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The Relationship between Algal Counting and Chemicals Consumption of Conventional Purification Systems at Qena Governorate, Egypt

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ABSTRACT

This study is concerned with studying the relationship between algal count (Diatoms, Green algae, Blue green algae), turbidity, pH, temperature, residual aluminum, alum and chlorine dose during one year (2018) at five surface plant intakes (Nag-Hammadi, Dishna, El-Salhyia, Qeft and Qous plants) at Qena governorate. Results show that alum dose had a linear relationship with temperature and turbidity; this indicates that the amount of chemicals and doses increases with increasing algae count in water intakes. In Nag-Hammadi plant the highest alum dose was recorded in January, 2018 whereas the least alum dose was in August, 2018, when the lowest algae count was recorded. So, it is advisable and less cost to study the algal count along one year for the expected intake for any new plant to know the required chemicals that this plant needs in the future. In addition, we have to take into consideration that the seasonal variation in these algal count, affects the chemical dosages required for water treatment.

INTRODUCTION

In Qena Governorate, the daily drinking water production is about 500,000 m^3; each one cubic meter consumes about 8-10 g of Alum, which produces 4-5 g of Aluminum hydroxides. The current plants under study considered the main sources of drinking water of Gena Governorate (MOHUUC,2019). There are many types of algae can be grow in the River Nile, due to pollution from the factories and households sewage water.

One of the most important needs of a society is a clean and secure water supply (Uduman *et al.*, 2010). The provision of safe drinking water plays an important role in preventing the incidence of many water transmissible diseases (Shehata *et al.*, 2008). Water is used for drinking after treatment to conform to quality parameters. Due to large amounts of nutrients such as nitrogen and phosphorus from both the production and consumption sectors are being discharged into water bodies every year, resulting in water eutrophication becoming an increasingly important problem. Permanent appearance of algae is considered to be an undesirable water pollutant in drinking water resources such as reservoirs and at water and wastewater treatment plants causing odor, taste and other severe health issues (F. Qu *et al*.,2012).The qualitative and quantitative analysis of phyto-zooplankton in treatment plants is important, not only for treatment efficiency, but also for monitoring changes in water quality (Uduman *et al*., 2010). Treatment prior to human consumption depends on the source water quality. At present, many cities that get their main water supply from lakes and rivers are affected by varying degrees of algal pollution (Shen *et al*., 2011). The presence of algae in source water can cause a variety of problems for drinking water treatment (Henderson *et al*., 2008). Algae are known to interfere with the water treatment process, causing increases in coagulant demand, and microbial regrowth in distribution systems (Plummer and Edzwald, 2001). Algae are typically removed using the following treatment chain: pre-oxidation, coagulation and flocculation, and clarification either by dissolved air flotation (DAF) or sedimentation, followed by granular media filtration. Direct filtration can also be used as a clarification process (Henderson *et al*., 2008 and Fast *et al*., 2014), as well as utilization of ultra filtration (Qu *et al*., 2012).

Coagulation is the key step in conventional water treatment processes. Chemical coagulation is commonly used in the treatment of water. The effective reduction of clay, silt, organic matter, algae, and bacteria in surface waters by coagulation and settling is demonstrated daily in water works operation. Even though the coagulation of clays and other inorganic sols has been reported in detail, similar attention has not been given to the coagulation of algae (Djamel *et al* .,2014). Algal extracellular products interfere with the coagulation-flocculation process leading to increased turbidity and impaired disinfection efficiency with chlorine. Algal penetration through filters imparts abnormal taste and odor (Babel et al., 2002). Chemical algae removal methods are considered as cost-effective and user-friendly, because the existing workflow would not be significantly changed and there would be no increase in the amount of large-scale equipments and structures. Numerous studies have showed that pretreatment with chemical agents such as chlorine, chlorine dioxide, ozone, or permanganate can enhance algae removal by chemical coagulation processes (Plummer and Edzwald, 2002 and Knappe *et al*., 2004). The chemical preoxidants are powerful oxidants and can improve algae coagulation by inactivating algal cells, destabilization of algal cells, or liberating extracellular organic matter (EOM). Chlorine acts to kill the algae by first penetrating through the cell wall then destroying enzymes within the cytoplasm (Shen *et al*., 2011 and Li *et al*.2016).

