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Ecological Risk Assessment of Desalination Plants Discharges on the Marine Environment Red Sea, Egypt

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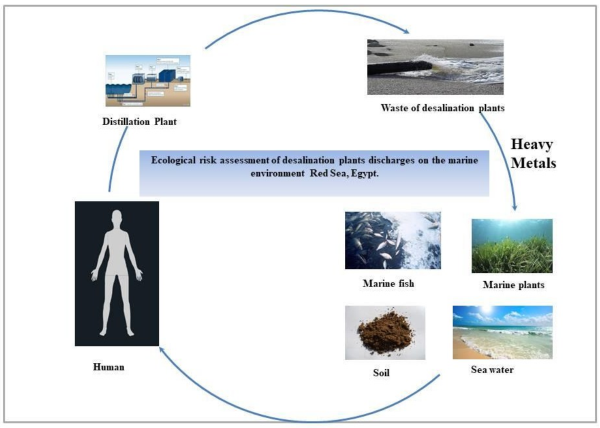
Abstract

Desalination has become one of the main alternatives to compensate for water shortages. Although seawater desalination is expensive and has many environmental risks, it is still an important option to compensate for water shortages in Egypt.The discharge of liquid waste (especially heavy metals) from the station into the sea has a negative impact on the water, so the spatial distribution of heavy metals (lead, cadmium, and copper) shows high concentrations near the outlets of both Al-Qusayr and the port of Al-Qusayr. Hamata desalination plants in the southern Red Sea. As for higher quantities of heavy metals - higher than the standard values - such as (Cu, Pb, Cd), they are classified as seawater pollutants, whether they show evidence of toxicity or not. The study demonstrated that seaweed has bio-absorption properties and can effectively absorb heavy metals from the surrounding water, and thus it can serve as a bio-indicator in tools for monitoring the degree of pollution, as well as evaluating water desalination activities.

Keywords: Desalination Discharges; Heavy Metals; Environmental Risk Assessment; Seaweed Environmental Bioindicator; South Red Sea



Introduction

The Red Sea has a very unique environment being a semi closed basin that has almost no fresh water input Except for rain water during the limited rainy season and very limited sedimentation rate under the effect of its north western monsoon wind [1].

Egypt is facing a water deficit problem despite having the Nile River. The rapidly growing development in Egypt demanded the mobilization of man-power from communities on the Nile valley to coastal zones on South Sinai and all along the Red Sea.

The Egyptian Red Sea Coastline extends for almost 700 km excluding the Suez and Aqaba Gulfs [2]. It is a hotspot for recreational activities and widely known for its exquisite nature and therefore, it has high economic value [3]. The potential sites for desalination project implementation was identify [4]. In Sinai Reverse osmosis RO is the appropriate technology for the development of the Sinai and Gulf of Aqaba region. With the rapid urban growth and touristic attraction, the demand on domestic and drinking water have natural fresh water resources could provide.

Desalination technologies are applied using two basic water resources, namely seawater and groundwater. Reverse osmosis desalination plants are used specifically for seawater treatment despite their various negative impacts on the environment. High energy consumption is one of their indirect negative impacts which could be mitigated by recent advanced technologies producing energy recovery systems [5].

Egypt has employed desalination technologies as a source of pure drinking water. Water treatment by desalination plants includes 58% of seawater, 22% of brackish water and 5% of wastewater [6]. Subsequently, desalination technologies are the most conventional approach to overcome the high demand on domestic water in the south of the Red Sea Egypt despite their negative impact on marine ecosystems [7].

Giving their importance in fresh water supply, desalination plants must be evaluated for their potential environmental impacts on the ecosystem. [8] Studied cumulative effects of large-scale desalination on the salinity of semi-enclosed seas and reported that Up to 61 million people could be dependent upon desalinated water drawn from the Red Sea and/or Gulf of Aqaba by 2050. The cumulative effect in the Gulf of Aqaba may be detectable but is likely to be within the bounds of natural variability.

Moreover, mitigation strategies should be applied as possible, in addition to comparatively investigate other different water resources and alternative water management approaches, so that a secure sustainable employment of seawater desalination could be achieved.

Finally, the present study aims to examine and differentiate the environmental impacts of two seawater desalination reverse osmosis (R.O.) plants on the south of the Red Sea Egypt, as an evaluation of their potential environmental risks on marine environmental.

Materials and Methods

Geomorphology of the Study Areas

El Quseir and Hamata desalination units are of those using Sea Water Reverse Osmosis technology (SWRO) on the Red Sea coast. El Quseir is a Red Sea city located at latitudes 26° 7'30.67"N and longitudes 34°16'13.63"E (Figure 1), bordered by Hurgada, 140 km to the north. While to the south, Marsa Alam. International airport lies 73 km away and likewise the city of Marsa Alam is 138 km to the south as well. El Quseir is known for phosphate mining activities, and is inhabited by a population of 85000 individuals. Hamata is a small village on Red Sea, which lies 100 km to the south of Marsa Alam at latitudes 24°17'9.61"N and longitudes 35°22'41.52"E (Figure1). Hamata is remarked by four archipelago islands surrounded by fringing reefs which are a well-known destination for divers and snorkelers, visited on regular daily basis trips by tourism operators. Hamata is populated by an estimate of 3000 individuals.

