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Compact Units Using a New Reverse Osmosis Membrane for Drinking Water Treatment

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ABSTRACT

Drinking water treatment is regarded as one of the most important challenges in this country in order to avoid scarcity and drinking water shortages, for which the raw water stream must be controlled and drinking water treatment plants must be qualified and efficient in order to provide good quality drinking water. Raw water sources will be assessed that compact units abstract their water. A comparison between the different treatment steps of different compact units was investigated. Improvement of water quality of drinking water compact units region will be followed up. The assessment of water quality produced by various plants was investigated. Experiments were focused on the nature of the raw water stream and the percentage of physical-chemical contaminants removed during the treatment process, according to this viewpoint.

Keywords: heavy metals, drinking water treatment, total dissolved solid, emerging pollutants, micropollutants, priority pollutants, persistent toxic substances, substances of very High concern, natural organic matter.

1. Introduction

Drinking water treatment (DWT) plants face great challenges in optimizing technologies to avoid human health problems and to ensure environmental sustainability, in direct correlation with population growth, water sources lower availability, deterioration due to land use and climate changes, hydrology and water quality changes. These water related problems are better understood and controlled through the improved detection and increased knowledge of the environmental, toxicological and biological effects of an ever increasing list of compounds currently known as: Emerging Pollutants (EPs) or Contaminants of Emerging Concern (CECs) or Micropollutants (MPs) or Priority Pollutants (PPs) or Persistent Toxic Substances (PTS) or Substances of Very High Concern (SVHC) (Li *et al.*, 2011; Sauve and Desrosiers, 2014).

Natural organic matter (NOM) is complex matrix of organic substances commonly found in surface and ground waters, as a result of different hydrological, biological and geological interaction schemes. In general, NOM can be generated within the water source through biological activities, mainly algal and microbial (autochthonous NOM), or introduced to the water body via drainage within watersheds including substances generated during the breakdown of terrestrial organisms (allochthonous NOM) (Sillanp *et al.*, 2018).

Through their presence, eco-toxicological and human health effects, bio-accumulative and degradation characteristics they may influence aquatic biota. Also the performance and costs of DWT technologies were investigated. Although a vast scientific literature is available on multiple aspects of concern regarding EPs' monitoring and analysis. EPs' research topics usually refer to: identification/ classification/ regulation of new compounds; environmental pathways and fate and human health risks (Stiborova *et al.*, 2017).

Development of advanced drinking water treatment processes (ADWT) for their removal from water (Deblonde and Cossu-Leguille, 2011); and development of tools for their environmental impact were assessed (Ternes *et al.*, 2015).

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The amount and composition of NOM in water resources could vary substantially from one location to another and also in the same water body after seasonal changes affecting natural phenomena such as floods, droughts, and rainfalls (Matilainen *et al.*, 2002; Sharp *et al.*, 2006a; Hirabayashi *et al.*, 2008; Kundzewicz *et al.*, 2014). Inherently, NOM is not toxic, but its presence in water, especially in drinking water sources is highly detrimental. Indeed, the presence of NOM tends to downgrade the quality of potential potable waters by altering their organoleptic properties (color, taste and odor). NOM also could act as a carrier of toxic organic and inorganic pollutants (Knauer *et al.*, 2017; Santschi *et al.*, 2017). In this context, the presence of NOM in natural waters was reported to increase bioavailability of hydrophobic anthropogenic compounds by increasing their solubility in water (Reid *et al.*, 2001).

In addition, various components of NOM, mainly humic acids (HA) and fulvic acids (FA), tend to form strong complexes with heavy metals, leading to the formation of organometallic complexes with increased transportation ability, bioavailability and toxicity (Matilainen *et al.*, 2011; Tang *et al.*, 2014). Equally important is the contribution of NOM to the formation of disinfection by-products (DBPs) (Golea *et al.*, 2017; Goslan *et al.*, 2017), which leads to the potential presence of carcinogenic compounds in conventionally treated waters (involving chlorination), including aliphatic halogenated trihalomethanes (THMs), haloacetic acids (HAAs), haloacetonitriles (HANs), haloketones and trichloronitromethane (Bond *et al.*, 2012; Serrano *et al.*, 2015), along with numerous aromatic halo-DBPs (Li *et al.*, 2016; Jiang *et al.*, 2017).

Recent studies have shown that these aromatic halo-DBPs generally present significantly higher developmental toxicity and growth inhibition than aliphatic halo-DBPs (Yang and Zhang, 2013; Liu and Zhang, 2014).

Thus, under such circumstances, the removal of NOM from drinking water supplies is becoming a challenging task requiring the application of reliable and highly efficient water treatment technologies able to deal with the high spatiotemporal variability of NOM and its increasing concentration in aquatic environments. These two main issues, along with the complexity of NOM (Mao *et al.*, 2017), are still compromising the efficiencies of various water treatment processes. In this regard, NOM is frequently identified as one of the main fouling agents in membrane-based technologies, causing pore narrowing and the formation of loose cake layer (Cheng *et al.*, 2017).

For processes based on the use of chemicals (e.g. coagulation and oxidation) and materials (e.g. adsorption), the increasing concentrations of pollutant requires using more chemicals or materials (Xu *et al.*, 2016a), which ultimately leads to the generation of more sludge or spent materials. For the adsorption process, heavy metals also tend to compete with the targeted micropollutants over the active sites thus lowering the removal efficiency of the adsorption technique for a wide array of organic and inorganic pollutants (Qi and Schideman, 2008; Zietzschmann *et al.*, 2014).

2. Material and Methods

All chemicals; nitric acid (HNO3, 70 %), hydrochloric acid (HCl, 36.5%) and hydrofluoric acid (HF, 48%) from Sigma Aldrich (Germany) were used. Subsamples of the sediments were digested according to the USEPA 3052 method USEPA 1996 using Microwave digestion system Multiwave pro Anton Paar (Graz, Austria) with 16 HF (100) rotor and HF (100) vessels, controlled by P/T sensor in a reference vessel.

1.5L of water samples were collected from different sites of seven cities (Quesina, Minuf, Al Khatatba, Kafr Dawoud, Ashmoun, El-Bagour and El Sadat) Menoufia governorate, Egypt as shown in Fig. 1 and its located dimensions is found in Table 1. During four seasons each sample was divided into 2 sub-samples and three replicates determination were done for each sub-sample providing 6 readings for each site (sample) with relative SD < 10%.

2.1. Water chemical analyses

The quality of water samples was determined by measuring pH, electrical conductivity (EC), turbidity, and TDS. Chemical analysis of trace elements (Aluminum, Iron, and Manganese) using ICP-MS were tested and the results were expressed in mg/L. All the physical and chemical analyses were done in duplicates and determined following the procedures of Standard Methods done for the Examination of Water and Wastewater (APHA, 2005).