Flocculation is the process where a solute particle in a solution forms an aggregate called a floc. Flocculation is the result of collisions between solute particles and the adherence to each other in a suspension (Pieterse and Cloot, 1997). Most microalgal cells have a size range between 5 and 50 µm (Djamel *et al* .,2014) and form stable suspensions with negatively charged cellular surfaces. The stability of these microalgal suspensions is dependent on the forces that interact between the cells themselves and between the cells and water. Hence they are considered as hydrophilic bio-colloids which aid in the understanding of the mechanisms of flocculation; namely charge neutralization and polymer bridging (Uduman *et al*., 2010). The most important factors related to the removal of algae by coagulation appeared to be alum dosage, the initial algae concentration, and the shape and size of the genera encountered (Djamel *et al* .,2014). The effects of chemical dose (coagulant and coagulant aid) and pH on the removal of algae count by coagulation were evaluated with jar tests experiments conducted on synthetic waters (Ayşe *et al.*, 2016).

. The amount of chemical required to remove the algae was largely governed by the number and size of the algae present. (Djamel *et al* .,2014) conducted that algal growth may be controlled with more frequent cleaning of the basins especially in summer periods and coverage of open sedimentation basins would be avoided to benefit from solar radiation disinfection and oxygen diffusion from the air as well as controlled of coagulant addition.Many developing countries can hardly afford the costs of imported chemicals for water and wastewater treatment (Ndabigengesere *et al*., 1995).Therefore the primary objective of this study is investigating the effect of biological properties of raw water from five surface plants (Nag-Hammadi, Dishna, El-Salhyia, Qeft and Qous plants) especially total algae count on the amount of chemicals consumed by these plants. So it will be possible to expect the chemical cost for treatment in each plant depending on the biological properties of its water source. The effect of these biological properties on raw water turbidity and drinking water residual aluminum was also followed.

MATERIALS AND METHODS

1.1. Sampling site description:

Water samples were collected monthly intervals during one year (2018) from five surface water treatment plants (Nag-Hammadi, Dishna, El-Salhyia, Qeft and Qous). These plants are shown in (Figure 1).

1.2. Water quality:

1.2.1. Physico-chemical characters:

Temperature, turbidity and pH of plant intakes samples were determined in the field according to the methods provided by APHA (2005). Then, the collected samples were brought to laboratory and analyzed for total dissolved salts and residual aluminum according to APHA (2005) within 24 hours.

1.2.2. Algae samples and counting:

Samples for biological analysis were also brought to laboratory and enumeration of phytoplankton was accomplished according to APHA (2005). 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%.

