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Using Ozone instead of Chlorine for Drinking Water Treatment under Egyptian Conditions

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Abstract

The aim of this study was to improve disinfection techniques by using ozone in water treatment instead of chlorine. Current study for Nile water treatment revealed that the optimum dose was 10 mg/L and 4.6 mg/L for ozone and chlorine, respectively. The concentration of ozone and chlorine were under permissible limits according to the Egyptian standards for drinking water. The current work was shown to monitor TBC, TCs, FCs, and non-FCs by removal percentage reaching to 99.87, 99.97, 99.96, and 99.02% for each, respectively, for chlorine. While with ozone the removal percentage reaching to 99.9, 99.95, 99.93, and 98.92%, respectively.
Microbiological examinations include: Total plate count, total coliform, total algal count, and microscopic examination. The ozone Algal counting analysis revealed that, total algae, green algae, blue- green algae, and diatoms with removal efficiencies of 91.07, 90.24, 100, and 88.24%, respectively, chlorine counting analysis show removal efficiencies of 94.42, 95.08, 100, and 91.62%, respectively. It's concluded that using ozone is one of the future ways to meet the environmental water standards and supply the water requirements of the growing population.

Keywords: Drinking water, Disinfectant, Pre-chlorination process, Pre-ozonation process.

Introduction

Water is regarded as the source of all life. Water quality, its use, and its maintenance have long been important to human. As a result, it ought to be clean and devoid of impurities. Disinfection is frequently used as a tertiary chemical treatment to eliminate unwanted bacteria from water and provide the population with safe drinking water. For the treatment of water, many different types of disinfectants have been employed. Chlorine, sodium hypochlorite, chlorine dioxide, chloramines, hydrogen peroxide, ozone, UV radiation, permanganate, or a mixture of these are some examples **(Jiang, 2007).**

Chlorine is an effective oxidizing water disinfectant. Even at low concentrations, it is affordable, effective, and leaves a residue (no post-treatment is required). The main advantage of this method is that the chlorine stays in the water longer as residual chlorine and continues to act as a disinfectant during storage and distribution **(Kataki *et al.*, 2021).** Filtration can be used in conjunction with active coagulation, flocculation, and clarification as a barrier to other pathogens. In many cases, coagulant-assisted clarification and filtration may be the only existing treatment barrier for protozoan pathogens **(USEPA, 2006).** Only bacteria and most diseases are resistant to chlorine disinfection. Chlorine combines with ammonia and organic matter in water treatment plants, where it is introduced to create chloramines and chloro-organic compounds **(How *et al.*, 2017).**

Chlorine is used disinfection method around the world due to its inexpensive cost and powerful disinfecting properties. However, the disadvantages of Cl, such as its unpleasant taste and odour, inability to kill protozoa eggs and cysts, generation of trihalomethanes, and more than 400 additional types of Cl by-products, have led to the development of alternative disinfection methods **(Gelete *et al.*, 2020).** There is no set rule on how much is necessary, which is another problem with Cl. However, the required amount is determined by the water quality and the need for disinfection **(Shamrukh and Hassan, 2005; Jiang, 2007; Mancayo-Lasso *et al.*, 2012; El-Dars *et al.*, 2015; Ljiljana *et al.*, 2019; Kokot *et al.*, 2020; Fathy *et al.*, 2020; Kali *et al.*, 2021; Helte *et al.*, 2022).**

In drinking water treatment, ozone units are installed as points of use for treatment systems. Ozone is highly oxidative for micro-pollutants and more efficient as well as safe alternative to chlorine for disinfection and oxidation of organic matter and for colour and odour removal. Therefore, its use in water treatment has been increased (**Mezzanotte *et al.*, 2007; Gad, 2010; Vereshchuk *et al.*, 2011; Xie, 2016; GAD *et al.*, 2015 and Hubner *et al.*, 2015; Liu *et al.*, 2021; Álvarez-Arroyo *et al.*, 2022).**

The effects of pre-chlorination and pre-ozonation are dependent on many factors including properties of the organic matter, pH, and type of coagulant. It was found that when alum was used as a coagulant, the previous ozonation process hindered turbidity removal **(Schneider and Tobiason, 2000).** Ozone has the disadvantage of decomposes quickly in water compared to other approaches, which is a downside. Thus, it is conceivable that recontamination in the distribution system can occur when this strategy is used. Ozone is very expensive, especially in terms of capital expenditures and operating expenses. Ozone can also form by-products including ketones, aldehydes, and bromate through reactions with bromide and organic materials **(Achour and Chabbi, 2014).** To increase the quality of the water treated in that study, it is necessary to determine the optimal dose of chlorine and ozone to be used in this process.

