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A Study on the Effects of Disinfectants Produced by Electrochemical Processes on the Growth of Algae in Drinking Water

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By

Intesar kareem Abdulhassan

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Coll. of Education. for pure Sciences /Ibn Al-Haitham
Baghdad University

Supervised by

Prof. Adel F. Hamed

Professor of Phycology
Botany Department, Faculty of Science
Ain Shams University

Dr. Hesham M. Abd El-fatah
Assistant Professor of Phycology
Botany Department, Faculty of Science
Ain Shams University

Prof. Gamal O. El-Sayed
Professor of *Chemistry*
Chemistry Department, Faculty of Science,
Benha University Benha

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Approval Sheet for submission Ph.D.

Thesis Name of candidate: Intesar kareem Abdulhassan

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This thesis has been approved by: Signature

1- Prof. Adel F. Hamed …….

Professor of Phycology, Botany Department, Faculty of Science, Ain Shams University

2- Dr. Hesham M. Abd El-fatah …….

Assistant Professor of Phycology, Botany Department, Faculty of Science, Ain Shams University

3- Prof. Gamal O. El-Sayed …….

Professor of *Chemistry,* Chemistry Department, Faculty of Science, Benha University Benha

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Dedication

I dedicate this study to the soul of my ceased father, peace be upon to him. I also dedicate it to my mother who encourages me to succeed and live this significant phase of my life, my husband (Hayder) whose support is felt in all my steps, my mother and my aunt Janan and to my son and daughters (Hussein, Amani , Zainab and Zahraa).

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Abstract

Removing of algae by electrochemical treatment was studied through the preparation of electrochemical generations of Sodium Persulfate and Hydrogen Peroxide in a fixed bed reactor. The cell was equipped with two electrodes (two identical graphite electrodes). The effect of different operating factors, such as the applied voltage and the amount of initial sodium sulfate added in the case of persulfate production, was evaluated. The effect of potential difference was also examined in the case of Hydrogen Peroxide production. The two treatments were optimized and found to be effective in removing algae-laden water when applied to the samples taken from the drinking water stations at El-Amyria and Rod Al-Farag. The pro-type system used with the proposed methods was found to be simple, rapid, and effective for removing of algae.

Keywords: algal denisty, electrochemical disinfectants, Sodium Persulfate, Hydrogen Peroxide.

Chapter I

1- Introduction

The safety of drinking water became a main requirement which increases with the development of economy. Surface drinking water has been known to be loaded with impurities which are introduced either naturally or anthropogenically. There are many water treatment techniques have applied over the years resulting in different quality drinking waters. If the water has undesirable taste or odor, aeration is applied to oxidize and remove causes of the undesirable taste and odor. Subsequently, the treated water is subjected to disinfection process**)Wigle, 1998(**. The disinfection process is applied to ensure the inactivation of all microbial pathogens in the water. Usually, the disinfectant kills the pathogenic micro-organisms or inactivates their activities. Most of disinfectants used in treating drinking water are specific chemicals (**Wigle**, **1998**).

In developing countries, microbial contaminants of drinking water sources have continued to pose the greatest health challenges in view of water borne diseases. Disinfection in public water supply is considered the most important process in drinking water treatment.

In terms of biosafety of drinking water, fungi and algae have not attracted great attention since they do not cause acute toxicity

like viruses and bacteria in drinking water. However, increasing of waterborne fungi and algae could cause a series of water pollution problems, such as change of taste, odor, turbidity, particles visible to the naked eye **(Reiff**, **1994).** Once the algae enter water distribution systems, they can threaten the safety of human being via drinking water, shower intake and other ways. Typical disinfection methods such as chlorine, ozone and ultraviolet (UV) has been widely used in water purification. A disinfection barrier is a common component of primary treatment of drinking water. Primary disinfection is typically a chemical oxidation process, although ultraviolet (UV) irradiation and membrane treatment are gaining increased attention.

However, chlorine is still the most widespread disinfectant in use in the water treatment due to the relative lower cost of the chlorine gas or pellets in relation to other chemical disinfectants including its hypochlorous form. The high disinfection efficiency and visible continued effect make chlorine one of the most widely used disinfectant. The large-scale usage of chlorine for disinfection caused the formation of disinfection by-products (DBPs) which are considered harmful to human health and generate unexpected chlorine resistant bacteria. In terms of disinfection efficiency and broad-spectrum microbicidal ability, ozone may be a better choice than chlorine in water treatment, while the safety issue and high cost of ozone limit its application. UV treatment has also become

increasingly popular owing to its high efficiency against most microbial pathogens and the non-formation of DBPs **(Yuancheng et al., 2022).**

One of the most plentiful and important resources is water on the surface of the Earth. Water is essential for human consumption as well as production in both industry and agriculture **(Patil et al., 2012).** Water contamination is a problem nowadays due to the growing population, industrialisation, and shift to a modern consum er society. **(El Sharkawi et al., 1995; Arslan-Alaton et al., 2009)**

River Nile is the primary and most significant supply of fresh water in Egypt, so its water quality should be a top priority. In an ideal scenario, water quality should be assessed using physical, chemical and biological parameters to provide a full spectrum of data for effective water management. However, this requires a lot more time and money, so the study of biological parameters is widely accepted to provide accurate information about water quality **(Singh et al., 2013).**

Chemical and physical parameters of the Nile water have an impact on water quality and may serve as reliable indicators of water pollution and pollutant resources **(Ali et al., 2014).** Also the study of water quality gives a water indicator of aquatic systems, and it is significantly evidence for the ecological status of the system **(Ali & El Shehawy, 2017)**.

One of the most crucial sanitary infrastructure initiatives is to provide access to clean water **(WHO, 2011; WHO & UNC, 2017; Lou et al., 2019)**. Worldwide, more than billion people still lack access to clean drinking water **(Malakotian & Hashemi, 2015).**

Today, there is special attention for limited water supplies at numerous locations around the globe to ensure that drinking water is safe for the general public to consume **(Ghanim, 2019; Rojas et al., 2020)** and it must be available in sufficient quantities and meet particular water quality standards **(Mohebbi et al., 2013 ; Badr & Al Naeem, 2012)**.

Contaminants in drinking water (DW) pose a serious risk to the public's health. Therefore, one of humanity's greatest effective public health efforts has been the supply of safe drinking water as well as a primary target in the underdeveloped world **(Ashbolt, 2015).**

According to a report from 2006 (**Tsoukalas & Tsitsifli; 2018),** DW consumption from certified and regulated water sources made up a small percentage of the global population. The percentage of people that consumed DW from certified and regulated water sources was 87%, which was much higher than the similar figure (77%) recorded in 1990.

Utilizing current/adequate techniques and methods, suppliers must manage, control, and monitor the produced DW quality in

order to offer consumers with safe drinkable water **(Tsoukalas & Tsitsifli, 2018; Curnin & Brooks, 2020).**

According to the World Health Organization (WHO) and United Nations Children **(UNC), (WHO & UNC, 2017)** and (**Grönwall and Danert, 2020)**, access to sufficient and safe drinking water is seen as a fundamental human right and a protection of both human health and sustainable development. However, more than 80% of infections affecting people are brought on by tainted water **(Hoseini et al., 2016).**

Also drinking of unsafe water may lead to child mortality **(Rezaee et al., 2011)** in many developing countries. On the other hand, it is extremely clear that the countries facing drought problems must limit water contamination, refine it, and reuse it **(Afsharnia et al., 2018).**

Reliable and clean water supply is among a society's most crucial needs **(Uduman et al., 2010).**The availability of clean drinking water is crucial in reducing the risk of several water-transmissible diseases **(Shehata et al., 2008).**

However, many steps required for water treatment to meet quality standards and then water is utilized for drinking. Development in the urban, industrial and agricultural sectors has led to several increase in consumption of scarce water supplies **(Alomran et al., 2015).**

Water eutrophication is becoming an increasingly serious issue as a result of the massive amounts of nutrients, such as nitrogen and phosphorus that are dumped into water bodies every year from both the production and consumption sectors.

Algae is a growing concern for many waterways with the potential for harmful algal blooms (HAB) to occur producing dangerous toxins that can impact ecosystems along with taste and odor of drinking water supplies.

Algae forms in waters that are rich in nutrients, such as nitrogen, phosphorous, and iron. Warmer water may help algae to grow quicker, forming blooms which can appear as scum or mats on the water surface and in different colors.

