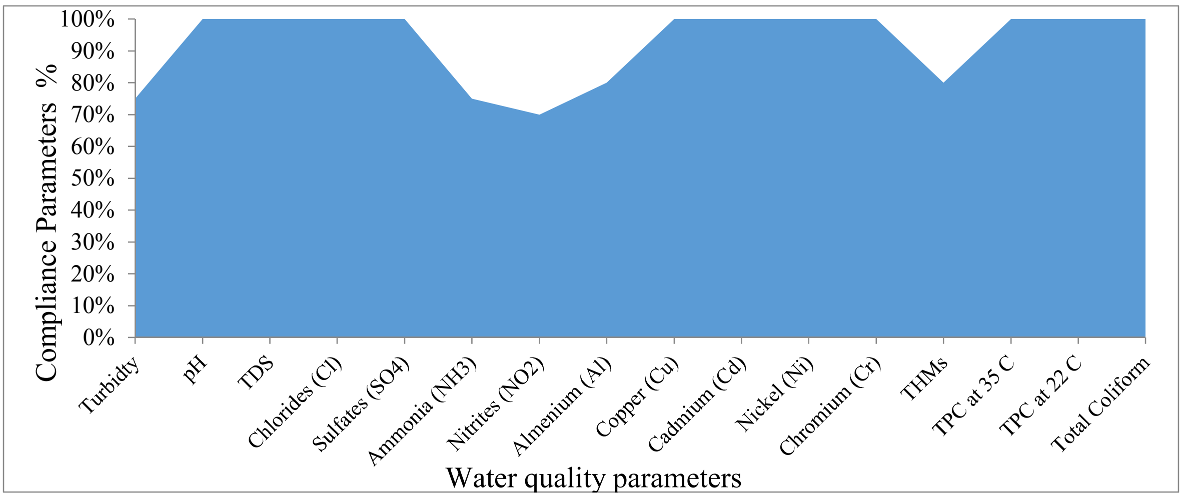
Fig. 3: Drinking water compliance parameters percentage for Edku area; (a) Al-Mamoura WTP and (b) EdfenaWTP.



(a) North Motobes WTP



(b)El-Khashaie WTP



(b) Baltem WTP.

Fig. 4: Drinking water compliance parameters percentage for Burullus area; (a) North Motobes WTP, (b) El-KhashaieWTP and (c) Baltem WTP.

Lakes Water Quality

The northern delta lakes are exposed to huge amounts of drainage water containing organic and inorganic pollutants (El-Moselhy *et al.,* 2016; El-Batrawy *et al.,* 2017; 2018). Water quality parameters showed a wide variation due to the discharge of drainage water from different pollution sources during different times (Abd El- Hamid *et al.,* 2017; Okbah and El-Gohary, 2002). Burullus lake water is more quality than Edku lake. Burullus Lake is the lowest lake which meets domestic, sewage water and industrial wastewater (Okbah *et al.,* 2017).

Despite that the two Lakes subjected to direct discharge of a group of agricultural drains which containing considerable amount of domestic sewage, the concentration of pollution indicators (DO , BOD, COD, and NH3) are seems acceptable comparing to the surface water in Rosetta Branch (Figure 5). That could attribute to the renewal of water in lakes due to mixing with seawater. The overall results of the both lakes shown that however, the contamination comes from different drains but the water quality in the lakes still affordable and even with a better quality if compared with the surface water quality in the study area.