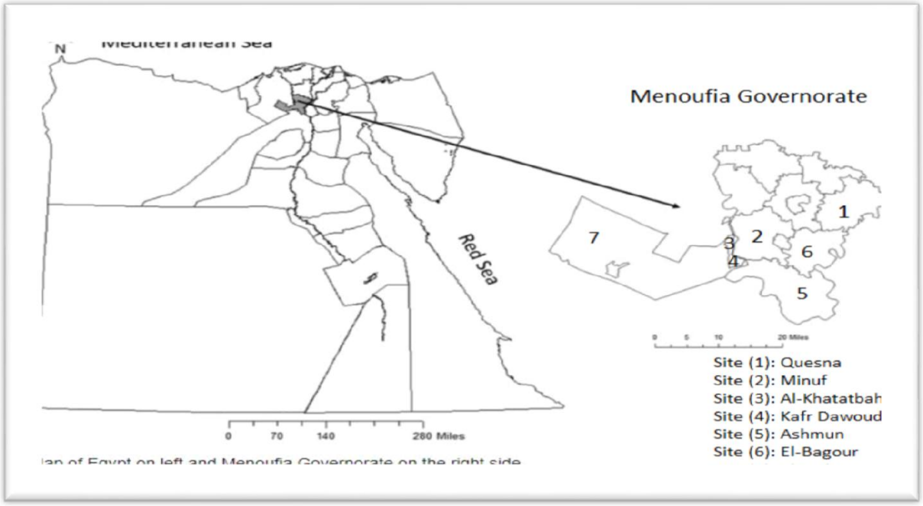

Fig. 1: Location map for the area of investigation and sampling sites

Table 2: No of units in each government

Site	Site location	Latitude	Longitude
1	Quesina	30.5625° N	31.1599° E
2	Minuf	30.4641° N	30.9358° E
3	Al Khatatbah	30.3604° N	30.8192° E
4	Kafr Dawoud	30.4649° N	30.8255° E
5	Ashmun	30.2945° N	30.9782° E
6	El-Bagour	30.4301° N	31.0364° E
7	El Sadat	30.3594° N	30.5327° E

2.2. Data analysis

The data were analyzed using statistical software (SPSS Version 17, SPSS INC, Chicago, IL, USA). Initially, descriptive statistics were computed. One-way ANOVA was used followed by Duncan's post hoc test (α 0.05). In all tests, p-values smaller than 5% were considered statistically.

Results

Quesna
TDS in plant water

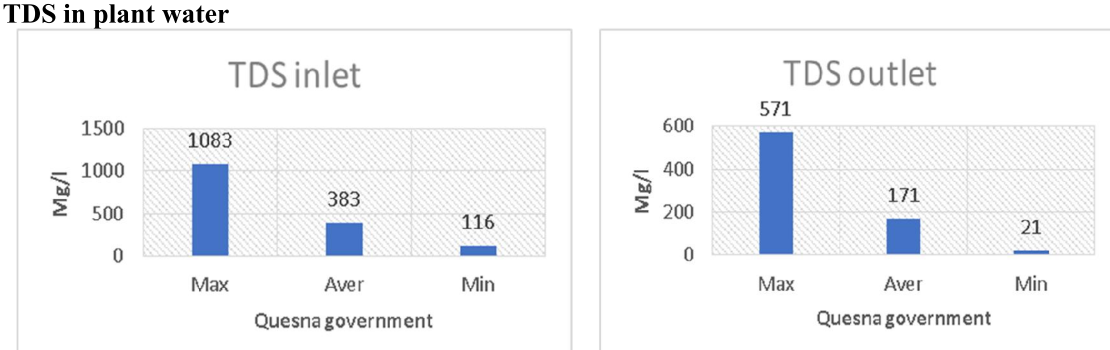

Fig. 2: Shows the TDS inlet and outlet in Quesna plant

Iron concentration in plant water

It was found that the concentration of iron in the inlet water exceeds the required level by 26.8%, and the distributed drinking water was higher than the decision of the Minister of Health by 12.7% as shown in Fig. 3.

The inefficiency of the design and the operating rate of the stations and the failure to wash the filters was the main reason for the increase in the iron element in the outlet water

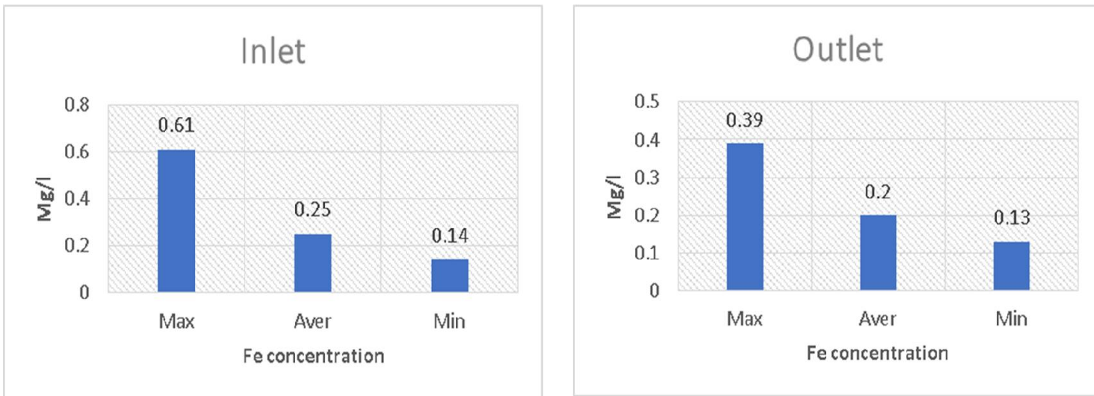

Fig. 3: Shows the concentration of Fe before and after treatment.

Manganese concentration in plant water

It was found that the concentration of manganese in the inlet water exceeds the required level by 28.2%, and the distributed drinking water was higher than the decision of the Minister of Health by 14.6% as shown in Fig. 4.

The inefficiency of the design and the operating rate of the stations and the failure to wash the filters was the main reason for the increase in the manganese element in the outlet water

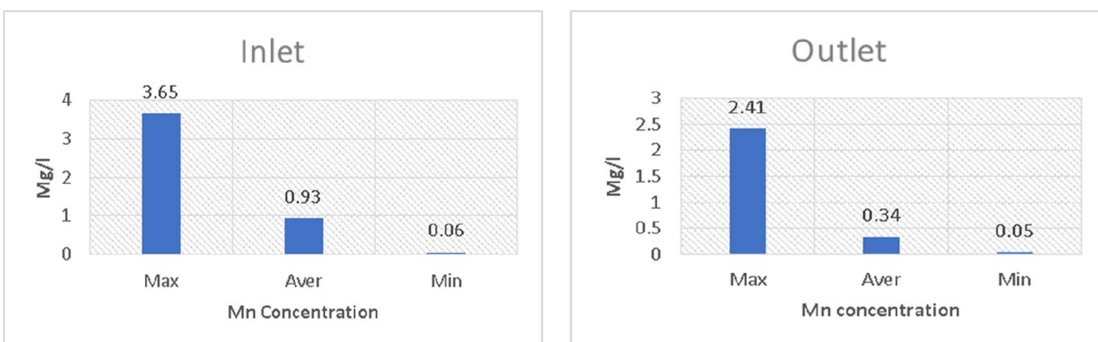

Fig. 4: Shows the concentration of Mn before and after treatment.