In fresh water, such as lakes and rivers HAB's are most formed from cyanobacteria and are often called blue-green algae because of their color. Algae that persist over time is thought to be a harmful water pollutant that can affect the taste, odor, and exert serious health hazards of drinking water resources including reservoirs **(Qu et al., 2012).** On the local and global level, algal blooms have emerged as a critical issue in inland freshwater systems **(Chen & Bridgeman, 2017).**

Currently, various levels of algal pollution impact many cities whose primary water supply comes from lakes and rivers **(Shen et al., 2011).** Qualitative and quantitative analysis of phytoplankton and zooplankton at treatment facilities is crucial for monitoring

changes in water quality as well as treatment effectiveness **(Uduman et al., 2010).**

Numerous issues with drinking water treatment might result from the presence of algae in water resources **(Henderson et al., 2008).** Algae are found during water treatment, increasing the need for coagulants and triggering microbial regrowth in distribution systems **(Plummer & Edzwald, 2001).**

Climate change and anthropogenic effects are among the physical, chemical, and biological elements that have contributed to the dramatic amplification of algal blooms. Harmful algal blooms have a major socioeconomic impact on human health, fisheries, tourism and recreation according to technical report developed by the Joint Research Centre of the European Commission **(Sanseverino et al., 2016)**.

Due to rising in water turbidity and unfavorable toxin production, algae overgrowth reduces the appropriateness of water sources for drinking, sanitation, irrigation, or industrial usage. Then algal removal from water and wastewaters has become more important in recent years, but their small size and low specific gravity make it difficult for advanced oxidation processes and other traditional and alternative water treatment methods to work effectively **(Gao et al., 2010; Monasterio et al., 2014)**.

Water that has been treated should not contain any coliforms; otherwise, treatment may not have been effective or contamination

may have been introduced during the process **(Yousefi et al., 2018).** Consequently, the goal of any water treatment is to remove impurities from water and to adapt it to the intended usage. Treatment of water includes processes using biology, chemistry, and physics to remove pollutants. Since the 1950s, there has been discussion on electrochemical disinfection as one of the most promising alternatives to currently employed treatment techniques **(Kerwick et al., 2005).** Electrochemical disinfection of algae offering advantages for both primary and residual disinfection when compared to traditional disinfection therapy. Additionally, the generation of highly germicidal chlorine species (Cl_2, HOCl, ClO) or chlorine radicals (Cl, Cl_2) as a result of chloride's presence in the electrolyte improved the effectiveness of cells inactivation. Effectiveness of electrochemical treatment strongly depends on electrolytic cell configuration, electrode material, electrolyte solution, and experimental parameters like flow rate or current density. According to reports, electrochemical disinfection can inactivate a wide range of microorganisms, including viruses, bacteria, algae, and motile euglenoids species like *Euglena* in a variety of water matrices **(Ghernaout et al., 2009)**.

Aim of the work

1. Collection of water samples from the waterways feeding the drinking water stations (El- Amyria and Rod El-Farag).
2. Determination of the algal composition and cell density of phytoplankton inhabiting the raw water during different seasons.
3. Preparation of electrochemical disinfectants and study their effectiveness on the removing of algae in terms of the determination of cell density as well as chlorophyll content after the treatment.

2- Literature Review

I. Water quality

Water quality refers to the chemical, physical, and biological characteristics of water based on the standards of its usage. It is most frequently used by reference to a set of standards against which compliance, generally achieved through treatment of the water, can be assessed. The most common standards used to monitor and assess water quality convey the health of ecosystems, safety of human contact, and condition of drinking water. Water quality has a significant impact on water supply and oftentimes determines supply options **(Bartram and Balance, 1996; Alley, 2000; Ahuja, 2009; Boyd, 2015)**. The parameters for water quality are determined by the intended use. Work in the area of water quality tends to be focused on water that is treated for potability, industrial/domestic use, or restoration (of an environment/ ecosystem, generally for health of human/aquatic life) **(Ahuja, 2013; Shaltami et al., 2020).**

II. Human Consumption

Contaminants that may be present in untreated water include microorganisms such as viruses, algae, protozoa and bacteria; inorganic contaminants such as salts and metals; organic chemical contaminants from industrial processes and petroleum use;

pesticides and herbicides; and radioactive contaminants. Water quality depends on the local geology and ecosystem, as well as human uses such as sewage dispersion, industrial pollution, use of water bodies as a heat sink, and overuse (which may lower the level of the water) **.**The United States Environmental Protection Agency (EPA) limits the amounts of certain contaminants in tap water provided by US public water systems. The Safe Drinking Water Act authorizes EPA to issue two types of standards: 1) Primary standards regulate substances that potentially affect human health, and 2) Secondary standards prescribe aesthetic qualities, those that affect taste, odor, or appearance.

The U.S. Food and Drug Administration (FDA) regulations establish limits for contaminants in bottled water. Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of these contaminants does not necessarily indicate that the water poses a health risk. In urbanized areas around the world, water purification technology is used in municipal water systems to remove contaminants from the source water (surface water or groundwater) before it is distributed to homes, businesses, schools and other recipients **(Zhang, 2014; Liu et al., 2020).**

III. Physico-chemical parameters:

1. Turbidity

Water turbidity is a physical characteristic that provides information about the health and productivity of a freshwater body (**APHA, 2012**), The amount of very small suspended particles, such as silt, clay, organic materials, and even microscopic creatures, determines the turbidity level in aquatic systems **(El-Manawy and Amin, 2004).** The degree of contamination in a body of water can be roughly gauged by its turbidity level **(Abd El-Hady and Hussian, 2012).**

2. Conductivity

The conductivity of the water is a proxy for its salinity. The conductivity of water is substantially changed under high temperature which leads to the increasing in salinity concentration in freshwater ecosystems. Aquatic biota could feel stressed as a result of this changing. The industrial, agricultural and sewage wastewaters may cause a rise in the conductivity of lakes and rivers. However, not all industrial processes will raise the conductivity of water. Oil, for instance, does not conduct electricity efficiently, therefore measuring water conductivity would not be able to identify oil-related water contamination (**Muharni et al., 2021).**

3. pH

The hydrogen ion concentration, or pH, is a crucial factor in regulating water quality and phytoplankton development. pH also controls the solubility of metal ions and has a significant impact on all chemical and biological activity within an aquatic ecosystem **(Abd El-Hady & Hussian, 2012)**. Freshwater aquatic life thrives best within a pH range of 6.5 to 9.0 **(Chin, 2013).** Seasonal variations in temperature, carbonate and bicarbonate content, and pH affect the chemical composition of water bodies **(Abdo, 2005).** pH fluctuations may disturb the distribution of phytoplankton and zooplankton in aquatic habitats **(Nassar, 2014).**

4. Dissolved oxygen

Dissolved oxygen in water is produced through photosynthesis by phytoplankton and benthic algae and by the contact of surface water with air oxygen **(Nassar, 2014).** Aquatic animals and fish rely on dissolved oxygen in water for respiration, while saprophytic microbes use it for organic matter decomposition **(Abd El-Hady & Hussian, 2012).**

5. Nutrients

Aquatic biota may be impacted by nutrient enrichment in freshwater systems caused by Nitrogen (N) and Phosphorous (P) inputs from urban and agricultural seepage, as well as from

industrial and home wastewater and even air deposition **(Dodds, 2003).**

The amount of total nitrogen in aquatic systems can be expressed as either ammonium ions, the amount of which can be influenced by organic inputs like domestic sewage and fertilizer runoff or nitrate and nitrite ions in a more reduced state, which makes assimilation less expensive in terms of energy **(Ali et al., 2014).** Numerous processes, such as photorespiration, protein degradation, and amino acid deamination, can produce it in cells **(Gardner et al., 2008).** In aquatic environments, phosphorus is a key element for the growth and primary generation of phytoplankton. The eutrophication that results from an abundance of phosphorus in the water can be a source of pollution **(Nassar, 2014).** In addition the sediments exists on the bottom of shallow rivers may release addition phosphate in water regime **(Ail et al., 2014).** Along with N and P, silicate also has an impact on the growth of phytoplankton. One of the key elements that restricts growth during the spring phytoplankton bloom, according to **Piepho et al., (2012),** is silicate. However, in summer blooms, phosphate, nitrogen, and silicate may become limiting. Phosphate, nitrogen, and silicate could all run out of supply.