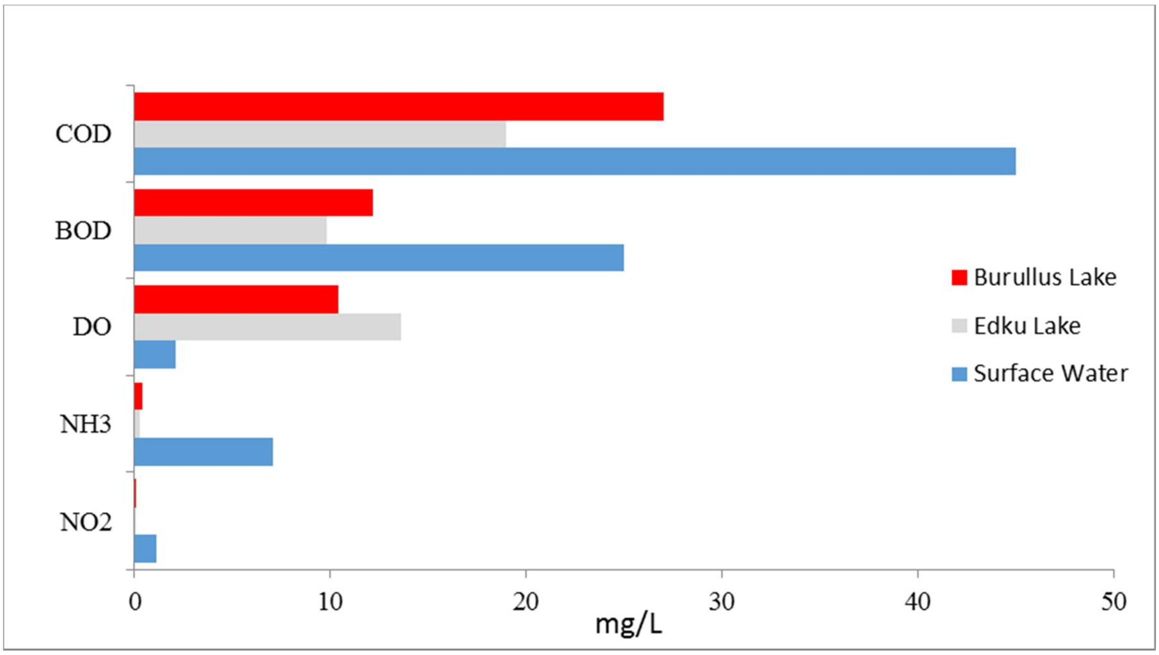
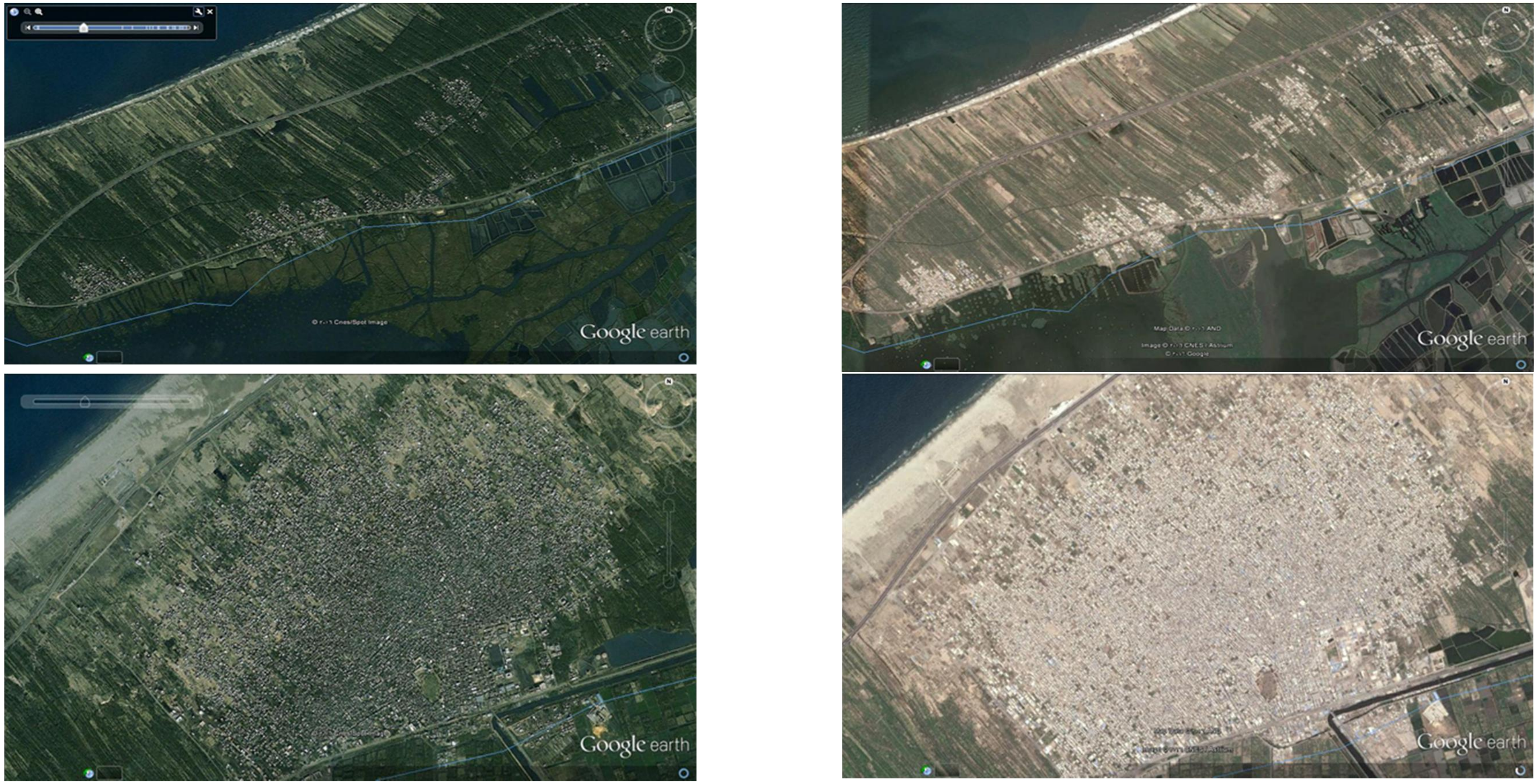


Fig. 5: Comparison between lakes and surface water quality (averages).