Materials and Methods

Sampling

Raw water samples collected from the Nile River (Damietta Branch) near conventional Water Treatment Plant (WTPs) in Daqahliya governorate - Shribeen branch.

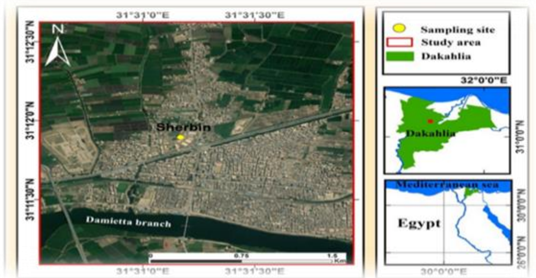

Figure (1): A map of Sherbin City in Daqahliya governorate illustrating the investigated Water Treatment Plant (WTP).

Chlorine and Ozone optimum dose

The beakers were filled with 1L of Nile water. The concentrations of chlorine were 4 to 5.8 mg/l and ozone were 4 to 12 mg/l were added individually to each beaker. Concentrations of chlorine and ozone solutions were 1 %. 4 ml of chlorine or ozone solution added to 1 L of Nile water to make concentration 4 mg/l. The other chlorine doses added in the same manner. 2.1 mg/l $Al_2(SO_4)_3$ added to each beaker. Coagulation/ Precipitation (C/P) process studied using Flocculator Jar Testing Apparatus. The contents in each beaker were mixed well at speed 122 rpm for 2 min, then mixed at speed 22 for 20 min. **(Mark, 1986; Mackenzie, and Cornell, 1991).** Thereafter, jars were kept standstill for 10 min to settle down on removal clarified water. The turbidity removal percent was calculated **Eq. 1.** The chlorine and ozone residues were measured by the colorimetric method DPD indicator (N, N, diethyl-pphenylenediamine) was used as chemical reagent for chlorine measurements. Free available chlorine (Cl_2, HOCl, OCl) oxidizes DPD to produce a red color. This color is then measured using DR2000, according to **(APHA, 1998).**

Turbidity Removal%=low turbidity/high turbidity (raw water)-1 (1)

Figure (2): Flocculator Jar Testing Apparatus.

Microbiological analyses

Microbiological analyses were performed by using different techniques indicating different microbial indicators. The counts of total coliforms (TC), fecal coliforms (FC), and fecal *Streptococci* (Non-FCs) were made using the membrane filtration technique. Total coliform colonies were counted after 24 hours of incubation of membranes on M-Endo (total Coliform), M-Entere (fecal *Streptococci*) and M.F.C agar (fecal Coliform). Incubate the plates for 20 to 22 hours at 35 °C for M-Endo, M-Entere, and M.F.C agar for 44.5° C. Total bacterial count (TBC) analysis was made by Plate Count Agar (also called tryptone glucose yeast agar), incubate at 35°C for 48 ± 3 h. **(APHA, 2017).**

Culture technique of algae

Algal assay including algal total count and identification their all species present in water after and before treatment process by adding Lugol's Iodine Solution that stain and inhibits algal growth then leave it for 48 hours, concentrate 1000 ml to 50 ml and 1ml only examine. Diatoms, green algae, blue green algae and total algae were counted on a compound microscope in a Sedgewick Rafter Counting chamber after preservation in Lugol's iodine. Cell counts were carried out to a minimum precision of 20% **(APAH, 2005).**

$$\text{Algal count/ml} = (\text{algal total count} \times \text{square total count} \times \text{examine sample size}) / \text{Numbered count square} \times \text{original sample size}$$