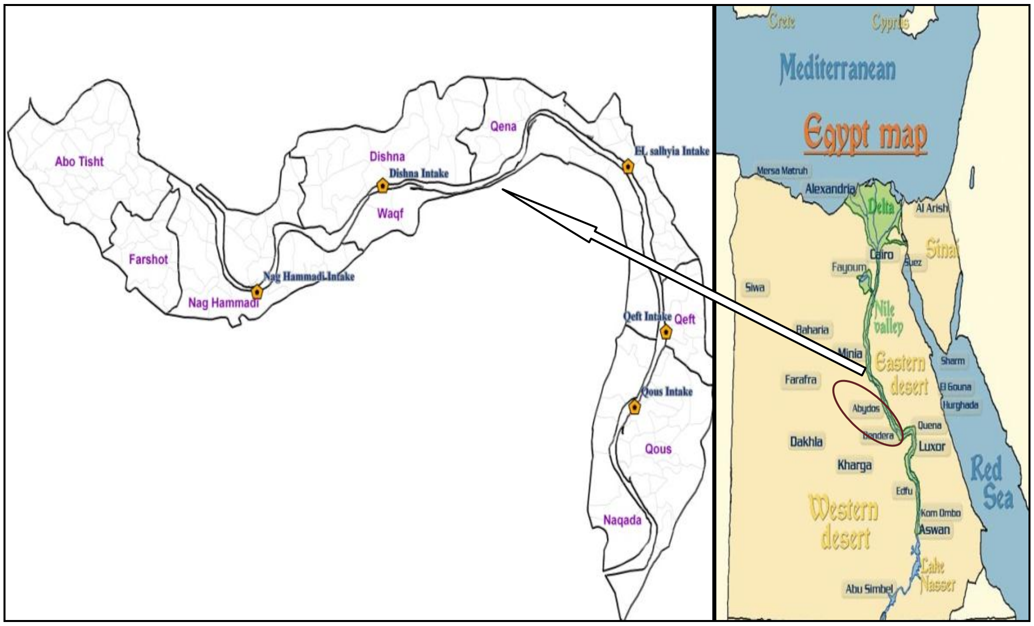

Figure (1): A map of Qena governorate illustrating the five selected of surface plant intakes under investigation.

1.3. Water treatment processes:

All the surface plants studied used free chlorine for disinfection and aluminum sulfate for coagulation. Chlorine dosage was determined according to break point test whereas alum dosage was determined according to standard Jar test which was conducted in one-liter beakers to evaluate coagulation efficiencies. Chlorine: Saturated chlorine water solution was used. The power of the available chlorine (concentration) was determined iodometrically (APHA, 2005). Jar Test: Coagulation and flocculation was conducted via the “Jar test” procedure which devised by (David (1993).

RESULTS

The monthly variation in the physio-chemical and algae count of surface plant water intakes (Figure 1) intakes is presented in Figures (2-9) whereas the correlation between these properties and alum and chlorine dosages is presented in Table (1). The experimental results showed that there is a positive correlation between the algal count of the raw water that feed surface plants and the chemicals used for treatment. For example alum and chlorine dosage increased when the turbidity increased in all surface plant water intakes (Figure 2), which was much more pronounced in winter season. Turbidity ranged from 1.5 NTU in summer season to 5.4 NTU in winter season whereas chlorine and alum dosages ranged from 3 to 8 and 7 to 15 mg l^{-1} for chlorine and alum respectively in the same season. This illustrates that chemical dosage of chlorine and alum doubled when the turbidity increased. Turbidity is often used to quantify suspended particles caused by biotic mass developments, microbial contaminations or tributary inputs (Znachor *et al*., 2008). High concentrations of particles irrespective of their origin are generally undesired in drinking water reservoirs as they cause economic costs necessitating treatment processes such as sedimentation, flotation and filtration (Scheifhacken *et al*., 2010). So it can be assumed that there is a positive correlation between water turbidity and chemical consumption. Also it was observed that there is somewhat increase in water turbidity of water samples from north plant intakes (such as Nag-Hammadi intake) when compared to the south plant intakes (such as Qous intake) which had pronounced effect on chemical consumption. This may be due to increasing water pollution as the water run from south to north along the River Nile.

As the hydrolysis products of aluminum coagulants are significantly affected by the pH of the solution (Lin *et al*., 2008 and Ayşe *et al*., 2016), the variation in pH was also followed. The data in figure (2) showed that there is no significant difference in pH of water samples collected from the different intakes along one year. pH of the different water samples was around pH =8 which aid in the coagulation process but did not have a direct effect on chemical consumption. Consistent with the reported results obtained by (Amuda and Amoo, 2007 and Yang *et al.,* 2010), turbidity removal efficiency increased obviously with pH when initial pH is lower than 6.0 and could reach about 90.5% for $Al_2 (SO_4)_3$, at the dosage of 10.0 mg/L (Al_2O_3) when the initial pH is between 7.0 and 9.0. The variation in temperature along one year was also detected in the different intake samples and shown in figure (3). The results illustrated that temperature is negatively correlated with alum and chlorine dosage in all water samples collected. When temperature decreased the chemical used for water treatment increased and vice versa. Azeez (2014) suggested that the increase in viscosity at a low temperature might negatively influence the settlement of the flocs. Similar results were also obtained by (Xiao et al. (2009).

The increase in turbidity which was much more pronounced when the temperature decreased may be related to the increase in algal count. The results in Figure 4 and 5 showed variation in algal count of plant intakes. River Nile water showed various phytoplankton structures belonging to three main groups, namely, Chlorophyceae (Green Algae), Cyanophyceae (Blue-Green Algae) and Bacillariophyceae (Diatoms). The highest count of algae was observed in winter season (Dec. to Feb.) whereas the least count was found in the summer season (Jun. to Oug.). The highest numbers were recorded for diatoms followed by green algae and finally for blue green algae. Generally there was a positive correlation between turbidity, algae count and the chemical consumption (alum and chlorine) its records that 0.818 and 0.2247, respectively for algal count and 0.5411 and 0.0262, respectively (table (1).