Land Use Analysis

The changes in land use were studied using the historical Google Earth images. The inspection has demonstrated that the residential areas surrounding the lakes have grown in both dimensions vertically and horizontally during the last decades. Figures 6 and 7 represent the land use surrounding Edku Lake and Burullus Lake, respectively.

In Edku area the situation is even worse, by making a correlation between the urban growth, the population and the produced drinking water quantity, the reported average population has grown from 300917 cap/2006 to 385825 cap /2016 (Table 2). By a population average growth rate of 2.8% yearly, while the amount of produced drinking water is only 38880 m^3/day. The estimated water share is 100.7 liters/day/cap. The produced water need to be doubled to compensate the gap of water balance, moreover, the expected population by the year 2027 is 493856 cap., thereby additional 28606 m^3/day will be needed to cover the new individuals (Kiand, 2004).



2006 **2016**

Fig. 6: Land use surrounding Edku Lake.

2006 **2016**

Fig. 7: Land use surrounding Burullus Lake.

The reported average population in Burullus area has grown from 337626cap./2006 to 400065 cap./2016 (Table 3). By a population average growth rate of 2.5% yearly, while the amount of produced drinking water is 71701 m^3/day. The estimated water share is 179 liter/day/cap. Figure (7) pointed to a shortage in water supply below 200 liter/day/cap mentioned in the Egyptian code, about 300000 m^3/day is needed to overcome the water shortage in study area. It is estimated that by year 2027 the population in the study area will reach 500000 capita, about additional 100000 m^3/day will be needed to cover the water demand cause a stress on the already limited water resources.

Desalination Opportunities

The deterioration of surface water in the Northern of Nile Delta Region put a stress on the water treatment plants along these resources. New strategies for water development and management are urgently needed to avert severe local water scarcities (Wahaab, 2006). Limitation of the conventional water treatment technology together with the continuous overburden in surface water resource constrains the sustainability of drinking water supply by the present situations. The Northern Delta lakes provide a potential alternative that could be desalinated with lower cost.

Many organizations have attracted to reduce desalination costs because of the expansion of the desalination market (Missimer and Storves 2002). Technological improvements in membrane design and systems have decreased the desalinated cost down by over half and consequently, the amount of energy required to produce 1 m^3 of fresh water decreased by over 64% (Arras *et al.* 2009).

A comparison between sea and brackish water desalination has been built based on the data from CDWR (2009) and RSWW (2016) and demonstrated in Figure (8). The average energy consumption of RO desalination treatment is estimated at about 12.3 kWh/kgal (3.2 kWh/m^3) for seawater and about 5.5 kWh/kgal (1.5 kWh/m^3) for brackish water desalination. Also, the cost of brackish water desalination unit instillation is estimated at about 1.53–2.76 US$/k gallon, while the cost of sea water desalination unit is 2.76–7.67 US$/k gallon. Cost comparison between seawater and brackish water desalination has shown that desalination of the brackish water as a resource, reduce the total production cost of 1m^3 by 30% (CDWR 2009). Based on the data compiled from Red Sea Water and Wastewater affiliated Company (RSWW, 2016), the average cost for 1 m^3 from desalination source is about 7.3 L.E. for year 2015/2016 excluding the cost of treatment chemicals.