IV. River Nile and Freshwater Habitat

The River Nile with its natural and artificial branches and canals are the main source of freshwater for Egypt's irrigation and drinking water needs **(Ail et al., 2014)**

The Nile, which is recognized as the greatest river in the world, is the only river to traverse the Sahara **(Abd El-Hady, 2014).** The basin of this ancient river, which has a length of roughly 6740 km, is what defines the majority of northern Africa **(Abdo & El-Nasharty, 2010).**

The first two significant rivers in the Nile basin system are the White and Blue Niles, which converge in Khartoum (Sudan). After there, the main Nile travels for 3080 kilometers until reaching the Mediterranean Sea **(Shehata et al., 2009).** Therefore, Egypt's sole source of freshwater is the Nile and its tributaries **(Ali et al., 2014).**

The building of Lake Nasser had a considerable impact on the river downstream by regulating flows and changing the biological characteristics of water **(Shehata et al., 2009).**

In fact, the quality of the water in the Nile is negatively impacted by the growth in industrial, agricultural, and recreational activities as well as by improperly built drainage and sewage infrastructure **(Goher et al., 2014).**

The quality of the River Nile's water is not solely determined by water management. Agricultural runoff, industrial, urban, and ship wastewaters, as well as interventions like the hydrodynamic systems regulated by the Nile barrages, all affect the use of water and land **(Shamrukh and Abdl-wahab, 2011).** The main point sources of pollution in the Nile River are the discharges of untreated sewage from open drains carrying agricultural flows, sewage, and industrial wastes **(Abdel-Star, 2017).**

There are many studies concerning water quality in the Nile **(Bartram and Balance, 1996., Alley, 2000., Dodds, 2003., El-Manawy and Amin, 2004., Abdel-Star, 2005., Abdo, 2005., Ahuja, 2009., Shehata et al., 2009., Shamrukh & Abdl-wahab, 2011., Abd El-Hady and Hussian, 2012., Morsy and El-Fakharany, 2012., Piepho et al., 2012., Ahuja, 2013., Ghoraba et al., 2013., Khalil et al., 2013., Ali et al., 2014., Goher et al., 2014., Fattah and Ragab, 2014., Nassar, 2014., Zhang, 2014., Boyd, 2015., Palamuleni and Akoth, 2015., El-Kowrany et al., 2016., El-Sheekh, 2016., Abdel-Satar et al., 2017., Ghobara and Salem, 2017., Negm and Armanuos, 2017., Salem et al., 2017., Sharaky et al., 2017., Yusuf, 2019., Khalid, 2019., Shaltami et al., 2020., Liu et al., 2020., Hussain et al. 2021., Mohamed et al., 2020., Muharni et al., 2021., Mohammad et al., 2022., Abouhalimaa & Li, 2023).** These studies combined methodologies across all water

quality standards with physico-chemical characteristics or microbiological analysis.

V. Nuisance Algae

Algae in water are of great concern because they adversely affect drinking water quality and water treatment processes. In particular, in tropical and semi-tropical zones, algae can grow excessively under high nutrient contents in surface water due to contamination by agricultural activity, domestic wastewater discharge and industrial effluents. The high concentrations of nitrogen and phosphorous can provide the ideal medium for the excessive growth of algae, which is detrimental not only from an environmental point of view but also for human health **(Sathe et al., 2015)**

Algae may cause problems, such as poor taste and odor in the water, and several studies have been reported in the literature on the possible problems connected with toxins released by algae **(Hamed, 2000 ; Mohamed et al ., 2015 ; Bhatt et al., 2022; Wang et al., 2023).** The presence of sub-lethal doses of cyanotoxins in drinking water is implicated as one of the key risk factors for the high occurrence of primary liver cancer.

Studies on algae in Egypt's freshwater environments, including the River Nile, its tributaries, and other freshwater habitats was studied by many authors **(Shehata et al., 2002; Szabo et al. ,2005,**

Shehata et al.,2008, Shehata et al., 2009, Ali, 2010, Ganai and parveen, 2014, Ali et al .,2017, Mahmoud et al., 2018, El-Gamal et al., 2019, Badr & Naeem., 2021,Saber et al.,2021)

VI. Chemical Disinfectants

1. Chlorine

It is the oldest and most popular disinfectant used in many countries of the world. It is used either in the form of free chlorine gas or chlorine pellets or in the form of calcium or sodium hypochlorite.

Chlorination is the process of adding chlorine to drinking water to kill parasites, bacteria, and viruses. Different processes can be used to achieve safe levels of chlorine in drinking water. Using or drinking water with small amounts of chlorine does not cause harmful health effects and provides protection against water-borne disease outbreaks.

Chlorine is a chemical disinfectant owing to its effectiveness against various pathogenic microorganisms. Chlorine gas and water react to form hypochlorous acid (HOCl) and hydrochloric acid (HCl). In turn, the HOCl dissociates into the hypochlorite ion (OCl^-) and the hydrogen ion (H^+), according to the following reactions:

(a) $Cl_2 + H_2O \Leftrightarrow HOCl + HCl$

Inactivation (disinfection) processes

$$(b)\ HOCl \Leftrightarrow H + + OCl^{-}$$

The reactions are reversible and pH dependent:

- between pH 3.5 and 5.5, HOCl is the predominant species
- between about pH 5.5 and 9.5, both HOCl and OCl– species exist in various proportions
- above pH 8, OCl^{-} predominates. The OCl^{-} and HOCl species are commonly referred to as free chlorine, which is extremely reactive with numerous components of the bacterial cell. HOCl can produce oxidation, hydrolysis and deamination reactions with a variety of chemical substrates and produces physiological lesions that may affect several cellular processes. Earlier findings had established that chlorine destroys microorganisms by combining with proteins to form N-chloro compounds.

Chlorine dioxide is a strong oxidant that has been used in the European Union as a secondary disinfectant in drinking water supply. Chlorine dioxide is highly soluble in water (particularly at low temperatures) and is effective over a range of pH values (pH 5–10). Theoretically, chlorine dioxide undergoes five valence changes in oxidation to chloride ion:

$$ClO_2 + 5e^{-} \rightarrow Cl^{-} + 2O_2^{-}$$

However, in practice, chlorine dioxide is rarely reduced completely to chloride ion. Chlorine dioxide inactivate microorganisms through direct oxidation of tyrosine, methionyl, or cysteine containing proteins, which interferes with important structural regions of metabolic enzymes or membrane proteins. In water treatment, chlorine dioxide has the advantage of being a strong disinfectant against bacteria, viruses and some protozoans *Giardia* and *Cryptosporidium* spp, and even more effective than chlorine at pH 8.5. It does not form Trihalomethanes (THMs) or oxidize bromide to bromate**.(Sivey et al., 2010)**

2. Hydrogen peroxide

Hydrogen peroxide works by producing destructive hydroxyl free radicals that can attack membrane lipids, DNA, and other essential cell components **(CDC, 2008).** Catalase, produced by aerobic organisms and facultative anaerobes that possess cytochrome systems, can protect cells from metabolically produced Hydrogen peroxide by degrading Hydrogen peroxide to water and oxygen. This defense is overwhelmed by the concentrations used for disinfection. Hydrogen peroxide is active against a wide range of microorganisms, including bacteria, yeasts, fungi, viruses, and spores. Under normal conditions, Hydrogen peroxide is extremely stable when properly stored (e.g., in dark containers). The

decomposition or loss of potency in small containers is less than 2% per year at ambient temperatures.

3. Ozone

Ozone is widely used in disinfecting drinking water in Europe. Its inactivation of microbes is not fully understood but it is thought to include both direct and indirect reactions with the gas and with the free radicals from its dissociation respectively. It is known to attack unsaturated bonds forming carbonyl compounds and participates in electrophilic and nucleophilic reactions with aromatic compounds and components of microbial cells. Carbohydrates and fatty acids react slightly with ozone but amino acids, proteins, protein functional groups and nucleic acids all react very rapidly with it. Therefore, microbes become inactivated through ozone acting on the cytoplasmic membrane (due to the large number of functional proteins), the protein structure of a virus capsid, or nucleic acids of microorganisms. However, heterotrophic bacteria are less susceptible to ozone inactivation than Giardia spp because these bacteria contain carotenoid and flavonoid that protect them from ozone **(WHO, 2004).**

4. Persulfate

The generation of sulfate radical and its disinfection efficacy is usually investigated by activating persulfate using ferrous iron Fe(II) at ambient temperature and slightly acidic pH **(Dawit&**

Haizhou, 2014). The strong oxidative potential of sulfate radical is likely to effectively inactivate bacteria at optimized treatment process.