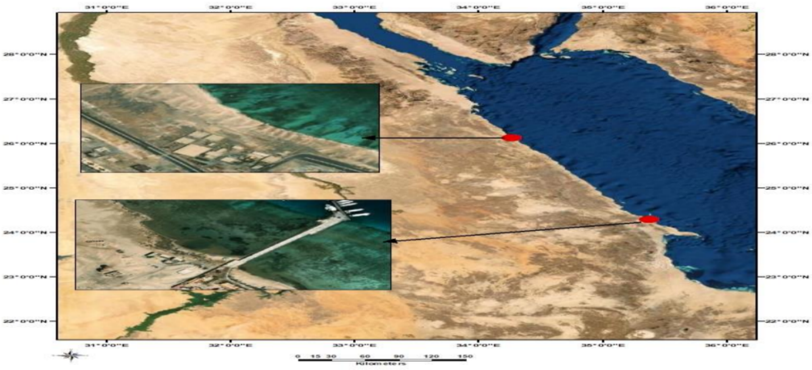


Figure 1: Study Locations along the Red Sea Coast, south Egypt

Sample Collection and Handling

Water samples were collected using the line transect method where three 100-meter-long transects were established perpendicularly across the coastline with an interval distance of 50 m [9] Each transect had three replicates, the first (P1, P2, P3) was located to the north of the discharge outlet of the desalination unit, the second transect (P4, P5, P6) was situated directly in front of the discharge outlet, while the third transect (P7, P8, P9) was to the south of the discharge outlet of the desalination unit. Meanwhile, the tenth water Sample (P10) was directly collected from the desalination plant water discharge [9]. The former methodology was applied for both El Quseir (Figure 2) and Hamata (Figure 3) desalination units. Besides, one control sample (P11) was collected from Marsa Ranga; a site located 80 km to the south of Marsa Alam and has no desalination plants in its vicinity. Consequently, a total of sixty- three waters samples (three replicate samples of each transect replication and direct water discharge for each desalination unit, plus three replicate samples of the control site) were collected from the coastal water surface of the Red Sea during February 2016 using Nansen bottle water sampler [10].

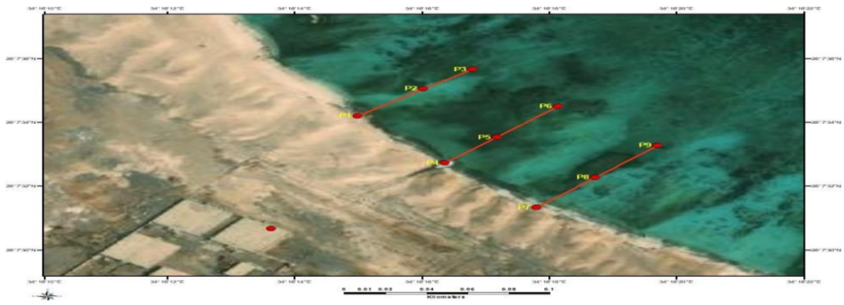


Figure 2: Distribution of sampling points in confrontation El Quseir Desalination plant.

Figure 3: Distribution of sampling points in confrontation Hamata Desalination plant

For elements analysis, water samples were immediately filtered using filter papers of size 0.45µm fitted on a thermal glass holder, the filtrates acidity was adjusted to pH = 2 by adding A.R. nitric acid, to avoid metal adsorption on the bottles internal surface [11].

On the other hand, fifty-seven sediment samples were collected (three replicate samples from each line transect replication from P1 to P9 for each desalination plant in addition to three replicate samples of the control site sediment). Sediment samples were air--dried for a week, sieved through 2mm mesh size to eliminate large particles and debris [12].

Similarly, algal samples (Figure 4) were collected from some sites as water samples (from El Quseir plant ambient water only). All algal samples were rinsed thoroughly by tapped water followed by bidistilled water; afterwards, they were oven dried at a temperature of 110oC for 48 hrs [13]. The dried algal samples were ground into powder using an agate mortar and preserved in polyethylene containers for further analysis.

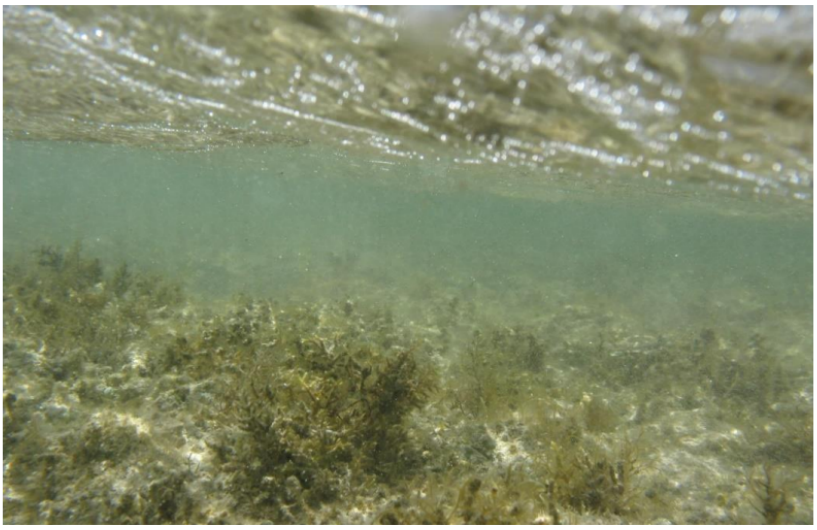


Figure 4: Species of micro-algae Vicinity El-Quseir Desalination Plant

Laboratory Methods and Treatment of Measured Data

The physico-chemical parameters of water samples were determined according to standard methodology [14]. Also, the chemical treatment of sediment samples was implemented using the referenced complete metal digestion approach [12]. And finally, algal samples were digested according to "Chemical analysis of ecological materials" [13].