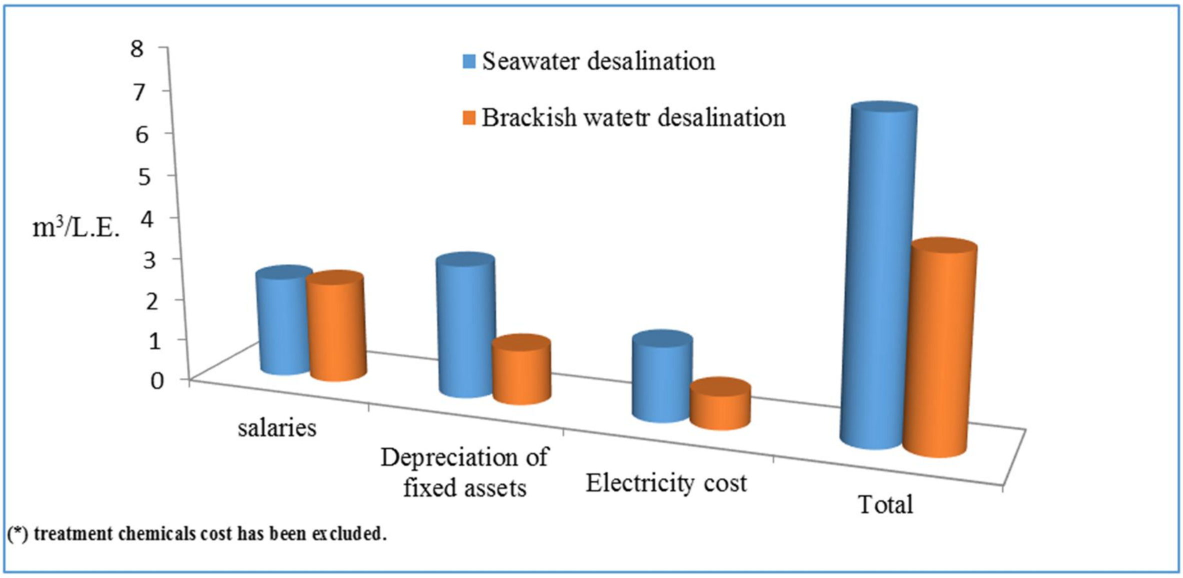


Fig. 8: Cost comparison between sea and brackish water desalination based on data adapted from (CDWR, 2009) and (RSWW, 2016).

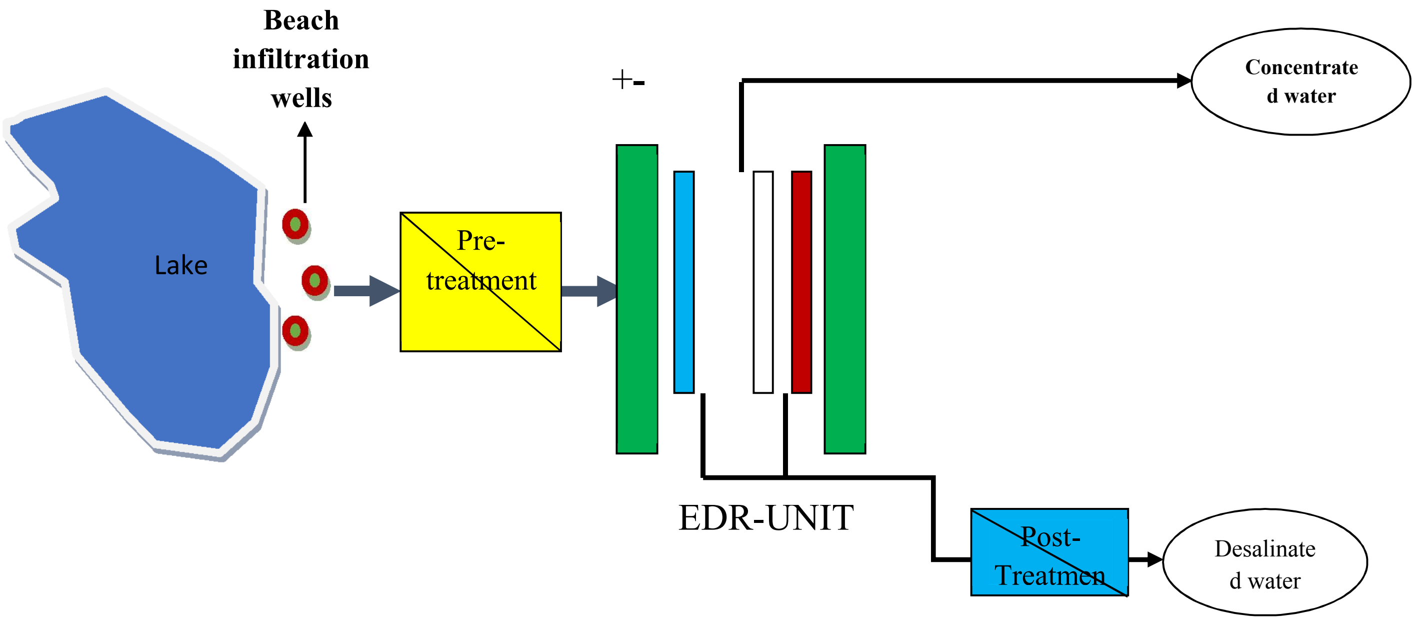


Fig. 9: Proposed treatment train for brackish water within the study area using EDR technique.