In recent years, the Sulfate Radical-based AOP (SR-AOP) has been proposed as an alternative process. It involves the generation of highly reactive free sulfate radicals ($SO_4^{\bullet-}$) with an oxidation potential of 2.5–3.1 V **(Ghanbari & Moradi, 2017).** Compared with the well-known hydroxyl radical ($^{\bullet}OH$), the $SO_4^{\bullet-}$ is more stable and more selective, and it has a longer half-life time. Peroxodisulfate salts are common precursors of sulfate radicals and can be found in the form of potassium, sodium, and ammonia salts; with the sodium peroxodisulfate ($Na_2S_2O_8$) being the most used **(Wacławek et al. ,2017).** The activation of persulfate under UV light is produced with a high absorption coefficient; it implies the generation of a sulfate radical with a high quantum yield **(Lutze et al., 2015).**

Physically, one of the most implemented processes is ultraviolet radiation (UV) in its most germicidal wavelength range, UV-C **(Javier et al., 2019).** UV light can also be used for the generation of radicals when it is combined with different chemicals, such as ozone, Hydrogen peroxide or persulfate. These processes are called Hydroxyl Radical based, which have been demonstrated as being effective for disinfection with different purposes **(Miklos et al., 2018).**

VII. Water and Wastewater treatment Methods:

As a common method of treating wastewater, disinfection has gained popularity. Disinfection is still the method most usually used to inactivate microorganisms **(Chaukura et al., 2020).** It is an important step in water treatment process that eliminates and renders inactive waterborne pathogens (**Huertas et al., 2007**) and help in eliminating pathogenic and dangerous bacteria **(Sun et al., 2019).** In water treatment, many physical methods of disinfection such as cleaning processes, and ultraviolet disinfection were used **(Richardson and Postigo, 1998).**

Numerous studies have demonstrated that chemical pretreatment using substances like chlorine, chlorine dioxide, ozone, or permanganate can improve the effectiveness of chemical coagulation techniques for removing algae **(Plummer & Edzwald, 2002; Knappe et al., 2004).** It was found that Chlorine is the most prevalent coagulant for water treatment **(Ghernaout, 2019).**

Consequently, using chemical oxidants to disinfect water has been one of the major advancements in public health have been made during the past century **(Ghernaout et al., 2009).** In traditional methods of treating water, coagulation is the crucial stage. It is widespread practice to treat water using chemical coagulation. Every day during the operation of waterworks, the efficient reduction of clay, silt, organic matter, algae, and bacteria in

surface waters is proved. Although detailed reports on the coagulation of clays and other inorganic sols have been made, but the coagulation of algae has not received the same level of research **(Djamel et al., 2014).**

Algal extracellular products hinder the coagulation-flocculation process, which increase turbidity and reduces chlorine disinfection effectiveness. Filter leakage by algae results in an off-putting taste and odor **(Babel et al., 2002).** Because they don't dramatically alter the current workflow, chemical techniques for algal removal are regarded as being both affordable user-friendly because there wouldn't be a big change to the current workflow and there wouldn't be an increase in the number of large-scale buildings and equipment. Chlorine affect algal cells firstly by piercing the cell wall and then damaging the cytoplasmic enzymes **(Shen et al., 2011; Li et al., 2016).**

Small household water filtration devices have become more prevalent in poorer nations in recent years. Reverse osmosis systems are one type of water treatment system. It include a front filter, a water pump and (PP cotton column and activated carbon adsorption column), Rear filter (usually an activated carbon adsorption column), reverse osmosis filter element, and water faucets are frequently used to treat residential drinking water **(Fahiminia et al., 2014; Garfi et al., 2016).** Peroxidation, coagulation and flocculation, clarifying by dissolved air flotation (DAF) or

sedimentation, and granular media filtration are the typical steps in the treatment chain used to remove algae. Both direct filtration and the usage of ultra filtration can be employed as a clarification technique **(Henderson et al., 2008; Fast et al., 2014; Qu et al., 2012).**

The chemical preoxidants, which are strong oxidants, can enhance algae coagulation by destabilizing or inactivating algal cells or by releasing extracellular organic materials (EOM). Activated carbon adsorption, ion exchange, reverse osmosis, electron dialysis, and the addition of disinfectants are some of the methods used to purify groundwater for residential use. Numerous methods, both with and without the use of chemical or biological agents, have been proposed to avoid the formation of blooms and to reduce algae. The two most popular pretreatment methods for increasing the effectiveness of algae removal are pre-oxidation and pre-chlorination. **(Chen et al., 2009; Ma et al., 2012)** The efficiency of algal removal depends on the amount of chlorine used, time of the treatment and the pH **(Ho et al. ,2006 ; Ma et al., 2012) .** Disadvantage in using of chlorine is to react with organic materials to create carcinogenic disinfection byproducts such trichloromethanes and chloroacetic acids, however, has recently raised concerns **(Gao et al., 2018). Chen & Bridgeman (2017),** discovered that *Chlorella vulgaris* concentration was significantly

lowered by UV- radiation from lamps that may be powered by solar panels, with clear changes by radiation level.

VIII. Electrochemical disinfection

Electrochemical disinfection has gained increasing interest in many sectors of social and industrial life. The reason is the growing need to disinfect the air, water, and special water surfaces of different nature such as drinking water, wastewater, pool water, and other water qualities. New research studies are reported and discussed. A stronger orientation on engineering aspects is intended, better cooperation between researchers and industry working together to improve cell design and disinfection technology. Partially, reaction kinetics is studied and discussed at higher levels of likelihood. Furthermore, it can be found that more research papers deal with hybrid technologies to create novelty, to use synergistic effects and to meet the demands of real system treatment under practical conditions. A major focus can be identified for wastewater treatment/disinfection emphasizing electrocoagulation and electro-photocatalysis.

Electrochemical disinfection (ED) belongs to the physical-chemical methods of disinfecting systems. Normally, these systems are of liquid nature. Sometimes, pathogen-containing gases are absorbed before being inactivated. Actually, ED is not clearly defined, and so, in the broadest sense, under ED, the killing or

inactivation of microorganisms (MOs) by means of electrochemistry must be understood. Electrochemical disinfection is mainly based on the oxidation power of disinfectants in the electrode layer or the bulk of **electrolytes (Bruguera-Casamada et al., 2016; Ghernaout, 2017)**. Often, damage to the intracellular enzyme system is mentioned as the main reason for inactivating MOs **(Bruguera-Casamada et al., 2016).**

MOs can also be killed at relatively low electrode potentials in electron exchange reactions when they are closely adsorbed to electrodes **(Matsunaga et al., 1994).** The method is time consuming and not efficient. The more modern technology is that of adsorbing MOs combined with electrochemical oxidation and killing of attached MOs are possible if radicals are produced by electrodes having higher oxygen overvoltage. The role of direct oxidation by hydroxyl radicals (OH) is often lower than expected - due to short radical lifetime, reaction competition, and when a relatively low number of MOs is adsorbed at the electrode **(Lllés et al. ,2019).** In the case of gas evolution, weakened MOs can be mechanically removed from the surface **(Rice et al. ,2018).**

The choice of electrode material poses a conundrum in terms of electrical conductivity, electrochemical stability, financial dependability, environmental availability and other factors **(Gao, et al., 2018).** Numerous electrode materials and cell designs have been researched in recent years **(Bakheet et al., 2018).**

Liang et al., (2011) detected a considerably reduced degree of *Microcystis aeruginosa* disinfection when chlorine free electrolytes were utilized in electrochemical tubes using Ti/RuO_2 as anodes. As a promising electrode material for the efficient electrochemical deactivation of algae, **Gao et al., (2018),** mentioned Monolithic Ceramic Electrode (MCE, i.e., monolithic titanium suboxides). The electrochemically process produced oxidative species on MCE were connected to the efficient deactivation of *M. aeruginosa*.

In addition, using Boron Doped Diamond (BDD) anodes considerably improved the removal of algae **(Wang et al., 2018).** It would seem that devices with high electrochemical treatment are effective, reliable, straightforward, and affordable design that would be better suited for in situ use.

According to **Locker et al., (2014),** it may be possible to use carbon-based electrodes in an extremely affordable, disposable assembly to produce antimicrobiological hypochlorite at the source using only a simple DC applied current in an undivided cell. **Saha & Gupta (2017),** showed that carbon electrodes have a lot of potential for electrochlorination systems as an affordable alternative device in comparing with the more expensive platinum electrodes.

IX. Electrochemical Production of persulfate

Sodium persulfate has been prepared by direct electrolysis. Usually, the electrolysis involved an aqueous solution of sodium sulfate and sulfuric acid as a feed or starting solution. Electrolysis of solutions containing initially sodium sulfate and ammonium sulfate and sulfuric acid have been described in which the relatively small amounts of sodium sulfate were used to facilitate obtaining higher concentrations of dissolved persulfate.