Aluminum concentration in plant water

It was found that the concentration of aluminum in the inlet water exceeds the required level by 19.7%, and the distributed drinking water was higher than the decision of the Minister of Health by 15.5% as shown in Fig. 5.

The poor operation of the stations and the lack of maintenance of the filters was the main reason for the increase in the aluminum element in the outlet water.

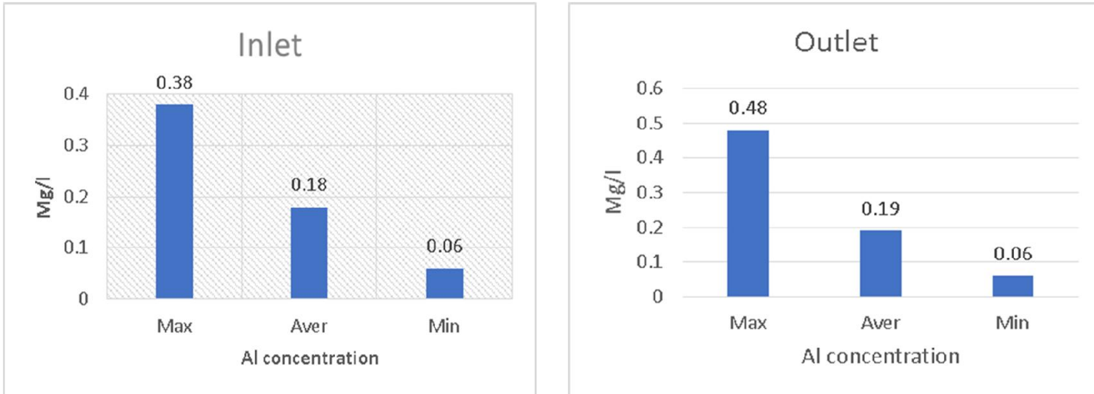

Fig. 5: Shows the concentration of Al before and after treatment.

Minuf
TDS in plant water

Fig. 6: Shows the TDS inlet and outlet in Minuf plant

Iron concentration in plant water

It was found that the concentration of iron in the inlet water exceeds the required level by 29.7%, and the distributed drinking water was higher than the decision of the Minister of Health by 35.1% as shown in Fig. 7.

The inefficiency of the design and the operating rate of the stations and the failure to wash the filters was the main reason for the increase in the iron element in the outlet water

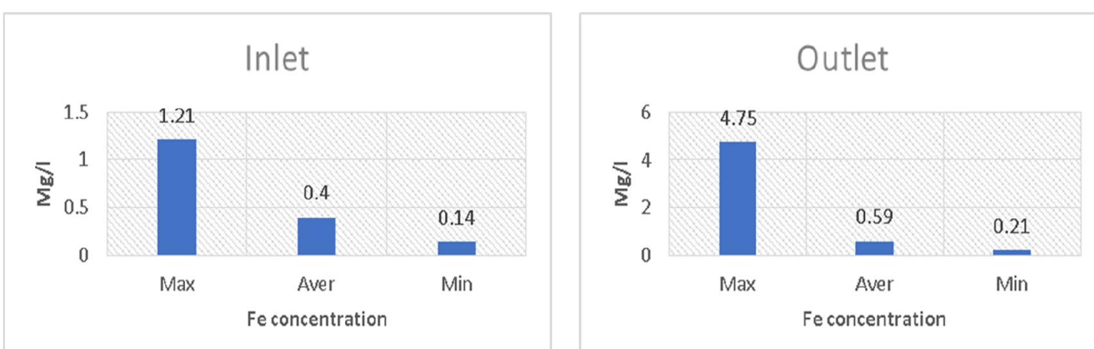

Fig. 7: Shows the concentration of Fe before and after treatment.

Manganese concentration in plant water

It was found that the concentration of manganese in the inlet water exceeds the required level by 16.2%, and the distributed drinking water was higher than the decision of the Minister of Health by 10.8% as shown in Fig. 8.

The inefficiency of the design and the operating rate of the stations and the failure to wash the filters was the main reason for the increase in the manganese element in the outlet water.

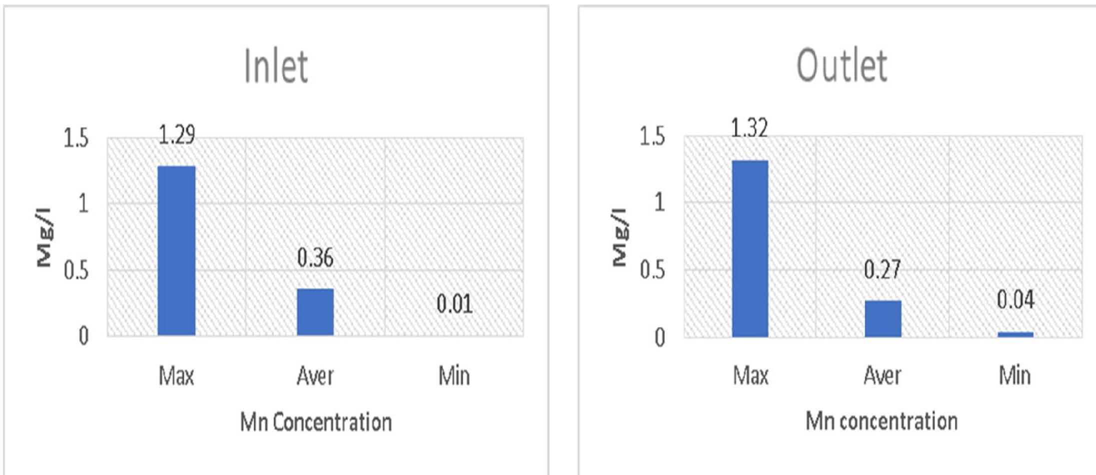

Fig. 8: Shows the concentration of Mn before and after treatment.

Aluminum concentration in plant water

It was found that the concentration of aluminum in the inlet water exceeds the required level by 43.2%, and the distributed drinking water was higher than the decision of the Minister of Health by 45.9% as shown in Fig. 9.

The poor operation of the stations and the lack of maintenance of the filters was the main reason for the increase in the aluminum element in the outlet water

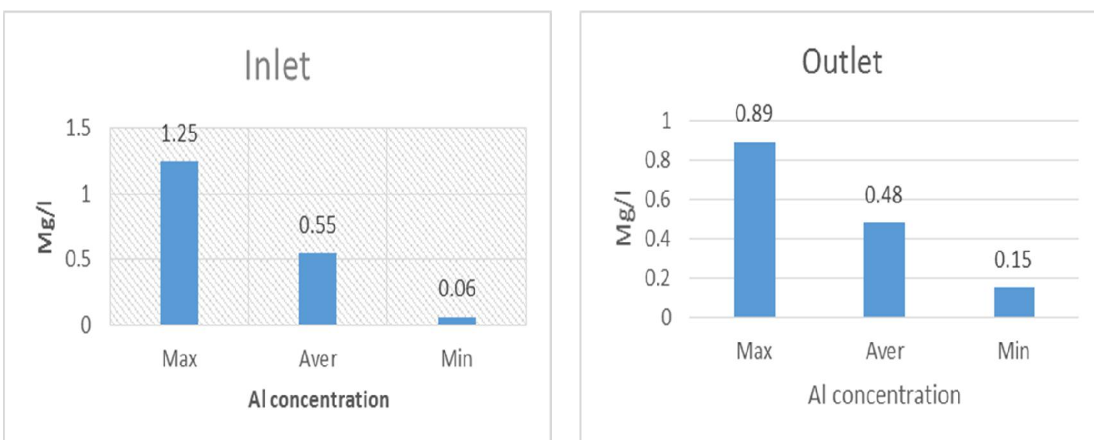

Fig. 9: Shows the concentration of Al before and after treatment.