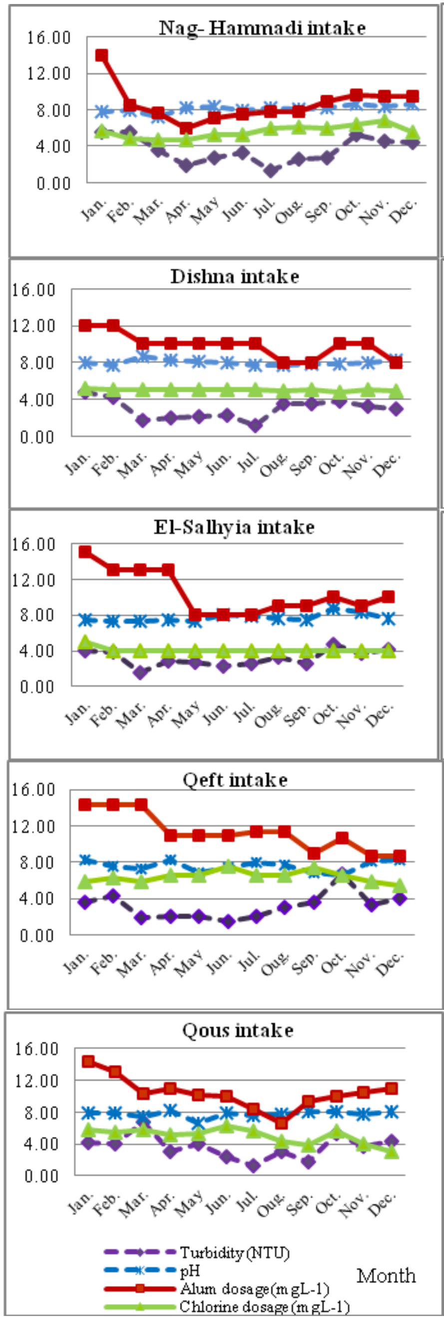

Figure (2): The variation in turbidity, pH, alum and chlorine dosages along one year in five surface plant intakes.

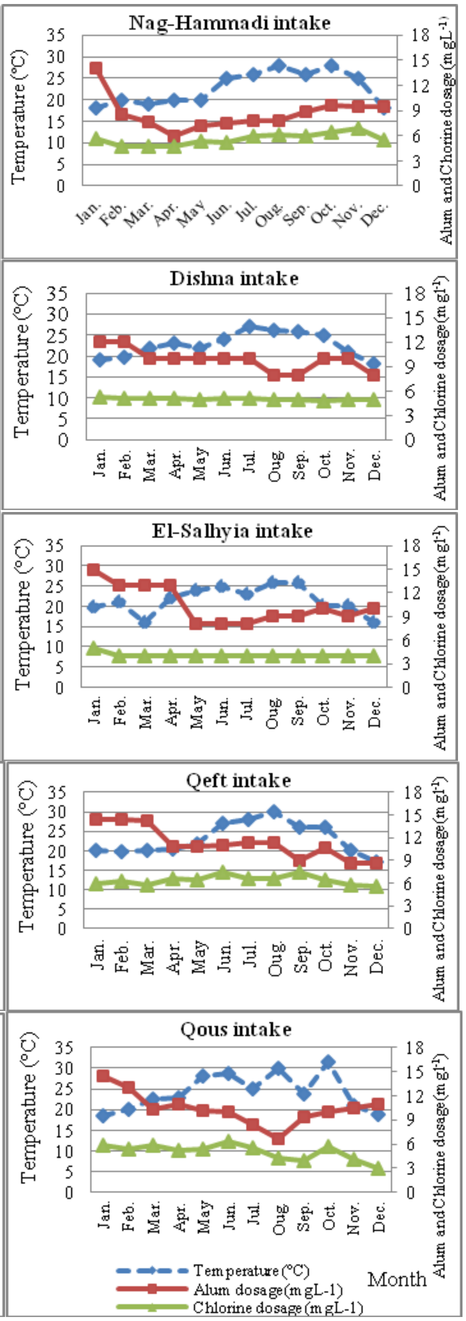

Figure (3): The variation in temperature, alum and chlorine dosages along one year in five surface plant intakes.