Protozoa and all kinds of pathogen worms' examination

The raw water samples were filtered through nitrocellulose acetate or polycarbonate membranes with 150 µm thick (0.45 µm in diameter). The water samples taken after the physicochemical treatment and after the disinfection process were also filtered through nitrocellulose acetate membranes with are 150 µm thick (0.45 µm in diameter). The membranes used in the filtration processes were washed twice with distilled water. To concentrate the samples, the volumes recovered from the washes were transferred to sterile polystyrene tubes and centrifuged for 20 min. Afterwards, the supernatant was discarded, leaving 1 ml of it on the pellet, which was transferred to a new sterile tube. To study microscopic forms, use a compound or inverted microscope **(APAH, 2017).**

Results and Discussions

Optimum dose of chlorine

A set treatment of raw water was done using jar test device to calculate the optimum dosage of chlorine for turbidity removal for WTPs. The result showed that turbidity removal percentage increased from 37 to 76% for turbidity at optimum alum dose up to 2.1 mg/l at normal pH 7.24. Measurement of residual chlorine was taken 30 minutes after dosing. According to the jar test the best dose of chlorine = 4.6 mg/l in which the residual chlorine is 0.7 mg/l in the distributing system which make water safety until receiving by consumer.

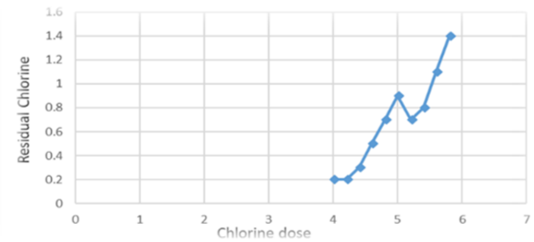

Figure (3): Effect of chlorine dose on residual chlorine of raw water.

Results of the present study similar with Gad, (2010) who studied the optimum chlorine dose 4.5 mg/l, lower than that obtained by Mezzanotte et al., (2007) by 5 mg Cl2/l and El-Dars et al. (2015) by 5.5 mg Cl2/l, because chlorine oxidizing the germ cells, altering cell permeability, altering cell protoplasm, inhibiting enzyme activity, and damaging the cell DNA and RNA. Chlorine appears to react strongly with lipids in the cell membrane, and membranes having high lipid concentrations appear to be more susceptible to destruction. For this reason, viruses, cysts, and ova are more resistant to disinfectants than are bacteria **(EPA, 1999).**

Different disinfectants work effectively at different pH ranges. For example, chlorine works well at lower pH 6–7 when compared to chloramines pH 7–8.5 (Mancayo-Lasso et al., 2012) like that study. Technically, a minimum of 0.5 mg/l residual chlorine must be maintained to ensure that water is protected from re-contamination during storage and that residual chlorine levels between 0.2 and 0.5 mg/l at the consumer outlet water due to the periphery of the supply network (WHO, 2011).

Pre- treatment chlorination is useful in controlling algae growth, improving taste and odors. Post-chlorination is the addition of chlorine to the water after treatment. Drinking water must be sufficiently chlorinated to maintain a minimum concentration of 2 mg/l throughout the distribution system. However, chlorine may combine with organic materials to form trihalomethanes which are carcinogenic. For this reason, other disinfectants such as iodine, bromine, lime and ozone are attracting great interest (Gad, 2010).

Optimum dose of Ozone

A raw water batch treatment was done using jar test device to calculate the optimal dose of ozone for turbidity removal for WTPs. The result showed that turbidity removal percentage increased from 41 to 77% for turbidity at optimum alum dose up to 2.1 mg/l at normal pH 7.12. Measurement of residual ozone was taken 30 minutes after dosing. According to the jar test the best dose of ozone = 10 mg/l, in which the residual free ozone is 0.7 mg/l in the distributing system which makes water safe from any micro-pollutants, organic matter, color, odor and algae removal.

In **Figure 4** showed results higher than that obtained by **Gad, (2010)** by 3 mg/l, **Vereshchuk *et al.*, (2011)** by 0.8 mg/l and by **Mezzanotte *et al.*, (2007)** that reported the best performances obtained at 3.6 mg/l at 12.8 min contact time, 4.6 mg/l at 12.8 min contact time), and 5.3 mg/l at 6.4 min contact time for fecal coliforms, total coliforms, and *E.* coli, respectively, the doses of ozone present differ due to water contamination. It can also be used for natural organic matter (NOM) decomposition and microorganism inactivation. Pre-ozonation has a remarkable effect on the subsequent treatment processes, especially coagulation **(Liu *et al.*, 2021).** Ozone can aggregate fine particles and break down large at the same time, making them more mineralized and easier to remove.