Elemental Analysis and Instrumental Technique

Concentrations of the heavy metals (Cu, Cd and Pb) were determined in water samples, sediment and algal extract solutions using atomic absorption techniques by the spectrophotometer (Model Solaar 909, ATI Unicam Comp.).

Quality Control and Assurance

The process of analyzing heavy metals accurately could be impaired due to probable contamination [15]. Therefore, laboratory equipment of glassware or plastic containers is better to be washed completely by diluted acid such as 10 % (v/v) nitric acid and rinsed afterwards with distilled and deionized water. That would guarantee heavy metal decontamination of laboratory equipment being utilized. Moreover, care should be taken during collecting and analyzing samples so that they won't be susceptible to any contamination source which would in turn, ensure reliable high-quality results. Hence, the following precautions should be taken. Avoid the use of metal utensils, if possible, collect sediment samples using stainless steel instruments and preserve them in nonmetal containers (e.g.; glass jars or polypropylene bags). Sediment samples to be stored at 4oC until being analyzed. Furthermore, a quality control system is essential during the analysis of valid and reliable results in due course.

Deionized water is used to prepare standard solutions of the elements being measured by atomic absorption spectroscopy, by diluting the stock solutions (1mg/ml) for the elements Cd, Cu, and Pb (BDH, England). According to research, the net accumulation of heavy metals in an organism is determined by the difference between the rates of accumulation and depuration [16], which is a highly significant factor contributing to the bioaccumulation of heavy metals. For further illustration, the bioaccumulation factor is determined through the following formula:

$$BF = C1/C2$$

Where C1 is the average metal concentration in the organism, while C2 is its average concentration in the ambient environment in which that organism lives e.g. water or surface sediment.

Data Analysis

The statistical analysis of the data resulted from the chemical analysis of different samples (water, sediments and algae) was performed by the statistical package program SPSS statistics V21. Besides, different variables were plotted on distribution maps using ArcGIS 10.5.

Results

The figures (4-10) are a demonstration of the analyzed data of different environmental samples collected from the ambient environment of the desalination units under study.

Water Samples

Physico–Chemical Parameters

Generally, salinity levels of water samples ranged between (43-46.9 ‰) and (43.9-45.6 ‰) for both Hamata and El-Quseir plants respectively (Figure 5, 6).

The studied water samples revealed harmonious variation between salinity levels and TDS contents in different study areas, where TDS values ranged between (39.9-41.2 g/l) -similarly- in both Hamata and El-Quseir vicinities (Figure 5, 6).

TDS in (P10) had had the highest (TDS) concentrations measuring (48.7 g/l) and (50.21 g/l) respectively.

Meanwhile, the (TDS) measured values were observed to decrease with distance -moving apart from the outlets-owing to the strong dynamics of water mixing (Figure 5, 6).

Seawater samples nearby Hamata and El- Quseir plants recorded high conductivity magnitudes of (1920 µmhos and 1926 µ mhos) respectively, while samples collected directly from the discharge outlets recorded (1929 µ mhos and 1988 µ mhos) for Hamata and El-Quseir plants respectively. They were the highest recorded values as they represent the crude brine discharge (Figure 5, 6).