The process of the present invention can be utilized as a continuous cyclic process for the direct electrolytic preparation of sodium peroxydisulfate ($Na_2 S_2 O_8$) with high current efficiencies in a plurality of electrolytic cells having protected cathodes by the direct electrolysis using neutral aqueous anolyte feed solutions in which there is dissolved a sufficient amount of a mixture of sulfates and peroxydisulfates of sodium and ammonium to provide a neutral anolyte **(Wan et al ., 2019).**

X. Electrochemical Production of Hydrogen peroxide

Electrochemical Hydrogen peroxide synthesis using two-electron oxygen electrochemistry is an intriguing alternative to currently dominating environmentally unfriendly and potentially hazardous anthraquinone process and noble metals catalyzed direct synthesis. Electrocatalytic two-electron oxygen reduction reaction (ORR) and water oxidation reaction (WOR) are the source of

electrochemical Hydrogen peroxide generation. Various electrocatalysts have been used for the same and were characterized using several electroanalytical, chemical, spectroscopic and chromatographic tools **(Hilles et al., 2016).**

Though there have been a few reviews summarizing the recent developments in this field, none of them have unified the approaches in catalysts' design, criticized the ambiguities and flaws in the methods of evaluation, and emphasized the role of electrolyte engineering. In addition, particularized discussions on fundamental oxygen electrochemistry, additional methods for precise screening, and the role of solution chemistry of synthesized Hydrogen peroxide are also presented.

There are many previous studies on the use of disinfectants to remove algae and bacteria) **Chena & Yehb, 2005., Shen et al., 2011., Mascia et al., 2013., Monasterio et al., 2014., Wang et al., 2016., Dong et al., 2017., Mohamed et al., 2020., Bhatt et al., 2022., Kekedy-Nagy et al., 2022., Yang et al., 2022., Shokoohi et al., 2023., Wang et al., 2023.**

Chapter II

Materials and Methods

A. Study area

1. Study area includes EL-Amyria drinking water station which is located in Cairo governorate (N 30^{o} 06' 39″, E 31 16' 451″). Water and phytoplankton samples were collected from the canal at site closing to the input of inuput of the Drinking treatment Station that serves EL-Amyria district the drinking water treatment plantet of EL-Amyria produces daily about 650 thousand m^{3} of Drinking – water. **Fig (1)**
2. Rod El-Farag water station is considered one of the oldest and largest water stations affiliated with the Drinking Water Company in Cairo (N 30^{o} 04' 53″, E 31 13' 418″), as it was established in 1865 and serves nearly 5 million citizens living in the areas of "El-Abagiya and Telal Zeinhom - and Sayeda Zainab, Shubra, Khalfawy, El-Daras, Bulaq Abu El-Ela, Mrs. Aisha, Ramses, Opera, Abbasiya, Al-Zawiya El-Hamra and Sabtieh The station operates 24 hours a day to meet the water needs of citizens within a sophisticated work system that ensures the sustainability of the service without interruption. produces 60,000 cubic meters per day.**Fig (1)**

Figure (1) Locations of sampling stations)a, b (of EL-Amyria and Rod El-Farag Drinking Water Stations.

B. Materials

Water samples were collected during winter and spring seasons and phytoplankton samples were collected seasonally from the water ways feeding the two drinking water stations during 2021-2022.

Methods

1. Collection of samples

Composite water samples were collected from two stations, stored in clean glass bottles containers, kept in a refrigerator, and analyzed a few hours after their arrival from the field. Some physical parameters were measured for each sample at the time of sampling.

Phytoplankton samples were collected from El- Amyria and Rod El Farag stations by filtering 40 liters of water in a **15** μm phytoplankton net. The volume of filtered water was calculated and reduced to a total volume equal to 100 ml. After the rapid examination, the samples were preserved in 4% formalin. Each sample was divided into two parts, one for identification and the other for counting and determination of algal biomass.

2. Preparation and analysis of algae samples

2.1 Cleaning of diatoms:

Identification of diatoms is mainly dependent on the fine ornamentation on the valve surface. firstly, it is necessary to remove

all organic matter and internal content **(Taylor et al ,2007).** Method has been used in order to clean diatoms as follows:

1- 01 ml of the fixed material was washed several times with distilled water and centrifuged till become free from formation

2- Under afume hood, 20 ml of H_2O_2 was added and allowed to boil for 20- 30 minutes to remove the organic matter

3- On cooling few drops of HCl were added to clear the material from colloidal organic carbon.

4- This mixture is then washed by distilled water several times till it becomes H_2O_2

5- Few milliliters of alcohol were added after the final washing to prevent the growth of pathogens.

2.3 Mounting of diatoms the method (Taylor et al; 2007) was adopted as follows:

1- A single drop of ammonium chloride (NH_4Cl; 10% solution) is added for every 10 ml of diluted diatom suspension to neutralize electrostatic charges on the suspended particles and reduce aggregation.

2-By means of a clean dry micropipette, 0.1ml of the cleaned diatom suspension was placed on clean cover slip.

3-The diatoms were distributed evenly on the cover and allow to dry without artificial heat.

4-The cover slip was heated gently to make the diatom frustules adhere firmly to the cover slip.

5-A suitable quantity of mountant of sufficiently high refractive index (R.1.= 1.68) was placed on a clean slide and allowed to be liquefied by gentle warming **(Elaishev, 1957).**

6-The cover slip with film of diatoms was inverted onto the slide and applied gently to the mountant .

7-The slide with the cover slip on it was warmed gently until medium had exactly filled the space between the slide and the cover in this step must take care to avoid the formation of air bubbles.

8-The slide was left to dry horizontally.

2.4 Identification of algal taxa

Examination identification and counting were carried out by using oil immersion lens (100x) in case of diatoms and 40 x lens in case of other algal taxa of trinocular microscope (Microstar AO) fitted with a digital camera for taking photomicrographs The algal taxa were identified according to **Desikachary, (1959), Prescott, (1962); Patrick and Reimer, (1966, 1975), Hortobagyi, (1973), Krammer and Lange-Bertalot, (1986,1988)., Round et al., (1990) and Bellinger and Sigee, (2015).**

2.5 Counting of algal taxa:

The counting of the identified algae was determined by using a counter chamber, where 1 ml of the sample was injected to fill the squares of the chamber, in case of colonial or filamentous species, each of the previous morphology was counted as one individual. The quantity of phytoplankton was estimated as number of individuals per liter.

2.6. Determination of Chlorophyll (mg/l): Chlorophyll was determined by fluorometer **(Aquaflour- Turner desing)**

3. Determination of the physico- chemical Characteristics of Water Samples

3.1 A. Physical parameters:

i-Turbidity (NTU): Turbidity was determined using turbidity meter (EZTECHTU-2016).

3.2 B. Chemical Parameters:

Chemechal parameters of water were measured according to **APHA (2012)** as follows:

i. Electrical conductivity (EC) (micro Siemens) : Was measured with EC meter, Orion 150A+, Thermo Electron Corporation , USA.

ii. Hydrogen ion concentration (pH): was measured with a pH Meter, 3510, Jenway, UK

iii. Carbonate (mg/l): Standard method 2320 (Titration method)

iv. Bicarbonate (mg/l): Standard method 2320 (Titration method).

v. Total Dissolved Solids (TDS) mg /l: EPA 160.1

vi. Biological Oxygen Demand (BOD) mg /l : International standards ISO 5815-1:2003.

vii. Dissolved Oxygen (DO) (mg/l): Dissolved oxygen concentration in water was determined using dissolved oxygen meter (JENWAY model 970).

viii. Chemical Oxygen Demand (COD)(mg/l): EPA 410.1

ix. Nitrite N-NO_2^- (mg/l): Was measured with VELP UDK29 Series Distillation Units.

x. Nitrate N-NO_3^- (mg/l): Was measured with VELP UDK29 Series Distillation Units

xi. Ammonia N-NH_4^+ (mg/l): Was measured with VELP UDK29 Series Distillation Units

xii. Phosphorus (mg/l): EPA 300.1

xiii. Silicon, mg /l: Analysis of heavy metals in gm / l inductively Argon , ICAP 6500 Duo ,Thermos Scientific , England . 1000 mg /l

multi – element certified standard solution, Merck ,Germany was used as stock solution for instrument standardization.