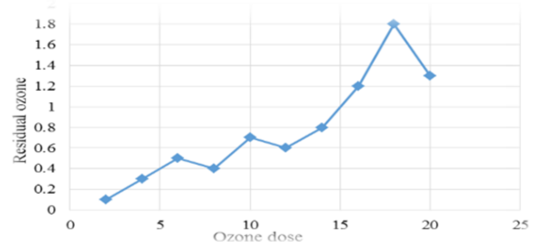

Figure (4): Effect of dose on residual ozone of raw water.

Ozone is now used in WTPs to remove source water contaminants and improve water quality. With increasing concern about chlorination by-products such as trihalomethanes and haloacetic acids, ozone is becoming widely adopted as an efficient pre-oxidant before coagulation instead of chlorine **(Camel and Bermond, 1998; EPA, 2000).**

Microbiological analyses

Bacterial analysis of treated water with chlorine

The results in **Table 3** and **Figure 5** showed the treatment of raw water by using alum and chlorine that there is a positive relationship between the bacterial count of the raw water that feed surface plants and the chemicals used for treatment. When monitoring the microbial pollution of all samples of raw water and treated water by using alum by determination of total bacterial counts (TBC) (raw water: $34.75\times10^3\pm500$; treated chlorine: 44.25 ± 4.35 CFU/ml) by removal percentage 99.87%, as well as, bacterial indicators (total Coliform (TCs) $46.5\times10^2\pm100$; < 1 TC/100 ml, fecal Coliform (FCs) $23.5\times10^2\pm57.7$; < 1 FC/100ml, and fecal *Streptococci* (Non FCs) 102 ± 22.05; < 1 FS/100ml), respectively, The removal percentage of bacterial indicators reached 99.97, 99.96, 99.02%, respectively as shown **Table 3.** The removal percentage were achieved exceed 99%.

Table (3): Mean values ±SD of bacterial analysis characterization of optimum chlorine dose 4.6 mg/l of raw water.

Items	Raw water	Treated water with chlorine	Removal percentage %	Standard of maximum allowed in drinking water (EWQS, 2007)
Bacterial total count	$34.75\times10^3\pm500$	44.25±4.35	99.87	50 CFU /ml
Total coliform bacteria	$46.5\times10^2\pm100$	<1	99.97	2 TC/100ml
Fecal coliform bacteria	$23.5\times10^2\pm57.7$	<1	99.96	(Free) FC/100ml
Nonfecal (*Streptococcus*)Bacteria	102±22.05	<1	99.02	FS/100 ml

< below count colonies/ml.

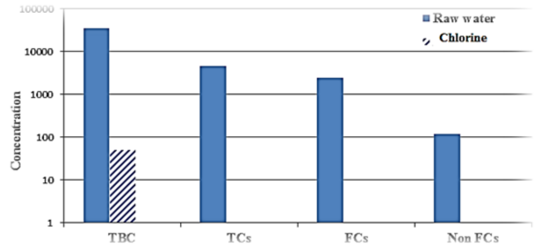

Figure (5): Bacterial analysis characterization of optimum chlorine dose 4.6 mg/l of raw water.

At 35°C, the highest total count of bacteria in raw water was 34.75×10^3 ±500 CFU/ml and the highest total count of bacteria in treated water was 44.25±4.35 CFU/ml by removal efficiency 99.87%.

At 44.5°C, the average number of total coliform bacteria in raw water was $46.5\times10^2\pm100$ TC/100ml, while no total coliforms were detected in treated water by removal efficiency 99.97%.

The average numbers of fecal coliform bacteria and fecal *Streptococci* bacteria in raw water were $23.5\times10^2\pm57.7$ FC/100ml and 102±22.05 FS/100ml, while no fecal coliforms and fecal *Streptococci* were detected in the treated water by removal efficiency 99.96% and 99.02%, respectively.