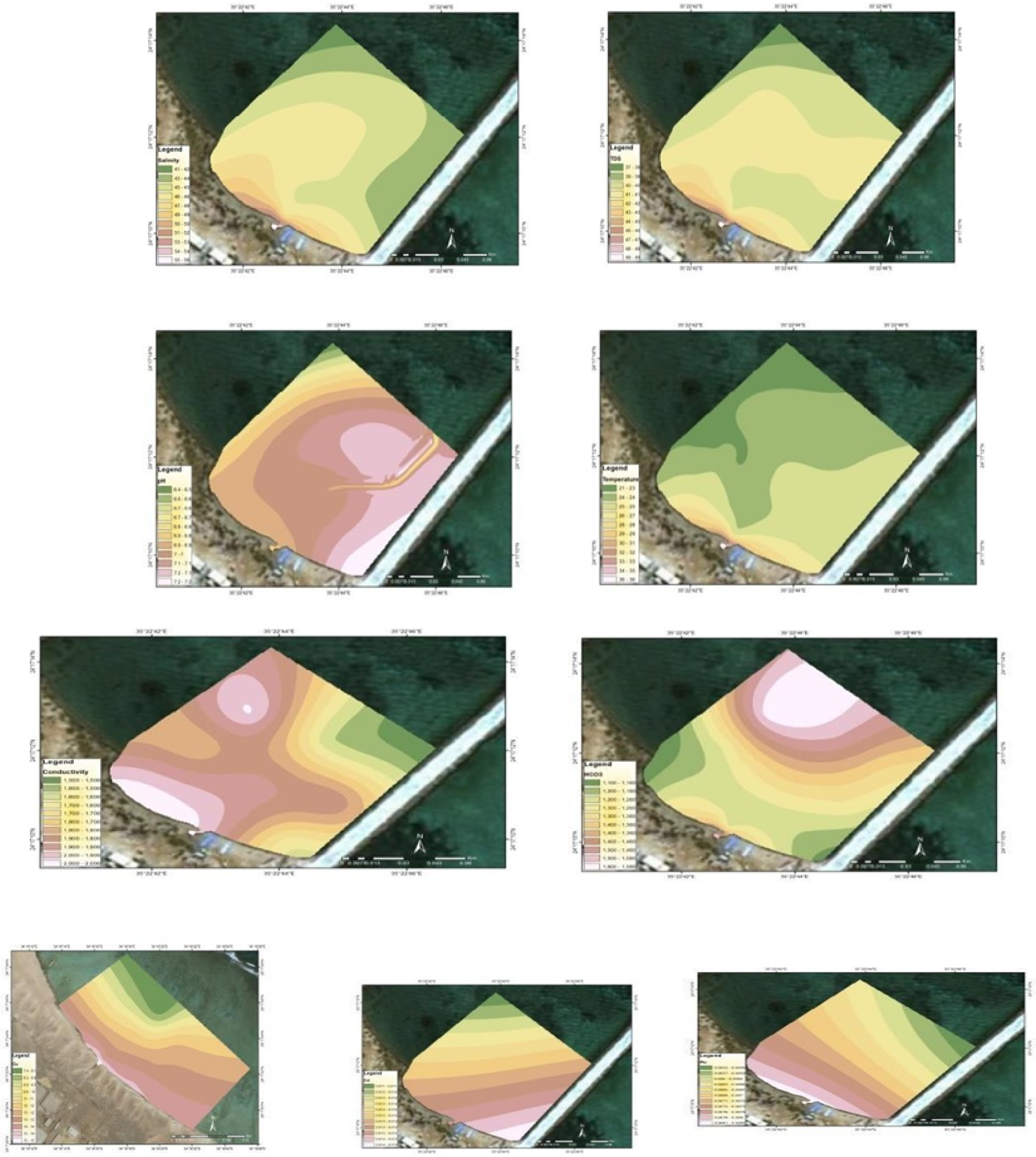


Figure 5: Distribution maps of TDS, Salinity, pH, Temperature, Bicarbonates, Conductivity, Pb, Cd and Cu values at the Hamata Desalination plant