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Al-Khatatba and Karf Dawoud Cities:
TDS in plant water:

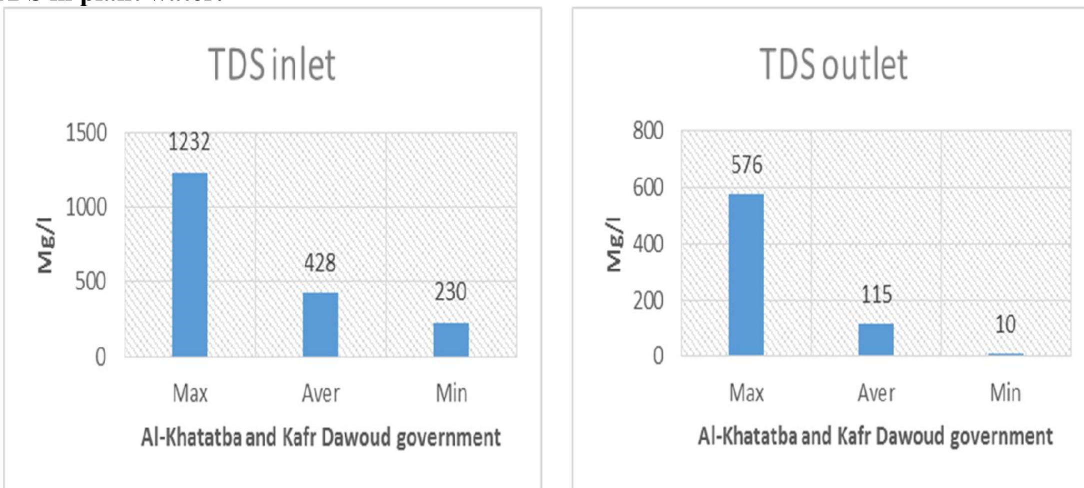

Fig. 10: Shows the TDS inlet and outlet in Al-Khatatba and Kafr Dawoud plants

Iron concentration in plant water

It was found that the concentration of iron in the inlet water exceeds the required level by 38.7%, and the distributed drinking water was higher than the decision of the Minister of Health by 25.7% as shown in Fig. 11.

The inefficiency of the design and the operating rate of the stations and the failure to wash the filters was the main reason for the increase in the iron element in the outlet water

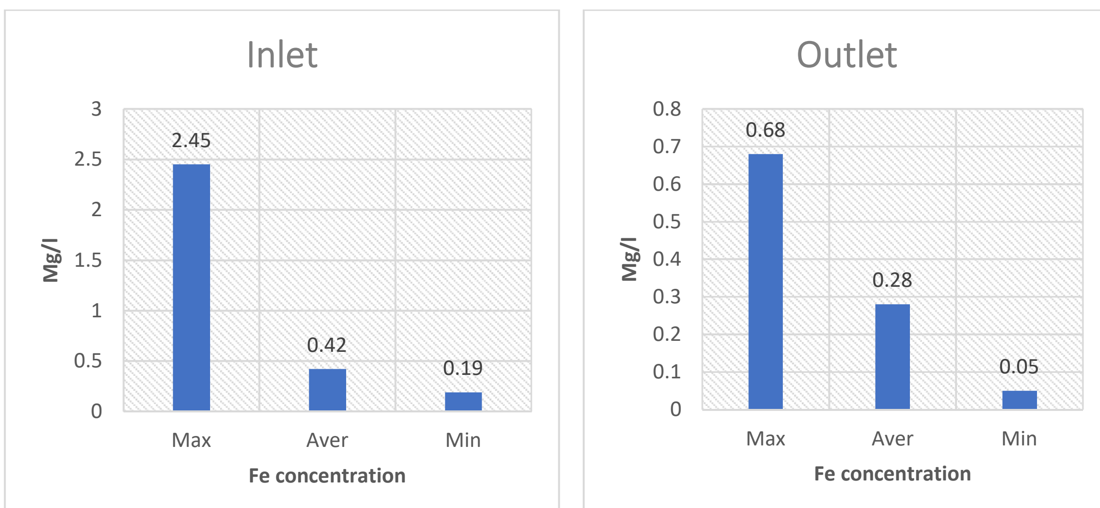

Fig. 11: Shows the concentration of Fe before and after treatment.

Manganese concentration in plant water

It was found that the concentration of manganese in the inlet water exceeds the required level by 16.2%, and the distributed drinking water was higher than the decision of the Minister of Health by 10.8% as shown in Fig. 12.

The inefficiency of the design and the operating rate of the stations and the failure to wash the filters was the main reason for the increase in the manganese element in the outlet water.

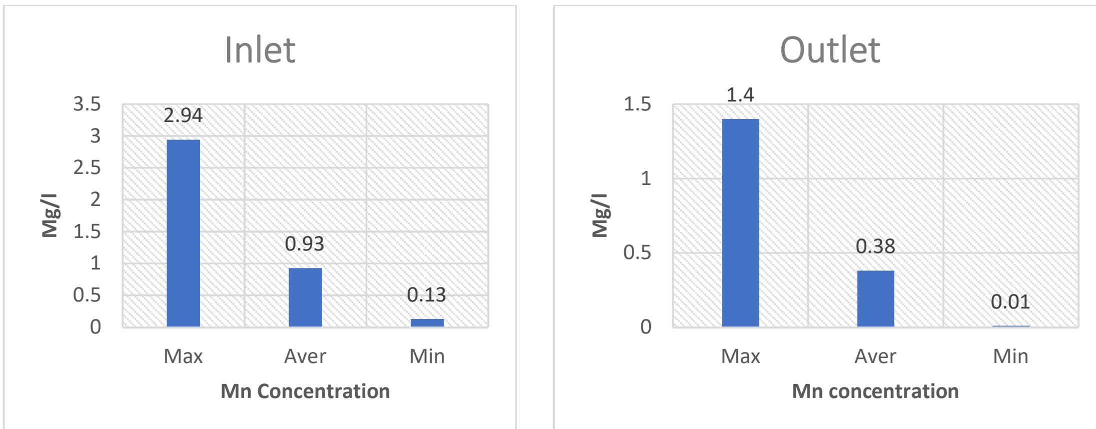

Fig. 12: Shows the concentration of Mn before and after treatment.

Aluminum concentration in plant water

It was found that the concentration of aluminum in the inlet water exceeds the required level by 70.9%, and the distributed drinking water was higher than the decision of the Minister of Health by 82.8% as shown in Fig. 13.