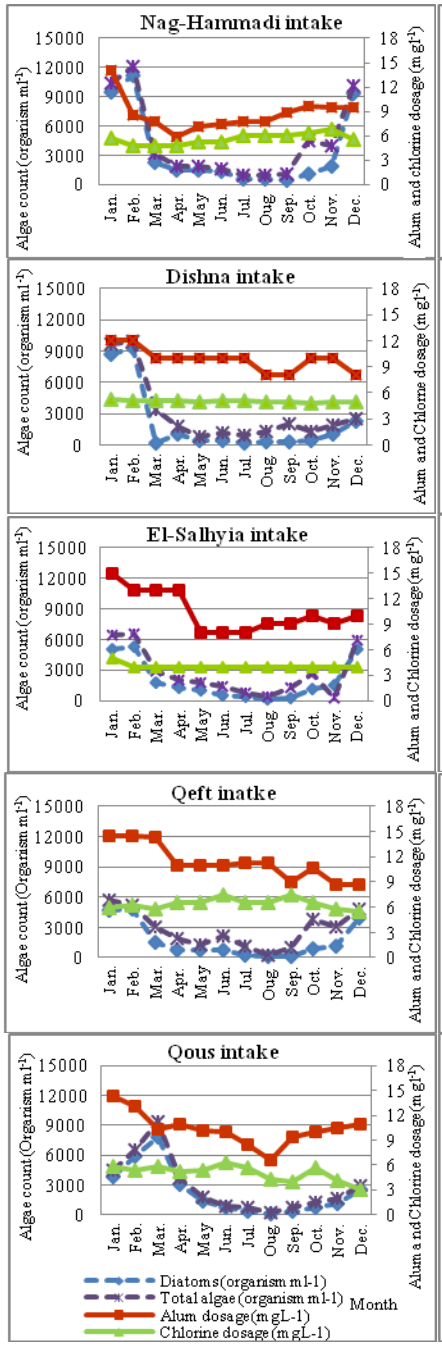

Figure (4): The variation in diatoms, total algae count, alum and chlorine dosages along one year in five surface plant intakes.

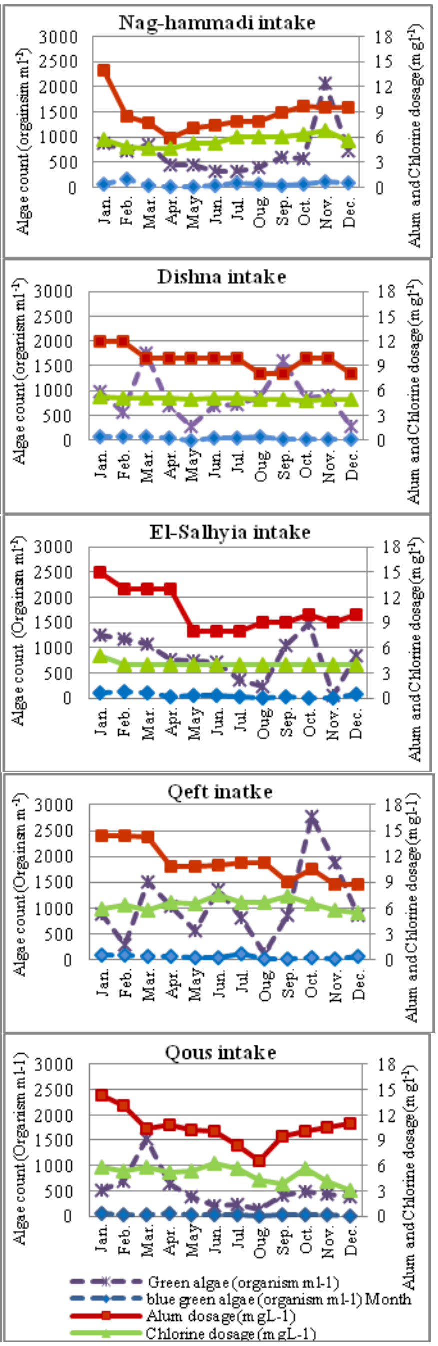

Figure (5): The variation in green, blue green algae count, alum and chlorine dosages along one year in five surface plant intakes.