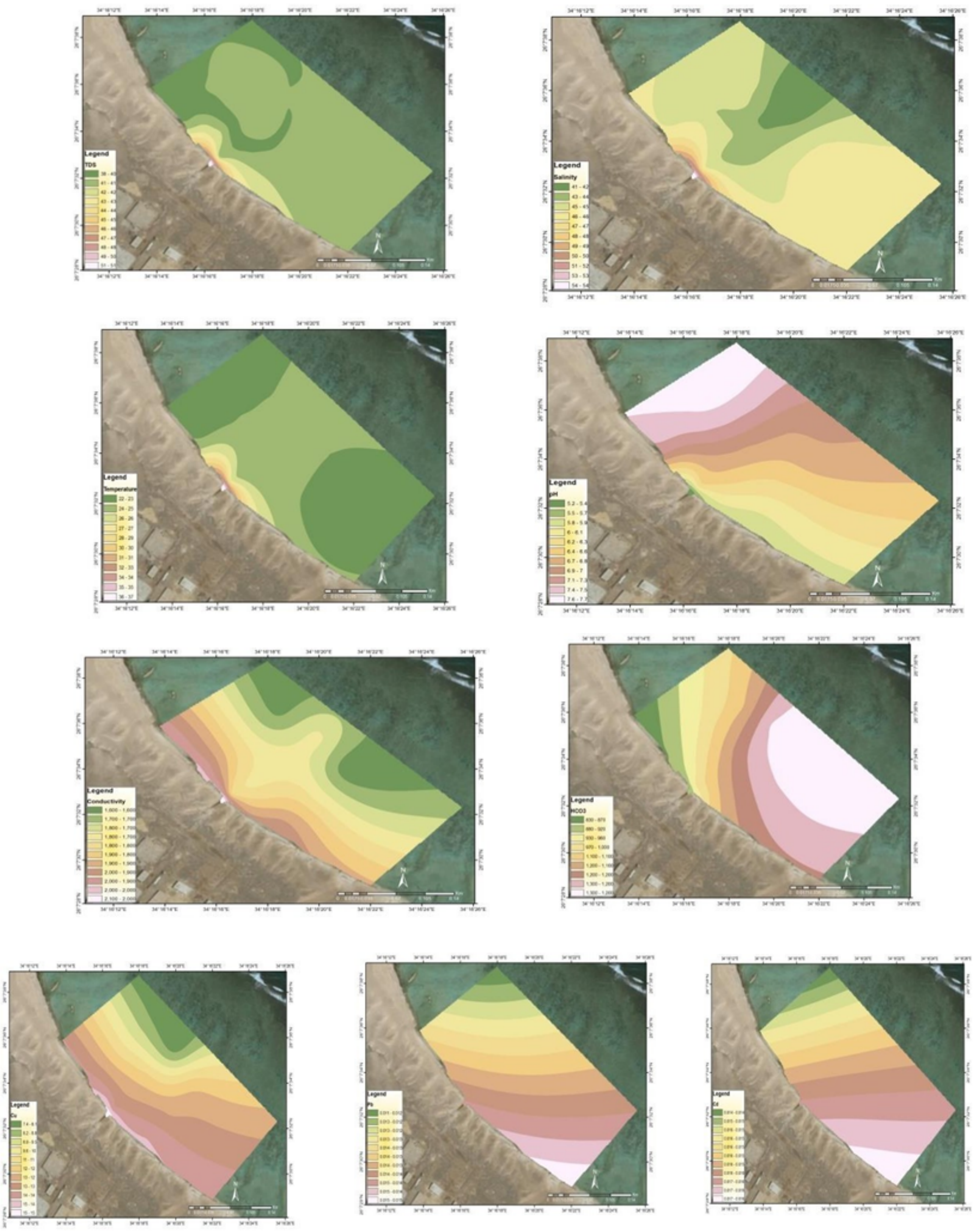


Figure 6: Distribution maps of TDS, Salinity, pH, Temperature, Bicarbonates, Conductivity, Pb, Cd and Cu values at the El Quseir Desalination plant

As demonstrated by figures (5 and 6), the higher the effluent water temperature, the warmer the ambient waters surrounding the plants' vicinities. Maximum water temperature was recorded at P7 and P4 stations of Hamata and El-Quseir plants respectively measuring (25.6oC). Typically, the water temperature at the direct discharge station (P10) was the highest of all recording (35.7 and 36.3 oC) for both Hamata and El-Quseir plants sequentially.

Investigating physicochemical parameters of water samples revealed moderate pH values ranged from (6.89 to 7.16) and from (5.73 to 7.37) for Hamata and El Quseir samples respectively (Figure 5, 6). On the other hand, the least acidic recorded pH values were (5.23 and 6.75) which belonged to water samples collected from the vicinity of El-Quseir and Hamata plants respectively.

Bicarbonate concentrations ranged between (1120 – 1480 mg/l) in Hamata water samples while they ranged between (872 -1232 mg/l) around El- Quseir waters. The highest bicarbonate levels (1480 and 1232 mg/l) were detected in water samples nearest to the plants.

Heavy Metals Analysis

Pb concentrations ranged between (0.0011 to 0.0125 µg/g) and (0.0021 to 0.0156 µg/g) for Hamata and El-Quseir sediment samples respectively, and likewise, Cd levels ranged between (0.0093 to 0.0159 µg/g) and (0.0035 to 0.0189µg/g) for Hamata and El-Quseir sediment samples respectively (figure 7, 8).

The spatial distribution of the heavy metals (Pb and Cd) shows high concentrations (0.0147& 0.0115) at P1& (0.0124&0.004) at P4 and (0.0159& 0.0125) at P7 for Cd and Pb, respectively, near the outlets of both studied plants (Figure 7, 8).

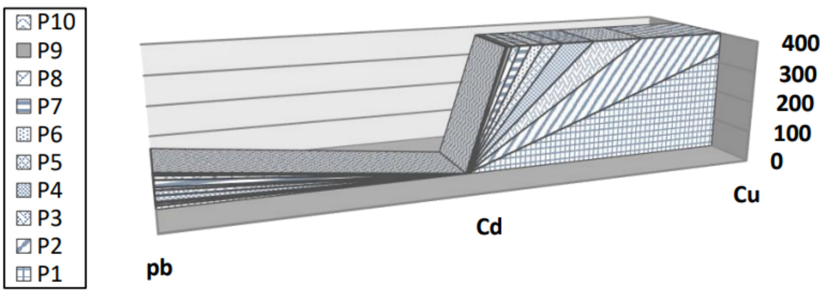


Figure 7: Evolution of Metal ion Concentrations (µgg-1) in Sediment Samples at Different Discharge Points vicinity Hamata Desalination Plant.

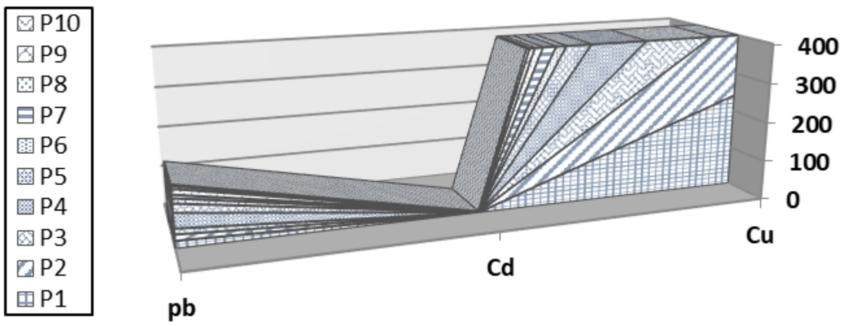


Figure 8: Evolution of Metal ion Concentrations (µgg-1) in Sediment Samples at Different Discharge Points Vicinity El-Quseir Desalination Plant

Copper recorded mean concentrations of (11.59 and 24.03 mg/l) at both El-Quseir and Hamata desalination plant effluents respectively (figure 7, 8), which were higher than copper concentration measured at the control sample at Marsa Ranga measuring (9.8 mg/l). In this study, sediment analysis revealed that Cu concentration was highest at station P7 near Hamata desalination plant recording (374.3 µg/g), while at El-Quseir plant, station P4 was the highest in Cu concentration recording (332.8 µg/g).