The poor operation of the stations and the lack of maintenance of the filters was the main reason for the increase in the aluminum element in the outlet water

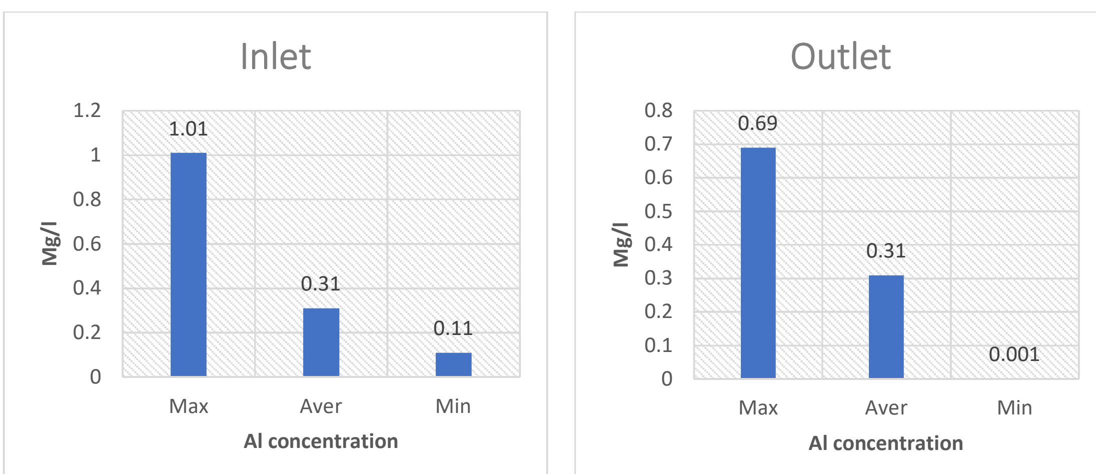

Fig. 13: Shows the concentration of Al before and after treatment.

Ashmoun

TDS in plant water:

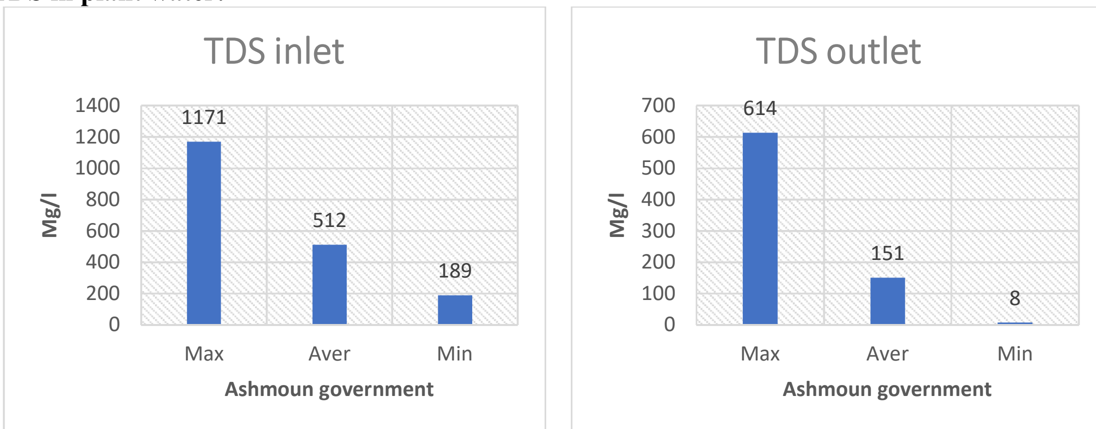

Fig. 14: Shows the TDS inlet and outlet in Ashmoun plants

Iron concentration in plant water

It was found that the concentration of iron in the inlet water exceeds the required level by 40.2%, and the distributed drinking water was higher than the decision of the Minister of Health by 22.6% as shown in Fig. 15.

The inefficiency of the design and the operating rate of the stations and the failure to wash the filters was the main reason for the increase in the iron element in the outlet water

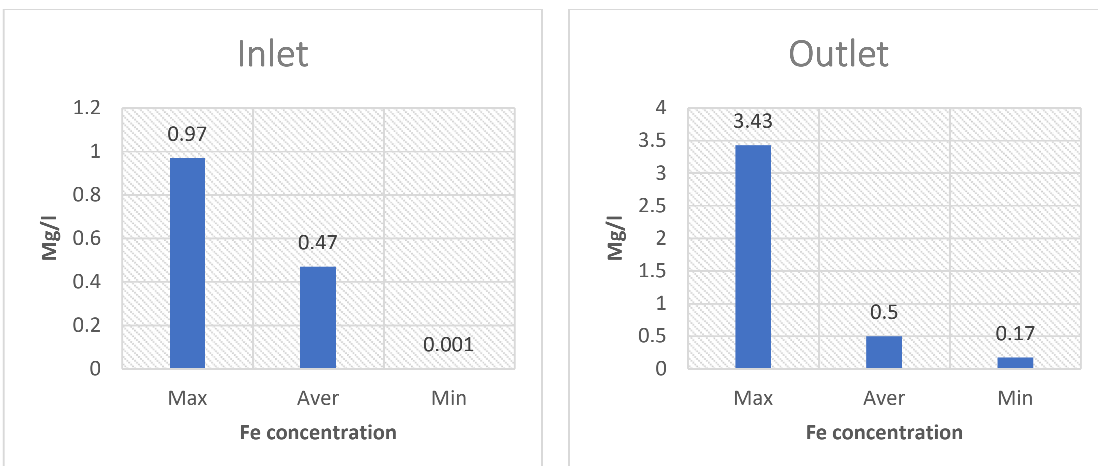

Fig. 15: Shows the concentration of Fe before and after treatment.

Manganese concentration in plant water

It was found that the concentration of manganese in the inlet water exceeds the required level by 20.5%, and the distributed drinking water was higher than the decision of the Minister of Health by 15.8% as shown in Fig. 16.

The inefficiency of the design and the operating rate of the stations and the failure to wash the filters was the main reason for the increase in the manganese element in the outlet water

Middle East J. Appl. Sci., 12(4): 515-531, 2022
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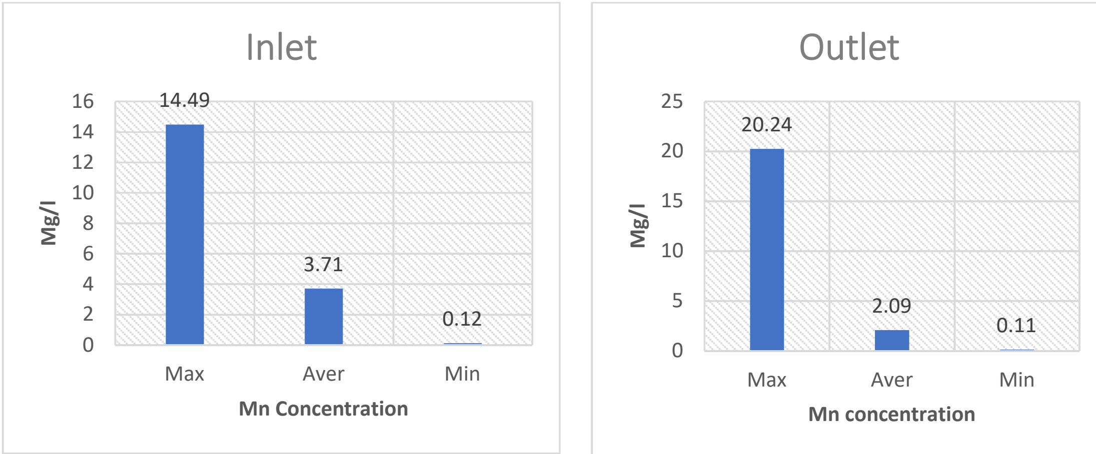

Fig. 16: Shows the concentration of Mn before and after treatment.