4. Preparation of Electrochemical Disinfectants:

1. Sodium persulfate :

Several concentrations of Sodium Sulfate were prepared 2.5%, 5%, 7.5%, 10% at pH concentrations 3 by adding HCl. 50ml from each concentration was added to 50 ml of raw water sample. These volumes (50 ml Sodium sulfate + 50 ml raw water) were inserted into the reactor cell having Graphite cathode and platinum anode. The operating condition of the experiment was adjusted at certain potential 2.0V/2.5 V during the duration of one hour. After 24 hours of electrochemical process, 20 ml of the electrolyzed sample was added to 0.5 g of KI. Some drops of starch and 1 ml of concentrated sulfuric acid were added. The appearance of a blue color indicates the formation of sodium persulfate. The sample was titrated by Sodium thiosulfate and the end point is achieved by the disappearance of the dark blue color. The concentration of the disinfectant (Sodium persulfate) was determined according to the following equations:

The production of persulfate is mainly occurred by electrolyzing the sulfate in an acidic solution and the main reactions are as follows:

$2SO_4^{2-} \rightarrow S_2O_8^{2-} + 2e^-$ ($E^o = 2.01$ V) (1)

$2HSO_4^- \rightarrow S_2O8_2^- + 2H^+ + 2e^-$ ($E^o = 2.12$V) (2)

$2H^+ + 2e^- \rightarrow H_2\uparrow$ ($E^o = 0.00$V) (3)

where reactions (1), (2) occur on anode surface and reaction (3) occurs on cathode surface **(Block et al., 2004).**

2. Hydrogen peroxide (H_2O_2):

Potassium Chloride (KCl) of 0.05g dissolved in 100 ml of distilled water. The pH was 5.6, 50 ml of KCl concentration was added to 50 ml of raw water. These volumes (50 ml KCl + 50 ml raw water) were inserted in the electrochemical devise. The operating condition was adjusted at 1.2 V potential during 30 minutes with the using of stirrer. After the electrochemical process, 20 ml of the analyzed sample was taken and added with 1 ml of H_2SO_4. Titration was carried out by Potassium Permanganate ($KMnO_4$) (0.016) grams Potassium Permanganate dissolved in 100 ml distilled water). The end point is indicated by the appearance of the pink color. Formation of the disinfectant Hydrogen peroxide is formed according to the equations:

Hydrogen peroxide (H_2O_2) is Electrochemically produced via oxygen (O_2) reduction on a carbon cathode surface. In order to enhance the production of H_2O_2, anodic loss pathways, which significantly reduce the overall H_2O_2 production rate, should be inhibited.

Two pathways are available for the electrochemical generation of H_2O_2:

(1) Reduction of O_2 on an appropriate cathode and

(2) Oxidation of water on a suitable anode material (e.g., an anode with a high overpotential).

$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$ Reduction (1)

$2H_2O \rightarrow H_2O_2 + 2H^+ + 2e^-$ Oxidation (2)

The electrochemical synthesis of H_2O_2 is still limited by the decomposition of H_2O_2 on the surfaces of both the cathode (Eqs. (3), (4)) and anode (Eqs. (5), (6), (7)) **(Hilles et al., 2016).**

$H_2O_2 + e^- + H^+ \rightarrow H_2O + \bullet OH$ (3)

$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$ (4)

$H_2O_2 \rightarrow HO_2\bullet + H^+ + e^-$ (5)

$H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$ (6)

$H_2O_2 + HO\bullet \rightarrow HOO\bullet + H_2O$ (7)

Apparatus

The apparatus used in the experiment was (Autolab potentiostat). A 100 ml glass cylinder cell was used as the electrolysis cell with two graphite electrodes (2×0.8×0.4 cm). Both the anode and cathode has a working surface area of about 6

cm^2. 100 ml of working solution (50 ml of raw water diluted with 50 ml of concentration) were taken for the experimental work. The working electrodes were connected together through external wires, while the potential was adjusted to the desired value. All experiments were conducted at room temperature (25°C ± 2°C) for 24 hours. The apparatus used in this Study is shown in Fig. (2).

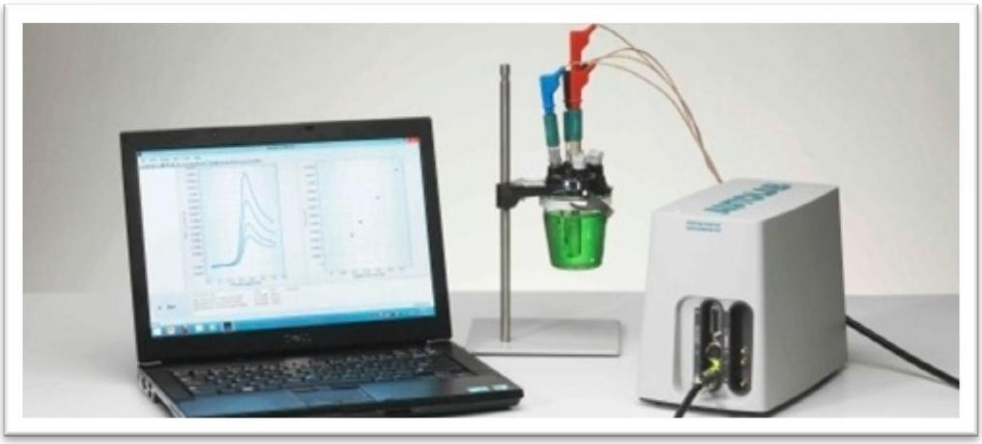


Fig. (2): Electrolysis apparatus with the working cell.

Results

A. Electrochemical disinfectants and treatment part

Electrochemical Production of Sodium persulfate ($Na_2S_2O_8$)

The electrolysis of pure water using inert electrodes, hydrogen gas is evolved at one electrode and oxygen gas is observed at the other. The two half-reactions and the overall balanced reaction are shown below:

$$2H_2O_{(l)} + 2e^- \rightarrow H_2(g) + 2OH^-_{(aq)}$$

Reduction reaction:

$$.2H_2O(l) \rightarrow O_2(g) + 4H^+ + 4e^-$$

Oxidation reaction:

$$2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_2(g)$$

By definition, the anode of an electrochemical cell is the electrode at which oxidation occurs and the cathode is the electrode at which reduction occurs. The production of hydrogen gas from water involve oxidation and/or reduction reaction, it may be helpful to review the rules for assigning oxidation numbers. 1. An element in elemental form has an oxidation state of zero 2. Oxygen always has an oxidation state of zero, unless it is a peroxide (O_2^{2-}) or superoxide (O^{-2}) 3. Hydrogen always has an oxidation state of +1 unless it is a hydride, in which case it has an oxidation state of –1 4. The sum of the oxidation states for the atoms in a Molecule must add to the charge on the Molecule from these rules, you should be able to see that in water the hydrogen has an oxidation state of +1 and the

oxygen has an oxidation state of –2. Therefore, the production of hydrogen from water is a reduction (from an oxidation state of +1 to 0) and occurs at the cathode, whereas the production of oxygen from water is an oxidation (from an oxidation state of –2 to 0) and occurs at the anode. Electrons enter the cell through the cathode (where the reduction reaction or "consumption" of electrons occurs), travel through the solution, and return through the anode (where the oxidation or "liberation" of electrons occurs). Therefore in an electrolysis cell the electrode connected to the negative terminal of the power supply is the cathode and is electrode connected to the positive terminal of the power supply is the anode.

The production of Sodium Peroxydisulfate ($Na_2S_2O_8$) can be done by performing electrolysis on a saturated solution of Na_2SO_4. The cell consists of a platinum anode and a graphite cathode. The associated half-reactions are:

$2H^+_{(aq)} + 2e^- \rightarrow H_2$ (g) reduction, cathode reaction can be done by performing electrolysis on a saturated solution of Na_2SO_4. The cell consists of a platinum anode and a graphite cathode. The associated half-reactions are:

$2H^+_{(aq)} + 2e^- \rightarrow H_2$ (g) reduction, cathode reaction

$2HSO_4^-{}_{(aq)} \rightarrow S_2O_8^{2-}{}_{(aq)} + 2e^-$ oxidation, anode reaction

The oxidation reaction has a large negative potential (-2.01 volts) and theoretically cannot compete with the oxidation of water (-1.23 volts). However, a high concentration of H_2SO_4 is employed (a saturated solution) to make the reaction less unfavorable. A starch-

iodine titration to determine the quantity of the $Na_2S_2O_8$ was performed. The peroxydisulfate ion is a strong oxidizing agent and is capable of oxidizing the iodide ion to Molecular iodine as shown by the equation:

$$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2$$

A standard method of determining iodine is the reduction to the iodide ion using sodium thiosulfate:

$$I_2 + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2I^-$$

In such titrations soluble starch functions as an indicator because it forms an intensely colored blue-black complex with Molecular iodine. As the thiosulfate is added, the iodine is reduced to the iodide ion, and the blue-black color disappears once all of the iodine has reacted. The method used for determining the content of synthesized sodium peroxydisulfate will be to allow a measured quantity to react with an excess of potassium iodide, producing Molecular iodine which then can be titrated with standard sodium thiosulfate using starch as an indicator.