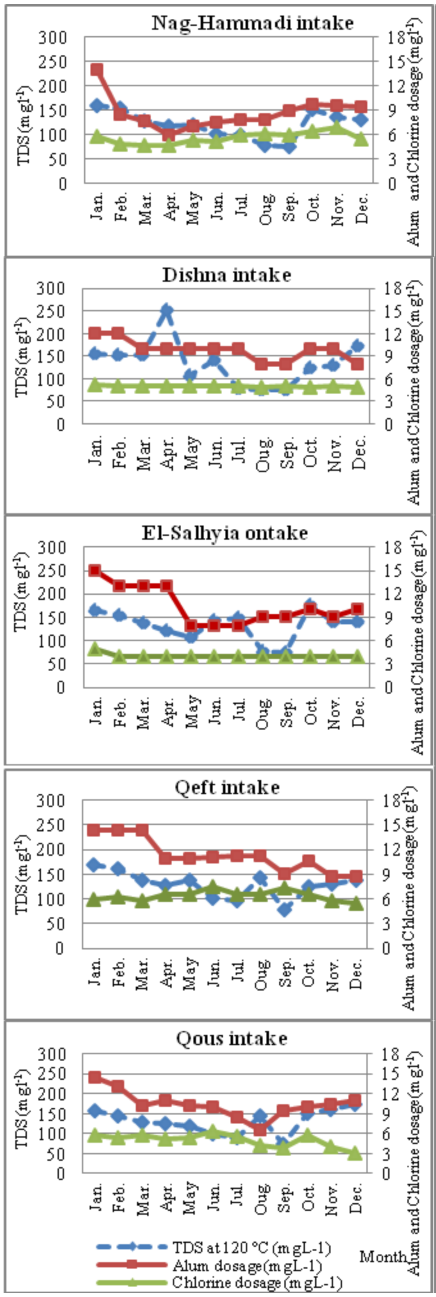

Figure (6): The variation in TDS, alum and chlorine dosages along one year in five surface plant intakes.

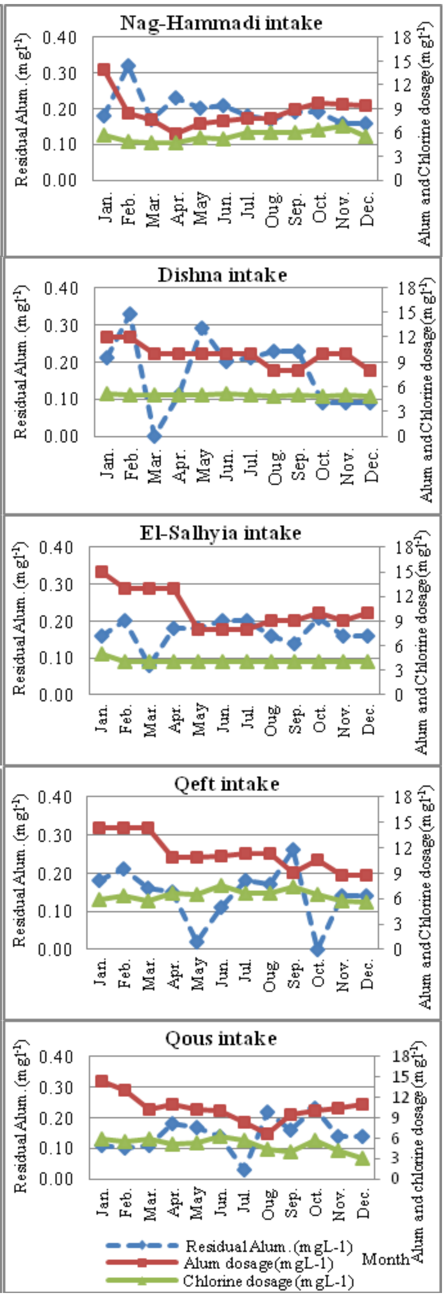

Figure (7): The variation in turbidity, pH, temperature, alum and chlorine dosages along one year in five surface plant intakes.