Aluminum concentration in plant water

It was found that the concentration of aluminum in the inlet water exceeds the required level by 68.9%, and the distributed drinking water was higher than the decision of the Minister of Health by 80.2% as shown in Fig. 17.

The poor operation of the stations and the lack of maintenance of the filters was the main reason for the increase in the aluminum element in the outlet water

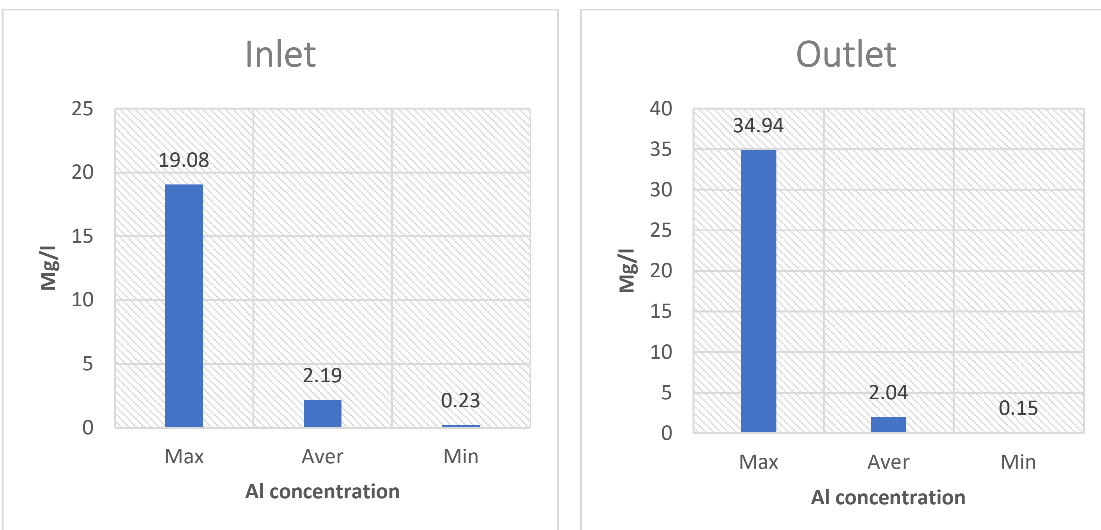

Fig. 17: Shows the concentration of Al before and after treatment.

Middle East J. Appl. Sci., 12(4): 515-531, 2022
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El-Bagour
TDS in plant water:

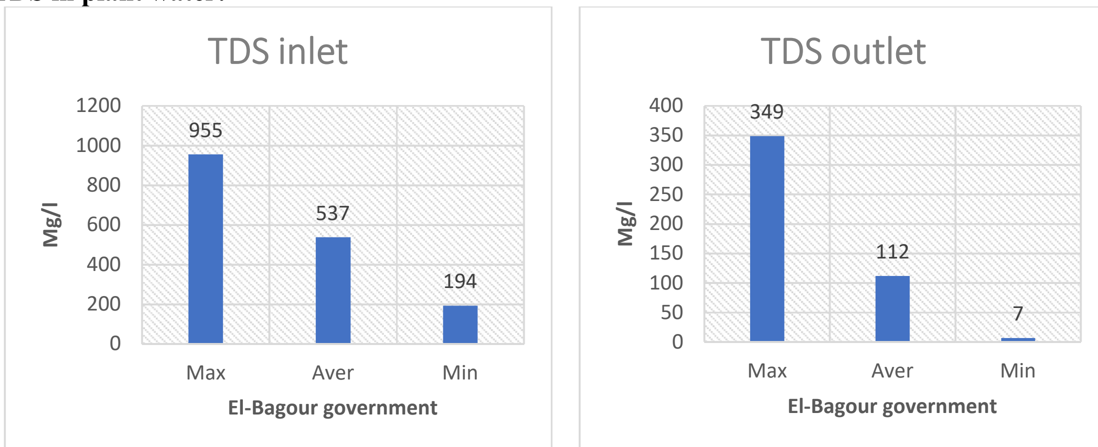

Fig. 18: Shows the TDS inlet and outlet in El-Bagour plants

Iron concentration in plant water

It was found that the concentration of iron in the inlet water exceeds the required level by 44.2%, and the distributed drinking water was higher than the decision of the Minister of Health by 25.6% as shown in Fig. 19.

The inefficiency of the design and the operating rate of the stations and the failure to wash the filters was the main reason for the increase in the iron element in the outlet water.

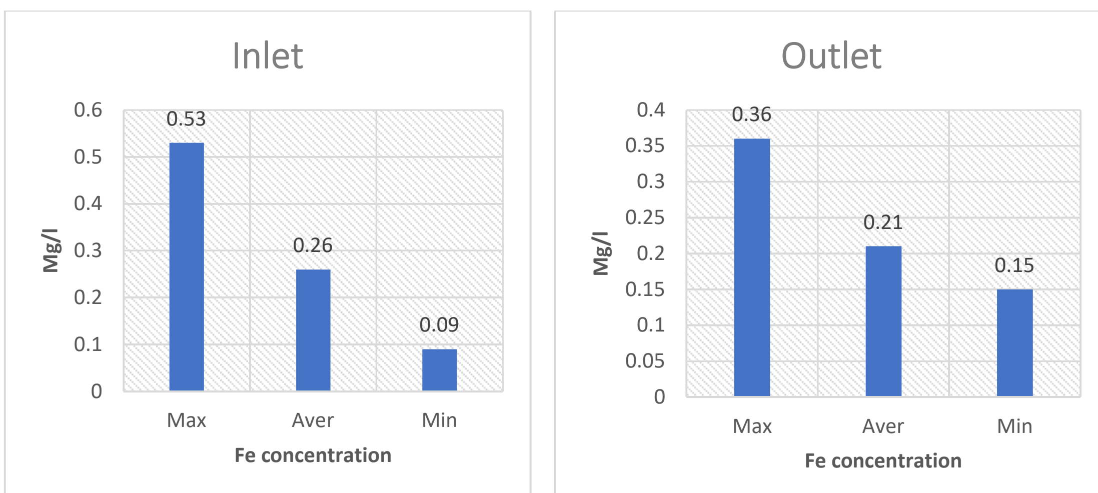

Fig. 19: Shows the concentration of Fe before and after treatment.

Manganese concentration in plant water

It was found that the concentration of manganese in the inlet water exceeds the required level by 30.5%, and the distributed drinking water was higher than the decision of the Minister of Health by 25.8% as shown in Fig. 20.