Brackish water cost is always lower than that of sea water because lower salinity feed water requires lower applied pressure and allows higher recovery. It is more difficult to estimate brackish water cost because of water quality and quantity changes from site to site and sometimes even at the same site. Electrodialysis reversal (EDR) technology can provide Low cost potable water quality from a brackish water source (Valero and Arbós, 2010). Typically, EDR is selected over reverse osmosis (RO) for systems that have a particular water chemistry issue (Ghaffour *et al.,* 2013). Figure (9) represents the proposed treatment train for brackish water within the study area using EDR technique

Figure (9) clarify that the site investigation is an important step to select the suitable place to uptake the salty water. Also, the beach infiltration wells would decrease the cost as well of the pretreatment process. The Electrodialysis Reverse desalination (EDR) technique would be an appropriate solution to desalinate the brackish water of the Lakes. The EDR could overcome the scaling problem that resulting from the precipitation of sparingly soluble salts present in the feed water (Kennedy *et al.,* 2018). Hence, the EDR technique will prevent the acid and the ant-scaling. These features would help in the decrease in the operating costs.

Conclusion and Recommendations

Egypt is one of the countries faced with the possibility of chronic water shortages in the future. Rapid increase in population growth will exaggerate the problems associated with water sector allocation. Discharges from domestic wastewater, agriculture drainage and fish cages along Rosetta branch can lead to an excessive increase of pollutants concentration in the water bodies. A sampling campaign was delineated to stand on the status of water quality of fresh water represented in Rosetta Branch and the drinking water produced from the drinking water treatment plants at study area. In same track, a group of samples were collected from both Edku and Burrullus lakes to investigate the quality of brackish water of both Lakes.

The drinking water quality investigation for Edku area showed that Al-Mamoura and Edfena WTPs have WQI of 76.93% and 65.3%, respectively, with fair drinking water quality. While, the drinking water quality for Burullus area has shown that North Motobas, El-Khashaie, and Baltem WTPs have WQI of 55%, 70.3%, and 80 % respectively, with average fair drinking water quality. The deterioration of drinking water quality is due to non-compliance of the drinking water in some parameters specially ammonia and nitrites. The elevated percentage in THMs could be attributed to that WTPs are enforced to increase the chlorine doses to overcome the elevated ammonia percentage at the raw water which cause customers vulnerable to possible carcinogenic disinfection byproducts (DBPs).

Edku Lake has a higher average salinity of (3369 mg/l) than Burullus Lake (2918 mg/l) and both are classified as brackish water with salinity ranges between 1800-3500 mg/l. Despite that Edku Lake and Burullus Lake subjected to direct discharge of a group of agricultural drains which containing considerable amount of domestic sewage, the concentration of pollution indicators (DO , BOD, COD, and NH_3) are seems acceptable comparing to the surface water in Rosetta Branch which remarkably influenced by the agricultural and domestic drainages from drains located on its banks

The changes in land use were studied using the historical Google Earth images. The inspection has demonstrated that the residential areas surrounding the lakes have grown in both dimensions vertically and horizontally during the last decades. Population growth threatens a severe shortage of drinking water supplies in nearest future synchronized with the increasing water demand accompanied with regular anthropogenic activities and improving of life style.

The Northern Delta Lakes represent a potential resource to provide the residential areas adjoining the Lakes regions by sustainable drinking water resource. However if brackish water is nearby available in sufficient quantities, this may be the preferred sources for desalination, depending on the distance to source. Cost comparison between seawater and brackish water desalination has shown that desalination of the brackish water as a resource; reduce the total production cost of $1m^3$ by 30%.

Desalination plants for drinking water and industrial use in areas where no other cheaper resources are available, will be developed as the demands grow in the year 2050. Brackish water Desalination cost is always lower than that of sea water because lower salinity feed water requires lower applied pressure and allows higher recovery. Electrodialysis reversal (EDR) technology can provide Low cost potable water quality from a brackish water source. Therefore, the authors proposed treatment train for brackish water within the study area using EDR technique. Further economic studies should be done in order to verify the proposed treatment train.

Based on these results, it is recommended that the decision-makers/takers must take appropriate measures to avoid further reduction of the lake water. While the long-term strategy might be achieved by conducting adequate treatment for agriculture and municipal wastes before being discharged into the lake for better sustainability of the water bodies of the lake. Edku and Burullus Lakes, which are classified as brackish water body, could play a significant role in the improving the water resources in the water system of the Northern Nile Delta. Desalination of its brackish water can be used as alternative and /or supplementary drinking water source for the Northern part of Nile Delta.

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