This increase in chemicals dosage was expected to increase with increasing algae count because algae removal is enhanced mainly by increasing the coagulant and chlorine dosage. The high levels of algae have a cost implication due to the resultant high chemical demand in the different stages of treatment (Hoko and Makado, 2011). The strength of this correlation between algae count and chemicals consumption increased in winter season with decreasing of temperature. (Shen *et al*., 2011) reported that the total algal biomass reaches the highest value when the daily water temperature is between 21 and 24 °C, the concentration of algae cells decreases gradually when the water temperature exceeds 24 °C. Although temperatures for optimum growth of algae differ among algae classes and genera, temperature is one factor that determines the succession of algae in a water body, and the growth rates of algae vary as function of temperature (Knappe *et al.*, 2004). Temperature would influence physiological responses, metabolic rates of algae and the utilized coefficient of nutrients. (Fathy *et al*., 2019) concluded that optimize the dose of chlorine to be adequate for the killing of water- borne microorganisms and to reduce the high risk from disinfection by-product formation.

The correlation between total dissolved salts (TDS) and alum and chlorine dosage used for treatment was shown in Figure (6). In most samples collected and analyzed, it was observed that when TDS increased the chemical dosages of alum and chlorine increased, so it can be said that generally there is a positive relationship 0.6545 and 0.4230, respectively, as shown in table (1). This can be explained on the basis that when TDS increased, algae growth increased which resulted in a pronounced increase in water turbidity require more chemical dosages.

Table (1): Correlation matrices of physio-chemical and biological properties determined with alum and chlorine doses

	Alum dose	Chlorine dose	Turbidity	pH	Temperature	TDS	Diatoms	Green algae	Blue green algae	Total algae	Residual Alum.
Alum dose	**1**										
Chlorine dose	**0.4230**	**1**									
Turbidity	**0.5411**	**0.0262**	**1**								
pH	**-0.0077**	**0.0862**	**0.2381**	**1**							
Temperature	**-0.5662**	**-0.0513**	**-0.3695**	**-0.1790**	**1**						
TDS	**0.6545**	**0.1832**	**0.6246**	**0.4060**	**-0.7401**	**1**					
Diatoms	**0.7825**	**0.2396**	**0.5720**	**0.0458**	**-0.7886**	**0.7145**	**1**				
Green algae	**0.3785**	**-0.0143**	**0.4640**	**0.0760**	**-0.2663**	**0.3121**	**0.0861**	**1**			
Blue green algae	**0.7451**	**0.2145**	**0.3264**	**0.0218**	**-0.6414**	**0.6153**	**0.8656**	**0.1168**	**1**		
Total algae	**0.8188**	**0.2247**	**0.6467**	**0.0431**	**0.0935**	**0.7493**	**0.9848**	**0.2437**	**0.8633**	**1**	
Residual alum.	**0.0740**	**0.0238**	**0.1702**	**-0.1283**	**0.3546**	**-0.1841**	**0.9848**	**-0.4124**	**0.0321**	**0.0935**	**1**

This increase in algae count and turbidity also affects slightly on the concentration of residual alum for drinking water samples which obviously explained in Figure (7).

The results indicated that in most cases there is a good correlation between increasing turbidity, alum dosage and increasing residual alum in drinking water produced, so it can be said that generally there is a positive relationship 0.074 and 0.1702, respectively, (table (1). But this increase in residual alum in all cases did not exceed the Egyptian standards for drinking water which ensure the maximum removal of turbidity (Henderson et al., 2010).

CONCLUSION

From all the previous results we can conclude that there is a positive correlation between chemical consumption and turbidity, algal count of plant intakes samples whereas there is a negative correlation between chemical dosages and temperature of the raw water. So, these factors are considered as the most effective factors because the other factors such as TDS did not show clear variation. Accordingly, chemical consumption could be estimated on the basis of algal analysis and turbidity estimation. The chemical cost is doubled two or three times when turbidity or algae count increased. So, it is advisable and less cost to study the algal count along one year for the expected intake for any new plant to know the required chemicals that this plant need in the future. In addition, we have to take into consideration that the seasonal variation in these algal count, affects the chemical dosages required for water treatment.

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