The results showed that all of raw samples were contaminated and treated samples were in permissible limits of the Egyptian standards for drinking water and free from any sewage contamination. The Egyptian standard for drinking water declared that potable water must be free from total coliforms; fecal coliforms, as well as fecal *Streptococci* in addition total bacterial counts must be less than 50 CFU/ml, similar results were observed by **El-Salam *et al.* (2017)** and **(El-Deeb, 1997).**

On the other hand, total algal count of raw water: 2240±146.4 and treated chlorine: 200±54.12 unit/ml, as well as (Green algae 820±102.5; 80±20.52 unit/ml, Blue- green algae 400±19.2; free unit/ml, Diatoms 1020±24.7; 120±33.6 unit/ml, Protozoa and all kinds of pathogen worms + ve; - ve), respectively, shown in **Table7** and **Fig. 6.** The removal efficiency of algae was reached 91.07, 90.24, 100 and 88.24%, respectively, as shown **Table 4.**

Table (4): Mean values ±SD of algal counting analysis characterization of optimum chlorine dose 4.6 mg/l of raw water.

Items	Raw water unit/ml	Treated water with chlorine unit/ml	Removal percentage%	Standard of maximum allowed in drinking water (EWQS, 2007)
Green algae	820±102.5	80±20.52	90.24	-
Blue- green algae	400±19.2	-	100	Free
Diatoms	1020±24.7	120±33.6	88.24	-
Total Algal count	2240±146.4	200±54.12	91.07	-
Protozoa & All kinds of pathogen worms	+ve	-ve	-	Free

(+ve) indicates the presence of Protozoa & All kinds of pathogen worms, whereas (_ve) denotes the absence of Protozoa & All kinds of pathogen worms .

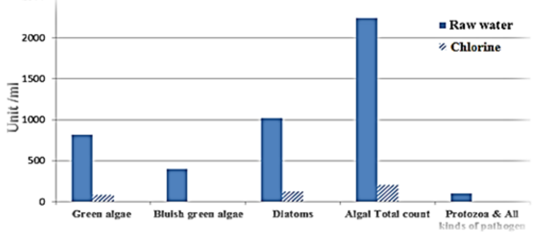

Figure (6): Algal counting analysis characterization of optimum chlorine dose 4.6 mg/l of raw water.

As shown in **Table 4** the total algal count value of raw water was 2240±146.4unit/ml, while in treated water 200±54.12 unit/ml that achieved reduction by 91.07%. Our results disagree with **El-Dars *et al.* (2015)** and agree with that reported by **(Shen *et al.*, 2011; El-Ghandour *et al.*, 1985; Abd El-Hady, 2014 and Mana-han, 2000).** The green algae (Chlorophyceae) value in raw water was 820±102.5 unit/ml and in treated water 80±20.52 unit/ml removal efficiency reached

90.24%, that proved by numerous studies by **(Plummer and Edzwald, 2002 and Knappe *et al.*, 2004).**

Blue- green algae (Cyanophyceae) value in raw water was 400±19.2 unit/ml and not found in treated water. On the other hand, Diatoms (Bacillariophyceae) in raw water was 1020±24.7 unit/m1 and in treated water was 120±33.6 unit/ml the removal achieved by 88.24%.

Diatoms predominated over Chlorophyta, Cyanophyta and Euglenophyta as the present study and also observed by **(El-Dars *et al.*, 2015).** This agrees with the findings of **Abd El-Hady (2014)** and **(Shehata *et al.*, 2008).** While protozoa and pathogen worms found in raw water in contrast, treated water that free of them as reported by **(Ljiljana *et al.*, 2019).** All of treated samples not filtered by rapid sand filter that make the removal efficiency not exceed 91.07%.

It's obvious that alum coagulant has a great reduction of total algal count and it depend on reducing in turbidity from 7.6±0.16 to 1.8±0.044 NTU, whereas alum and chlorine dosage were 2.1 mg/l and 4.6 mg/m^3 for alum and chlorine, respectively that disagree with that obtained by **El-Dars *et al.* (2015)** by 30 mg/l alum and 5.5mg Cl_2/l, in contrast that reported by **(Fathy *et al.*, 2020).**

Bacterial Analysis of treated water with Ozone

The data in **Table 5** and **Fig.7** showed that the results that examined by using alum dosage 2.1 mg/l and ozone dosage 10 mg/l that achieved turbidity removal percentage increasing from 41 to 77%. The results indicate the total bacterial counts (raw water: 21.25 ×10^3±1258.3; treated ozone: 12±3.6 CFU/ml) by removal percentage 99.9%, as well as, bacterial indicators (total Coliform 21×10^2±81.7; <1 TC/100 ml, fecal Coliform 11.75×10^2±150; < 1 FC/100 ml, and fecal *Streptococci* 73.5±15.6; <1 FS/100 ml), respectively. The removal percentage of bacterial indicators reached 99.95, 99.93, and 98.92%, respectively as shown **Table 5.** The removal percentage were achieved exceed 99%.