A Sample Calculation Let's work an example of the type of calculation you will be performing in lab. Suppose that a 0.25-gram sample of $Na_2S_2O_8$ is titrated according to the procedure described above. If 12.50 ml of 0.10 M $Na_2S_2O_3$ are required to reach the end point, determine the purity of the sample. According to the stoichiometry of the reaction, 1 Mole of Sodium Persulfate ions oxidizes two Moles of iodide ions to 1 Mole of Molecular iodine. This one Mole of Molecular iodine reacts with two Moles of Sodium Thiosulfate. Ultimately, therefore, one Mole of Sodium Persulfate

ions reacts with two Moles of thiosulfate ions. The number of Moles of thiosulfate ion added can be determined from the volume and concentration of the solution: 0.0125 l x 0.10 Mol/l = 0.00125 Moles Now apply the reaction stoichiometry; two Moles of thiosulfate ion are required to react with one Mole of Sodium Persulfate ion. Therefore, the number of Moles of Sodium Persulfate ion in the sample is half this number. Number of Moles of $S_2O_8^{2-}$ = 0.00125/2 = 0.000625 Moles Now multiply this number of Moles by the Molar mass of Sodium Persulfate: 0.000625 Moles x 238.11 gm /Mol= 0.15 grams Finally, express this as a percentage of the original mass: (0.15 grams / 0.25 grams) x 100 = 60%.

The volume of Sodium Persulfate formed in the raw water of the El-Amryia drinking water station during the spring season were shown in **Table 1**.

The volume was at a concentration of 2.5% and for a voltage of 2 Volt 0.00055 Mol, while at a concentration of 5.0% the volume of Sodium Persulfate was 0.00037 Mol/l At a concentration of 7.5%, the volume of Sodium Persulfate was 0.00032 Mol/l. At a concentration of 10.0%, the volume was 0.00040 Mol/l.

As for the voltage 2.5 Volt and for the same concentrations, the volume of Sodium Persulfate in a concentration of 2.5% was 0.00050 Mol/l and the volume in a concentration of 5.0% was 0.00055 Mol/l . At a concentration of 7.5%, the volume was 0.00100

Mol/l, while the volume at a concentration of 10% was 0.00180 Mol/l .

Table 2 shows the results of the volume of Sodium Persulfate formed in the raw water of El-Amyria drinking water station for the summer using four different concentrations of sodium sulfate. The volume was at a concentration of 2.5% and for a voltage of 2 Volt 0.00087 Mol/l , while at a concentration of 5.0% the volume of Sodium Persulfate was 0.00370 Mol/l At a concentration of 7.5%, the volume of Sodium Persulfate was 0.00175 Mol/l **.** At a concentration of 10.0%, the volume was 0.00175 Mol/l

As for the voltage 2.5 Volt and for the same concentrations, the volume of Sodium Persulfate at a concentration of 2.5% was 0.00110 Mol/l , and the volume at a concentration of 5.0% was 0.00085 Mol/l At a concentration of 7.5%, the volume was 0.00115 Mol/l , while the volume at a concentration of 10% was 0.00140 Mol/l .

Table 3 shows the results of the volume of Sodium Persulfate formed in the raw water of El-Amyria drinking water station for the fall season using four different concentrations of sodium sulfate. The volume was at a concentration of 2.5% and for a voltage of 2 Volt 0.00085 Mol/l , while at a concentration of 5.0% the volume of Sodium Persulfate was 0.00055 Mol/l At a concentration of 7.5%, the volume of Sodium Persulfate was 0.00085 Mol/l . At a concentration of 10.0%, the volume was 0.00067 Mol/l

As for the voltage 2.5 Volt and for the same concentrations, the volume of Sodium Persulfate in a concentration of 2.5% was 0.00057 Mol/l , and the volume in a concentration of 5.0% was 0.00062 Mol/l At a concentration of 7.5%, the volume was 0.00065 Mol/l , while the volume at a concentration of 10% was 0.00070 Mol/l

Table (1). Volume (V) and Concentration (Mol/l) of Sodium Persulfate prepared at different voltage condition in relevancy with the investigated percentages at El-Amyria Drinking Water Station during Spring season.

No.	% (Na_2SO_4)	V ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_8$)
	2 Volt			
1	2.5%	110	0.00110	0.00055
2	5.0%	75	0.00075	0.00037
3	7.5%	65	0.00065	0.00032
4	10.0%	80	0.00080	0.00040
	2.5 Volt			
1	2.5%	100	0.00100	0.00050
2	5.0%	110	0.00110	0.00055
3	7.5%	200	0.00200	0.00100
4	10.0%	360	0.00360	0.00180

Table (2). Volume (V) and Concentration (Mol/l) of Sodium Persulfate prepared at different voltage condition in relevancy with the investigated percentages at El-Amyria Drinking Water Station during Summer season.

No.	% (Na_2SO_4)	V ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_8$)
	2 Volt			
1	2.5%	175	0.00175	0.00087
2	5.0%	750	0.00750	0.00370
3	7.5%	350	0.00350	0.00175
4	10.0%	345	0.00345	0.00175
	2.5 Volt			
1	2.5%	220	0.00220	0.00110
2	5.0%	170	0.00170	0.00085
3	7.5%	230	0.00230	0.00115
4	10.0%	280	0.00280	0.00140

Table (3). Volume (V) and Concentration (Mol/l) of Sodium Persulfate prepared at different voltage condition in relevancy with the investigated percentages at El-Amyria Drinking Water Station during Autumn season.

No.	% (Na_2SO_4)	V ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_8$)
	2 Volt			
1	2.5%	170	0.00170	0.00085
2	5.0%	110	0.00110	0.00055
3	7.5%	170	0.00170	0.00085
4	10.0%	135	0.00135	0.00067
	2.5 Volt			
1	2.5%	115	0.00115	0.00057
2	5.0%	125	0.00125	0.00062
3	7.5%	130	0.00130	0.00065
4	10.0%	140	0.00140	0.00070

From **Table 4** it was found that, during winter the volume was at a concentration of 2.5% and for a voltage of 2 Volt 0.00040 Mol/l. while at a concentration of 5.0% the volume of Sodium Persulfate was 0.00052 Mol/l. and at a concentration of 7.5%, the volume of Sodium Persulfate was 0.00057 Mol/l. At a concentration of 10.0%, the volume was 0.00062 Mol/l.

As for the voltage 2.5 Volt and for the same concentrations, the volume of Sodium Persulfate in a concentration of 2.5% was 0.00085 Mol/l. and the volume in a concentration of 5.0% was 0.00092 Mol/l. At a concentration of 7.5%, the volume was 0.00095 Mol/l. while the volume at a concentration of 10% was 0.00100 Mol/l.

In case of using potential difference 2.0 volt is higher than that in case of 2.5 volt, and that volume increases with increase in sodium sulfate content from 2.5% to 10.0%. This result indicates that the suitable potential for maximum production of Sodium Persulfate is 2.0 volt. As in figures.(3 and 4)

Table (4). Volume (V) and Concentration (Mol/l) of Sodium Persulfate prepared at different voltage condition in relevancy with the investigated percentages at El-Amyria Drinking Water Station during Winter season.

No.	% (Na_2SO_4)	V ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_8$)
	2 Volt			
1	2.5%	80	0.00080	0.00040
2	5.0%	105	0.00105	0.00052
3	7.5%	115	0.00115	0.00057
4	10.0%	125	0.00125	0.00062
	2.5 Volt			
1	2.5%	170	0.00170	0.00085
2	5.0%	185	0.00185	0.00092
3	7.5%	190	0.00190	0.00095
4	10.0%	200	0.00200	0.00100

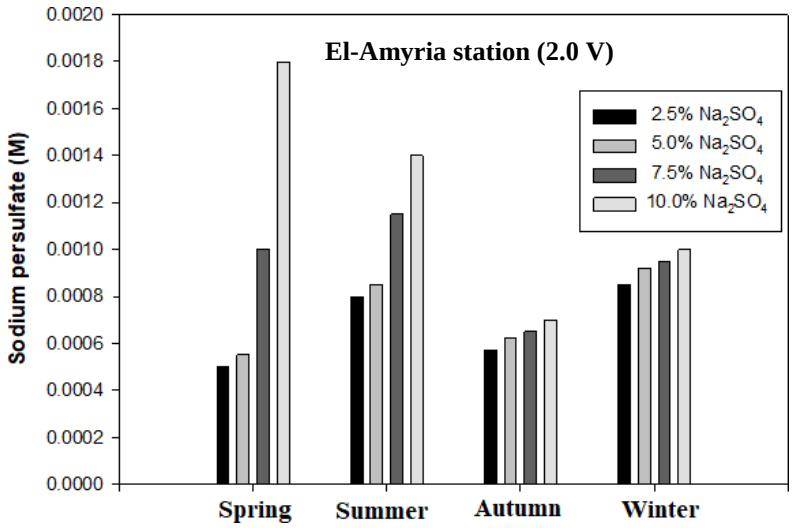


Figure (3): Relationship between Sodium Persulfate (M) production and initial sulfate concentration for El-Amyria Drinking Water Station at potential voltage 2.0 V along different seasons.