The inefficiency of the design and the operating rate of the stations and the failure to wash the filters was the main reason for the increase in the manganese element in the outlet water

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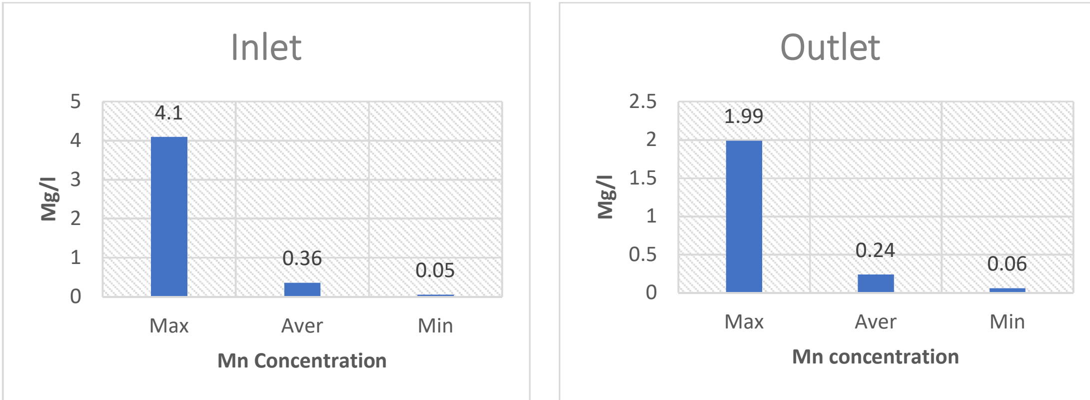

Fig. 20: Shows the concentration of Mn before and after treatment.

Aluminum concentration in plant water

It was found that the concentration of aluminum in the inlet water exceeds the required level by 68.9%, and the distributed drinking water was higher than the decision of the Minister of Health by 80.2% as shown in Fig. 21.

The poor operation of the stations and the lack of maintenance of the filters was the main reason for the increase in the aluminum element in the outlet water.

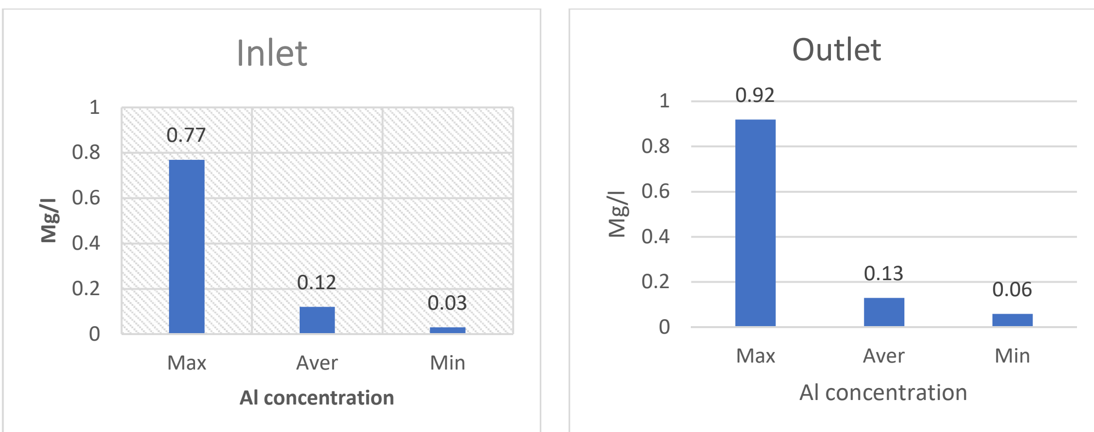

Fig. 21: Shows the concentration of Al before and after treatment.

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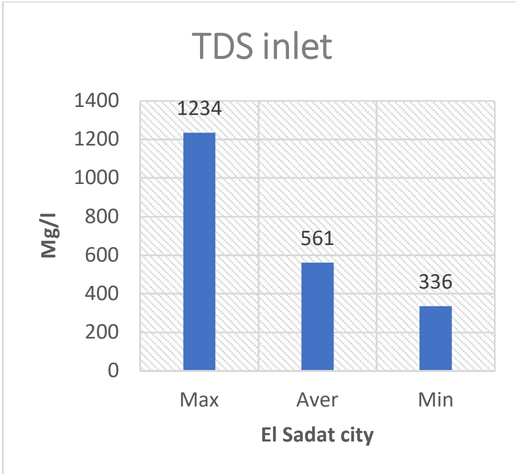
El-Sadat city:
TDS in plant water:



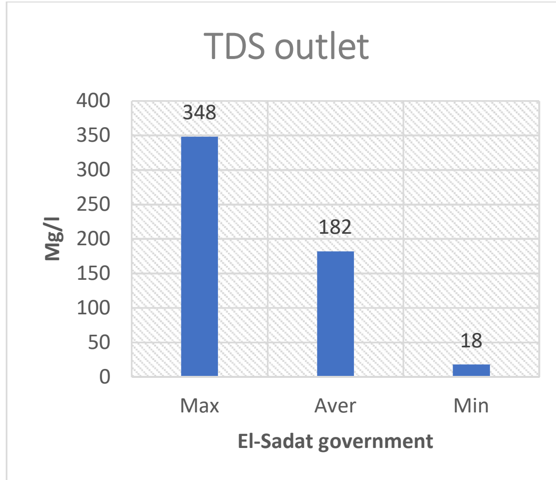
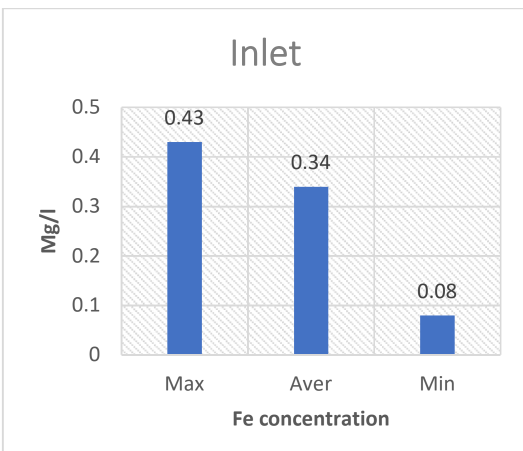


Fig. 22: Shows the TDS inlet and outlet in El-Sadat plants

Iron concentration in plant water

It was found that the concentration of iron in the inlet water exceeds the required level by 44.2%, and the distributed drinking water was higher than the decision of the Minister of Health by 25.6% as shown in Fig. 23.

The inefficiency of the design and the operating rate of the stations and the failure to wash the filters was the main reason for the increase in the iron element in the outlet water.



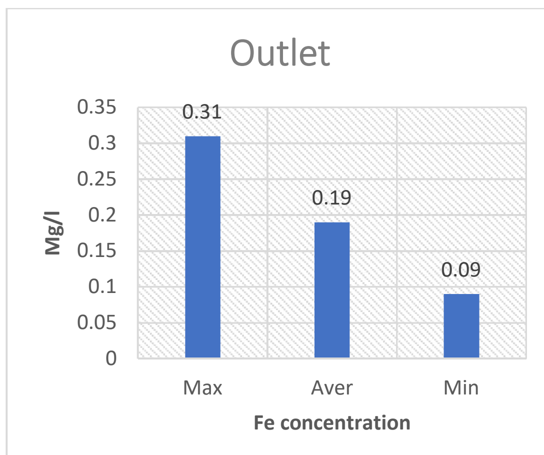


Fig. 23: Shows the concentration of Fe before and after treatment.