Table (5): Mean values ±SD of bacterial analysis characterization of optimum ozone dose 10 mg/l of raw water.

Items	Raw water	Treated water with ozone	Removal percentage%	Standard of maximum allowed in drinking water (EWQS, 2007)
Bacterial total count	21.25×10^3±1258.3	12±3.6	99.9	50 CFU/ml
Total coliform bacteria	21×10^2±81.7	<1	99.95	2 TC/100 ml
Fecal coliform bacteria	11.75×10^2±150	<1	99.93	(Free) FC/100 ml
Non fecal (*Streptococcus*) bacteria	73.5±15.6	<1	98.92	(Free) FS/100 ml

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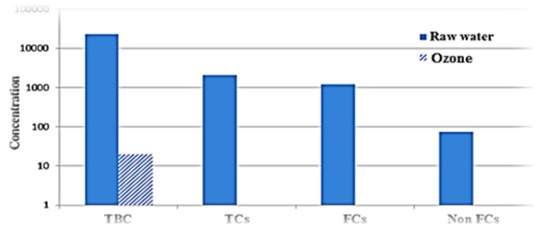

Figure (7): Bacterial analysis characterization of optimum ozone dose 10 mg/l of raw water.

At 35°C, the highest total count of bacteria in raw water was 21.25×10^3±1258.3 CFU/ml and the highest total count of bacteria in treated water was 12±3.6 CFU/ml by removal efficiency 99.9%. At 44.5°C, the average number of total coliform bacteria in raw water was 21×10^2±81.7 TC/100ml, while no total coliforms were detected in treated water by removal efficiency 99.95%.

The average numbers of fecal coliform bacteria and fecal *Streptococci* bacteria in raw water were 11.75×10^2±150 FC/100ml and 73.5±15.6 FS/100ml, while no fecal coliforms and fecal *Streptococci* were detected in the treated water by removal efficiency 99.93% and 98.92%, respectively.

The results showed that all of raw samples were contaminated and treated samples were in permissible limits of the Egyptian standards for drinking water and free from any sewage contamination. The Egyptian standard for drinking water declared that potable water must be free from total coliforms; fecal coliforms, as well as, fecal *Streptococci* in addition total bacterial counts must be less than 50 CFU/ml, similar results were observed by **Mezzanotte *et al.*, (2007)** proved that the effect of ozonation on total and fecal coliforms and on *E.* coli is comparable, while chlorination displays higher removals for total coliforms compared with fecal coliforms and *E.* coli.

On the other hand, Total Algal count of raw water: 3300±162.99 and treated ozone:

184±28.9 unit/ml by removal efficiency 94.42%, as well as, (Green algae 1220±98.72; 60±12.07 unit/ml, Blue- green algae 600±21.41; free unit/ml, Diatoms 1480±42.86; 124±16.83 unit/ml, Protozoa and all kinds of pathogen worms +ve; - ve), respectively. The removal percentage efficiency of other algae was 95.08,100, and 91.62%, respectively, as shown in **Table 6** and **Figure 8.**

Table (6): Mean values ±SD of algal counting analysis characterization of optimum ozone dose 10 mg/l of raw water.

Items	Raw water Unit/ml	Treated water Unit/ml	Removal percentage %	Standard of maximum allowed in drinking water (EWQS, 2007)
Green algae	1220±98.72	60±12.07	95.08	-
Blue- green algae	600±21.41	Free	100	Free
Diatoms	1480±42.86	124±16.83	91.62	-
Total Algal count	3300±162.99	184±28.9	94.42	-
Protozoa & All kinds of pathogen worms	+ve	-ve	-	Free

(+ve) indicates the presence of Protozoa & All kinds of pathogen worms, whereas (_ve) denotes the absence of Protozoa & All kinds of pathogen worms

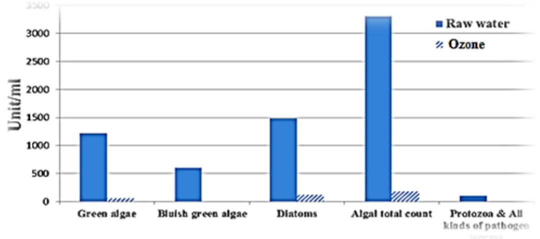

Figure (8): Algal counting analysis characterization of Optimum ozone dose 10 mg/l of raw water.