Discussion

Water Samples

Physico–Chemical Parameters

The plant's discharged effluent directly affects the marine and coastal environment; the magnitude of its impact is highly influenced by its physicochemical properties which in turn controlled by the desalination processs itself as well as the pretreatment applied [16].

The high recorded salinity is attributed to the availability of abundant cations of Cal3cium (Ca+2), Mag4nesium (Mg+2), Sodium (Na^+) and Potassium (K^+) and, the anions of carbonates (HCO^-), sulfates ($SO2^-$) and chlorides (Cl^-) in water samples. As a result of the desalination process, enormous amounts of salts are discharged into seawater leading to the exceptionally elevated salinity of the surrounding environment causing severe fluctuation in salinity levels.

These fluctuations are believed to have a fatal effect on marine organism's intolerant to sudden changes in salinity around the desalination plant outlets [5]. Furthermore, benthic communities are threatened the most, since the highly saline water mass of the discharges tends to sink into depths due to their relatively higher density. Fluctuation of salinity levels can easily impact sensitive ecosystems, disrupting microbiota, changing biofilms composition as well as the distribution of benthic communities [17]. Specifically, at slightly higher levels of salinity, several marine organisms could lose their osmotic regulation characteristics and eventually die of dehydration [18, 19].

Naturally, seawater contains certain concentrations of dissolved solids. Additionally, higher water total dissolved solids (TDS) could result from mining activities or industrial wastewater effluents that if exceeded 1000 mg/l the water is considered "brackish" [19]. Moreover, natural water bodies could change in their (TDS) content by the effect of salt water intrusion, i.e. the movement of highly saline water into natural water bodies [19]. Total dissolved solids (TDS) constitute of different minerals and organic particles that could be either micronutrients or contaminants judging by their origin.

Qualitatively, water conductivity is a reproduction of inorganic contamination and the abundance of ions in water as well as a reflection of total dissolved solids. It was noticed that the values of TDS and accordingly, conductivity values were considerably higher in effluent discharge than ambient seawater owing to the lack of cooling water discharges associated generally with power plants.

Such elevated temperature has potential impacts on several levels, the continuous discharge of hot RO reject, hyper saline water, has a deleterious effect on marine life that could lead to a constant shift in marine communities' distribution and species abundance around the area of discharge. Furthermore, some chemicals and metals, under elevated temperatures could interact and transform into toxic forms that harm the marine ecosystem [20].

Mostly, marine organisms can adapt small scale fluctuation in salinity levels and temperature while other hard species can endure unfavorable conditions to considerable extents. However, long term exposure could lead to drastic consequences eventually. Similarly, a study on the Arabian Gulf marine environment has emphasized that, the resulted brine of desalination process has complicated nature that can impact the marine life in different ways totally altering its physicochemical properties and thus all living communities around the discharge area. For more elaboration, first, there is the thermal pollution and second, the chemical composition of the brine itself that includes chlorine, cationic and anionic coagulants, acids, anti-scalants, heavy metals, and anti-foaming agents, all of which have a drastic effect on the ecosystem [21-23]. Third, calcium carbonates and sulfates in the brine could shift water pH into more alkaline medium [24]. The change in these three parameters- temperature, pH and chemical composition-could easily be reflected on the surrounding biota.

For example, phytoplankton can be affected by the elevated amounts of nitrogen and sulfur that in addition to elevated temperature can result in eutrophication. Furthermore, the bioaccumulation ability of some marine organisms such as sea shells, sea grasses and sea weeds turned them into (Indicator species), the health of ecosystems could be monitored through theirs [25-26].

In the light of the above, it is clear how desalination plants can harm the marine environment on both construction and operation levels altering the marine habitat and community in a way that could lead to habitat degradation or total loss [27]. The algal cover availability around the studied areas is believed to influence the variations in pH values especially near the El-Quseir plant (figure 9). The pH values were observed to decrease towards the discharge outlets in both of the desalination plants (specifically at stations P1, P4 and P7) which is predominantly attributed to CO2 sequestration in the discharged waters (figure 5, 6) [20].

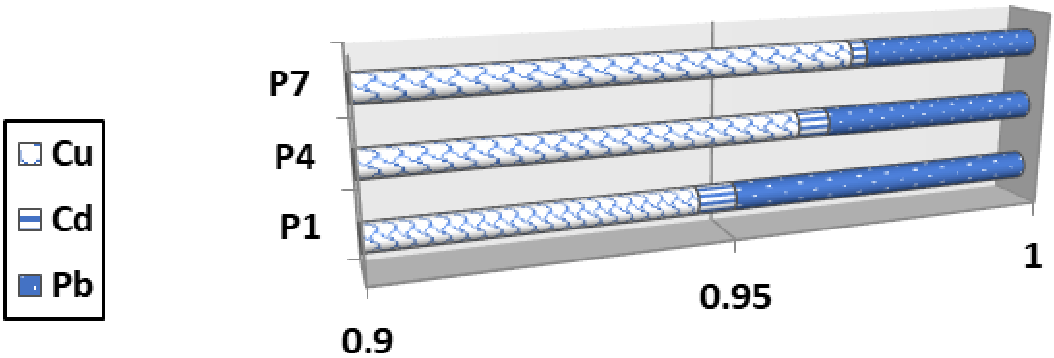


Figure 9: Existence of Cu, Pb and Cd Ions Concentration (μgg-1) in Algae Samples Vicinity El- Quseir Desalination plant.