Manganese concentration in plant water

It was found that the concentration of manganese in the inlet water exceeds the required level by 32.5%, and the distributed drinking water was higher than the decision of the Minister of Health by 28.8% as shown in Fig. 24.

The inefficiency of the design and the operating rate of the stations and the failure to wash the filters was the main reason for the increase in the manganese element in the outlet water.

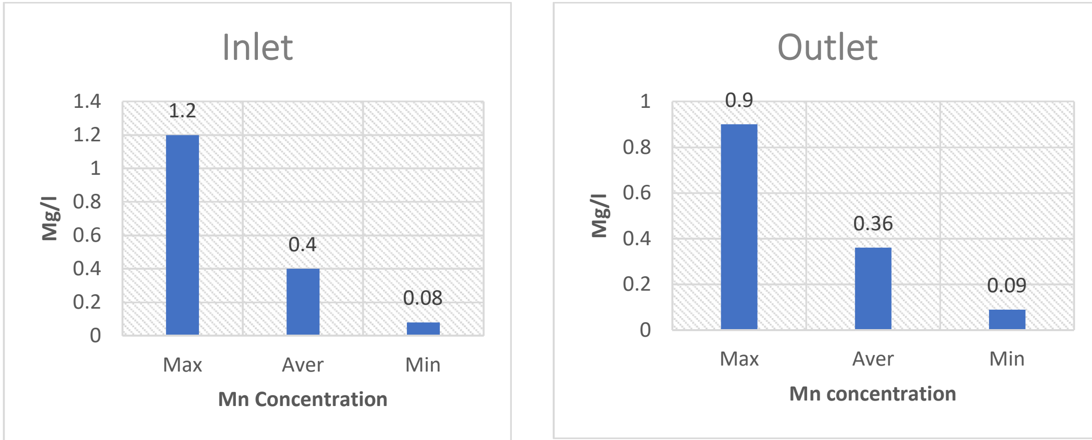


Fig. 24: Shows the concentration of Mn before and after treatment.

Aluminum concentration in plant water

It was found that the concentration of aluminum in the inlet water exceeds the required level by 66.9%, and the distributed drinking water was higher than the decision of the Minister of Health by 75.2% as shown in Fig. 25.

The poor operation of the stations and the lack of maintenance of the filters was the main reason for the increase in the aluminum element in the outlet water

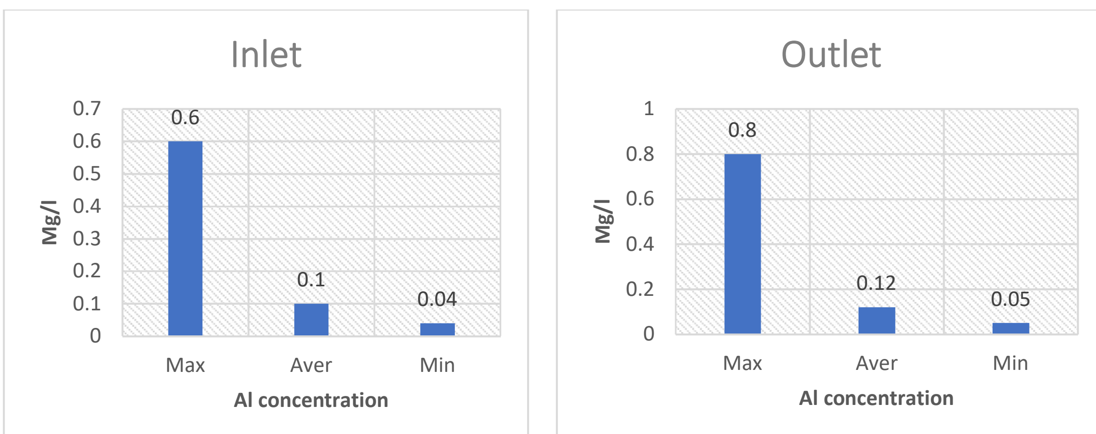


Fig. 25: Shows the concentration of Al before and after treatment.

Discussion

Compact units depend on reverse osmosis (RO) technology for iron and manganese removing are used for groundwater improvement. The efficiency of pretreatment protocols including chlorination, activated carbon, and Birm filters (greensand) before RO membrane was evaluated for drinking purposes .The program was performed for 222 plants (Two hundred twenty-two) during seven government sites in Menoufia Egypt (Table 2) with continuous monitoring of produced and wastewater. The final treatment effects over removal % of metals were conducted. We found that there are 81 units (Eighty-one) of samples were above the WHO allowable limits and produce drinking water with TDS lower that 100 mg/l by a percentage 36.48 % from total units and we recommended to rise TDS to be between (100 to 300) mg/l as per WHO recommendations also there are 127 units (One hundred twenty-seven) good efficiency of TDS result between (100 to 300) mg/l by a percentage 57.2% from total units and there are 13 units (Thirteen) poor efficiency of TDS result up 300 mg/l by a percentage 5.8% from total units and we recommended to maintenance tools of these units (Table 2; Fig. 26).

Table 2: No of units in each government:

No.	Site location	No of plants
1	Quesna	61
2	Minuf	19
3	Al Khatatbah	24
4	Kafr Dawoud	11
5	Ashmun	48
4	El-Bagour	53
7	El Sadat	6
Total plants		222

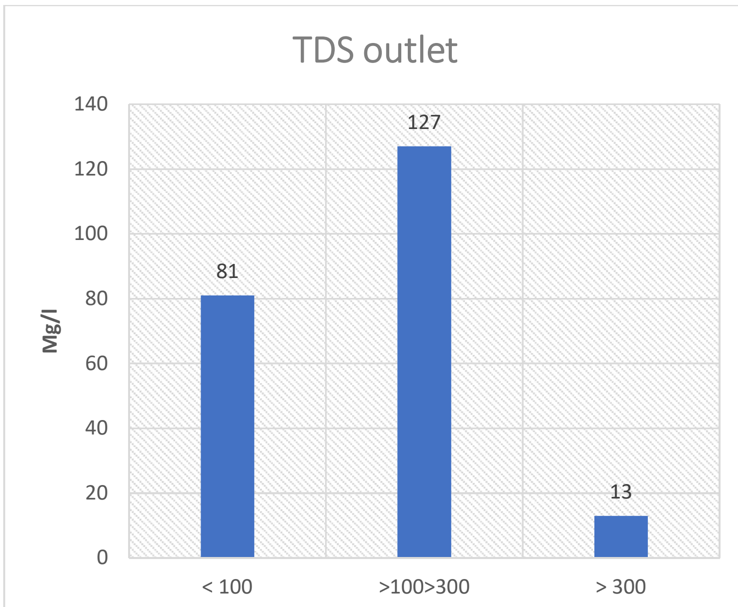


Fig. 26: Shows specification of the water leaving the stations after treatment, quantitatively and proportionally

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