As shown in **Table 6** the Total Algal count value of raw water was 3300±162.99 unit/ml, while in treated water 184±28.9 unit/ml that achieved reduction by 94.42%. The green algae (Chlorophyceae) value in raw water was 1220±98.72 unit/ml and in treated water 60±12.07 unit/ml removal efficiency reached 95.08%.

Blue- green algae (Cyanophyceae) value in raw water was 600±21.41 unit/ml and not found in treated water that removed by removal efficiency 100%. On the other hand, Diatoms (Bacillariophyceae) in raw water was 1480±42.86 unit/ml and in treated water was 124±16.83 unit/ml the removal achieved by 91.62%. Diatoms predominated over Chlorophyta, Cyanophyta and Euglenophyta as the present study and also observed by **(El-Dars *et al.*, 2015).**

Ozone oxidant had increased the removal efficiency of total algal count at normal pH at 7.12 ±0.14 and it depend on reducing in turbidity from 7.89±0.074 to 1.8±0.11 NTU. It was found **(Schneider and Tobiason, 2000)** that when alum was used as a coagulant, pre-Ozonation hindered the removal of turbidity. Ozone is a strong oxidizing agent that is widely used in water supply to achieve water quality improvement and disinfection. Due to its antioxidant capacity, it is now one of the most effective disinfection techniques used in water treatment. Ozone is a more effective disinfectant compared to chlorine. Its most important advantage is that it does not produce unwanted by-products because ozone is converted into oxygen **(Gad, 2010).**

Conclusion

Microbiological analyses of water were analyzed in water samples collected from the Nile River (Damietta Branch) to evaluate the effectiveness of chlorine and ozone in improving water quality. The obtained results indicated that ozone is a more effective disinfectant compared to chlorine, and that treated samples were within the permissible limits of the Egyptian standards for drinking water. Ozone has the disadvantage that it quickly decomposes in water compared to chlorine, which is a negative aspect. When utilizing this strategy, a final dose of chlorine must be added to ensure safe water quality in the distribution system until received by the consumer.

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الملخص العربي

عنوان البحث: استخدام الأوزون بدلاً من الكلور في معالجة مياه الشرب في ظل الظروف المصرية

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الهدف من هذه الدراسة هو تحسين تقنيات التطهير المياه باستخدام الأوزون في معالجة المياه بدلاً من الكلور. أظهرت الدراسة الحالية لمعالجة مياه نهرالنيل أن الجرعة المثلى هي ١٠ مجم / لتر و ٤,٦ مجم / لتر للأوزون والكلور على التوالي. وكان تركيز الأوزون والكلور ضمن الحدود المسموح بها طبقاً للمواصفات القياسية المصرية لمياه الشرب. وأثناء العمل لمراقبة العد الكلي البكتيري والبكتيريا القولونية الكلية والبرازية والسبحية من خلال نسبة الإزالة التي تصل إلى ٩٩,٨٧ و ٩٩,٩٧ و ٩٩,٩٦ و ٩٩,٠٢ ٪ لكلاً على التوالي للكلور. بينما مع الأوزون وصلت نسبة الإزالة إلى ٩٩,٩ و ٩٩,٩٥ و٩٩,٩٣ و ٩٨,٩٢٪ على التوالي. أظهر تحليل عد الطحالب للأوزون أن العد الكلي للطحالب والطحالب الخضراء والطحالب الخضراء المزرقة والدياتومات تم إزالتها بكفاءة ٩١,٠٧ و ٩٠,٢٤ و ١٠٠ و ٨٨,٢٤٪ على التوالي، بينما فحص الكلور أظهر إزالة كفاءتها ٩٤,٤٢ و ٩٥,٠٨ و ١٠٠ و ٩١,٦٢٪ على التوالي. وأوضحت النتائج السابقة أن استخدام الأوزون هو أحد الطرق المستقبلية لتلبية معايير المياه البيئية وتزويد الاحتياجات المائية للتزايد السكاني.