The highest bicarbonate levels could be the product of CO2 reactivity with the hydroxide anion (OH-) in an aqueous3 solution giving bicarbonate (HCO3-) according to the ubiquitous formula (CO2 + OH- → HCO -) [28].

Heavy Metals Analysis

Heavy metal contamination to the environment is a global concern, giving their toxic and non-decaying nature, they tend to bioaccumulate in the environment and eventually reach the food web in high concentrations [29-30]. As a result, efforts are exerted to investigate the outspread of heavy metal contamination and evaluate their potential impacts in different ecosystems specifically their lethal effect on the marine environment [31-32].

Lead is a poisonous heavy metal can intervene with and affect the whole process of hemoglobin synthesis, since it binds with the Oxo- groups in enzymes, reduces the amounts of heme production, by inhibiting the synthesis of porphyrin1 [33]. Lead poisoning in humans was reported to affect the central nervous system causing seizures, brain swelling, and intellectual disabilities.

On the other hand, severe cadmium exposure in humans could lead to the "Itai - Itai" disease which is accompanied by severe bone pain besides, it was associated with renal failure, liver dysfunction and high blood pressure [34-36]. Although, studies suggested that feeding lifestyle as a whole is a significant indicator of cadmium toxicity rather than just the metal availability in diet [36].

1. Porphyria is a disease results from heme deficiency that could be a result of lead poisoning as one of many causes, porphyrin synthesis throughout hemoglobin formation is inhibited by lead poisoning leading to anemia.

Cadmium has the ability to bioaccumulate in the tissue of organism reaching toxic levels slowly and gradually, it is among few hazardous compounds designated by the EPA and a priority contaminant. Therefore, its globally prohibited to be discharged into water bodies [36].

In general, all stations recorded relatively low cadmium levels, however, trace amounts of cadmium could still be severely harmful over time or when overly consumed [37]. Most of Cadmium (Cd) in the marine environment primarily originated from anthropogenic sources [36]. Similarly, it was reported that different aquatic biota is susceptible to absorb cadmium available in the sediment as well as water column [38].

Although copper is a vital trace element for living organisms, elevated concentrations could be highly toxic when ingested. After investigating the concentrations of Pb, Cu and Cd heavy metals in different water samples collected from the discharges of two desalination plants on the Red Sea coast (figure 5,6), we can conclude that Pb contents were lower than acceptable standard values, however, Cu and Cd have exceeded the permissible standard values [39].

Sediment Analysis

The harmful impact of high heavy metal concentrations in seawater are achieved when they get transported by water movement and be deposited and accumulated in coastal sediments where they transform into a particulate form that alters their potential toxicity levels. This variability may induce changes in heavy metals distribution between dissolved and particulate phases, and thus changes of their toxicity. Most metal ions are also removed from the water column by transport into sediments. Generally, most heavy metals from seawater get mobilized and accumulate into coastal sediments as sink overtime. Previously, several types of research have investigated the magnitudes of heavy metal contamination in the sediments of the Red Sea coasts [34, 40-43].

Generally, anthropogenic activities are the main source of heavy metal contamination of marine ecosystems. Due to an increase in land-based activities and the use of leaded fuel over the past forty years, air inputs of Cd, Pb, and Zn were frequently introduced to the marine environment [44].

Typically, copper as an element is dispersed under the effect of water motions to be deposited in coastal sediments eventually. Over time, the metal concentration exceeds its safe limits and becomes toxic depending on its bio-availability in sediment [45]. Interestingly, it was observed that Pb and Cd concentrations at the vicinity of both plants were significantly lower than detected Cu levels (Figure 7, 8).

Low levels of lead and cadmium is a healthy indicator considerably as they have toxic potential in nature, while copper is naturally a vital element as long as it doesn’t exceed permissible limits. Mainly, the negative impact of heavy metals in the marine environment evolves from the fact that they tend to bio-accumulate and enter marine food chain pathways and biomagnified as they reach the top of the food pyramid leading to fatal consequences for higher predators including human beings [46-47].

Surface sediments of Marsa Alam and El-Quseir, where found to be at risk by elevated concentrations of Cr and Ni according to Salem et al. (2014). While Hurghada was found to be at higher risk, high levels of Pb, Cd, and Co were recorded in bottom sediments due to different human activities, urban development, intensive tourism and non-sustainable fishing around the Mabahis bay area to the north, in addition to several other sites according to recent literature [48-49]. Meanwhile, Makadi Bay as well as Safaga bay were found to be pristine with traces of heavy metal contamination recorded at Safaga ordered Zn > Cu > Pb [50-51].

In a comparative study, Sharm Al Sheikh was contaminated by Cd and Pb at Um al Sid while Ras Muhammed was clean except for Pb due to geochemical processes as well as tourism activities in the vicinity. Hurghada had high amounts of Pb, Cu, Zn, and Ni. While Quseir in the south, was contaminated by Cd and Pb. Pb and Zn were attributed mainly to anthropogenic activities while Cu were originated from both natural as well as human activities [52-53]. In addition, dredging processes have led to increased Cu and Pb concentrations in the sediments of Al Hamrawin Bay [41].

On the other hand, natural sources can significantly contribute to the heavy metal content of coastal areas. The Wadi system along the Red Sea coast can leach different minerals and metals with storm waters to be precipitated into sediments. That was recorded at Wadi El-Hamra, Wadi El-Esh, Wadi Abu-Shaar, Wadi El-Gemal, and Wadi Khashir (Hamata) [54-55]. Regionally speaking, over the past two decades, the concentrations of Cd, Cu, Pb, and Zn in the coastal surface sediments from the Red Sea countries were higher than permissible limits designated by the UCC and highly correlated to human activities [56].

Algal Samples Analysis

The heavy metal polluted discharged effluents produced by desalination plants could be toxic to different marine and aquatic fauna and flora that are mostly can't tolerate heavy metal toxicity. However, marine algae can withstand elevated levels of heavy metal contamination. Marine algae are also known as "thallophytes" they are plant-like organisms with undifferentiated organs (roots, stems, and leaves), they acquire all chlorophyll pigments necessary for photosynthesis and have no sterile covering surrounding their reproductive cells [57].

Additionally, along the Red Sea, molluscs and gastropods have the ability to accumulate significant amounts of heavy metals as copper, lead, zinc, manganese, and iron in their tissues and hard shell. since they are subjected to significant quantities of heavy metals [58].

After analyzing algal samples under study, it was found that algae have a high capacity to accumulate heavy metals in their tissues (figure 9), since they acquire the needed defense mechanisms to tolerate absorbed heavy metals and store them into vacuoles in the form of phytochelatin and metallothionein complexes.

Fibrous cell wall structure of algae and the amorphous embedding matrix are responsible for their bioaccumulating nature. Their macroscopic structure has the ability to adsorb metals depending on both their electrostatic attraction and their chemical form [59-61]. Evidently, seaweeds could absorb copper, cobalt, nickel, lead and zinc from waste water effectively that they would be used on industrial levels [62].

Bioaccumulation Factors

Calculating the bioaccumulation factor for different heavy metals in algal samples from different media (water and sediment) revealed that, in algal samples from sediments, cadmium had the highest factor (Figure 10) followed by copper and lead had the least bioaccumulation factor (Cd > Cu > Pb). On the other hand, the three elements in algae from seawater had different orders where the lead accumulation factor was the highest and copper the lowest (Pb> Cd > Cu). These findings reflect the algal high capacity to accumulate metals generally. Furthermore, as shown in figure (10), the highest accumulation values were those derived from seawater which means that algae have a higher capacity to absorb heavy metals from seawater than sediments.

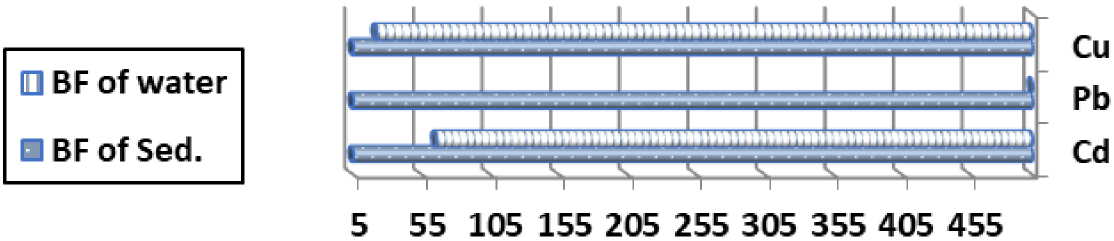


Figure 10: Bioaccumulation Factors of Studied Metals in Algae Samples from water and Sediment of El- Quseir Desalination plant.

Being the first level of the food chain of marine organisms, plankton tends to accumulate heavy metals in high concentrations, therefore, some heavy metals were found to specifically disperse within surface and bottom water layers in the following order Cu› Zn› Mn› Cd [63].

Conclusions

Although reverse osmosis desalination of seawater could meet the rising need for freshwater, the nearby maritime environment could be negatively impacted by the conventional technologies being used. Thus, the present study offers fundamental information regarding the impact of RO desalination plants on the surrounding marine ecosystem along the Red Sea coast.

The presence of heavy metals such as Cu, Cd, and Pb, which have a substantial impact on the surrounding marine environment and the Red Sea shoreline, was examined in the desalination effluents. Heavy metals can deposit and build up in benthic sediments, especially in dynamic coastal water with shifting physicochemical properties. Whether or if they exhibit signs of toxicity, elevated concentrations of heavy metals, such as Cu and Cd, that are above standard values are classified as environmental pollutants.

Recommendations

It is necessary to look at desalination plant drawbacks. Therefore, the study suggests management and mitigation measures to lessen the harm of desalination plants on marine ecosystems.

1. Plant design optimization is a viable strategy that should take into account numerous engineering factors.

2. Brine should be treated prior to discharge rather than being discharged directly.

3. To stop additional harm to the Red Sea ecosystem, laws and regulations for desalination operations should be put into action.

4. Since seaweeds have the ability to effectively absorb heavy metals from its environment, its suggested to be used as a bioindicator in potentially polluted environments. Seaweeds are also widely available, with high growth rate, and are widespread in the Red Sea. Therefore, they have a commercial value for mineral absorption. As a result, the study suggests assessing desalination activities as well as adopting seaweed as monitoring techniques for pollution levels.

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