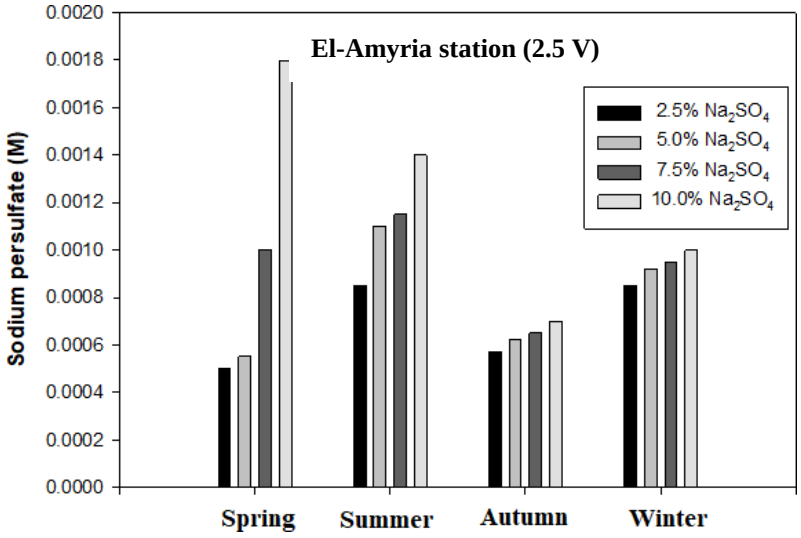


Figure (4): Relationship between Sodium Persulfate (M) production and initial sulfate concentration for El-Amyria Drinking Water Station at potential voltage 2.5 V along different seasons.

For Rod El-Farag drinking water station it was observed that, during spring the volume was at a concentration of 2.5% and for a voltage of 2 Volt 0.00072 Mol/l. while at a concentration of 5.0% the volume of Sodium Persulfate was 0.00100 Mol/l. and. At a concentration of 7.5%, the volume of Sodium Persulfate was 0.00107 Mol/l. At a concentration of 10.0%, the volume was 0.00112 Mol/l. As for the voltage 2.5 Volt and for the same concentrations, the volume of Sodium Persulfate in a concentration of 2.5% was 0.00085 Mol/l. and the volume in a concentration of 5.0% was 0.00055 Mol/l. At a concentration of 7.5%, the volume was 0.00047 Mol/l. while the volume at a concentration of 10% was 0.00042 Mol/l. **(Table 5).**

Table 6 shows the results of the volume of Sodium Persulfate formed in the raw water of the Rod El-Farag drinking water station for the summer using four different concentrations of sodium sulfate. The volume at a concentration of 2.5% and for a voltage of 2 Volt was 0.00072 Mol/l. while at a concentration of 5.0% the volume of Sodium Persulfate was 0.00100 Mol/l. and. At a concentration of 7.5%, the volume of Sodium Persulfate was 0.00107 Mol/l. At a concentration of 10.0%, the volume was 0.00075 Mol/l.

As for the voltage 2.5 Volt, the volume of Sodium Persulfate in a concentration of 2.5% was 0.00085 Mol/l and the volume in a concentration of 5.0% was 0.00047 Mol/l , while at a concentration of 7.5%, the volume was 0.00055 Mol/l. while the volume at a concentration of 10% was 0.00042 Mol/l.

In Table 7 it was noticed that, the volume was at a concentration of 2.5% and for a voltage of 2 Volt 0.00057 Mol/l. while at a concentration of 5.0% the volume of Sodium Persulfate was 0.00062 Mol/l. and. At a concentration of 7.5%, the volume of Sodium Persulfate was 0.00069 Mol/l. At a concentration of 10.0%, the volume was 0.00070 Mol/l. As for the voltage 2.5 Volt and for the same concentrations, the volume of Sodium Persulfate in a concentration of 2.5% was 0.00085 Mol/l. and the volume in a concentration of 5.0% was 0.00055 Mol/l. at a concentration of 7.5%, the volume was 0.00085 Mol/l. while the volume at a concentration of 10% was 0.00067 Mol/l.

Finally, during winter the volume was at a concentration of 2.5% and for a voltage of 2 Volt 0.00085 Mol/l. while at a concentration of 5.0% the volume of Sodium Persulfate was 0.00092 Mol/l. and. At a concentration of 7.5%, the volume of Sodium Persulfate was 0.00095 Mol/l. At a concentration of 10.0%, the volume was 0.00100 Mol/l. As for the voltage 2.5 Volt and for the same concentrations, the volume of Sodium Persulfate in a concentration of 2.5% was 0.00040 Mol/l. and the volume in a concentration of 5.0% was 0.00052 Mol/l. while at a concentration of 7.5%, the volume was 0.00057 Mol/l. while the volume at a concentration of 10% was 0.00062 Mol/l. **(Table 8).**

Table (5). Volume (V) and Concentration (Mol/l) of Sodium Persulfate prepared at different voltage condition in relevancy with the investigated percentages at Rod El-Farag Drinking Water Station during Spring season.

No.	% (Na_2SO_4)	V ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_8$)
	2 Volt			
1	2.5%	145	0.00145	0.00072
2	5.0%	200	0.00200	0.00100
3	7.5%	215	0.00215	0.00107
4	10.0%	225	0.00225	0.00112
	2.5 Volt			
1	2.5%	170	0.00170	0.00085
2	5.0%	110	0.00110	0.00055
3	7.5%	95	0.00095	0.00047
4	10.0%	85	0.00085	0.00042

Table (6). Volume (V) and Concentration (Mol/l) of Sodium Persulfate prepared at different voltage condition in relevancy with the investigated percentages at Rod El-Farag Drinking Water Station during Summer season.

No.	% (Na_2SO_4)	V ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_8$)
	2 Volt			
1	2.5%	145	0.00145	0.00072
2	5.0%	200	0.00200	0.00100
3	7.5%	215	0.00215	0.00107
4	10.0%	150	0.00150	0.00075
	2.5 Volt			
1	2.5%	170	0.00170	0.00085
2	5.0%	95	0.00095	0.00047
3	7.5%	110	0.00110	0.00055
4	10.0%	85	0.00085	0.00042

Table (7). Volume (V) and Concentration (Mol/l) of Sodium Persulfate prepared at different voltage condition in relevancy with the investigated percentages at Rod El-Farag Drinking Water Station during Autumn season.

No.	% (Na_2SO_4)	V ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_8$)
	2 Volt			
1	2.5%	115	0.00115	0.00057
2	5.0%	125	0.00125	0.00062
3	7.5%	139	0.00139	0.00069
4	10.0%	140	0.00140	0.00070
	2.5 Volt			
1	2.5%	170	0.00170	0.00085
2	5.0%	110	0.00110	0.00055
3	7.5%	170	0.00170	0.00085
4	10.0%	135	0.00135	0.00067

Table (8). Volume (V) and Concentration (Mol/l) of Sodium Persulfate prepared at different voltage condition in relevancy with the investigated percentages at Rod El-Farag Drinking Water Station during Winter season.

No.	% (Na_2SO_4)	V ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_3$)	Conc. Mol/l ($Na_2S_2O_8$)
	2 Volt			
1	2.5%	170	0.00170	0.00085
2	5.0%	185	0.00185	0.00092
3	7.5%	190	0.00190	0.00095
4	10.0%	200	0.00200	0.00100
	2.5 Volt			
1	2.5%	80	0.00080	0.00040
2	5.0%	105	0.00105	0.00052
3	7.5%	115	0.00115	0.00057
4	10.0%	125	0.00125	0.00062

The results indicated that the suitable result indicates that the suitable potential for maximum production of Sodium Persulfate is 2.0 volt. (Fig. 5 and 6)

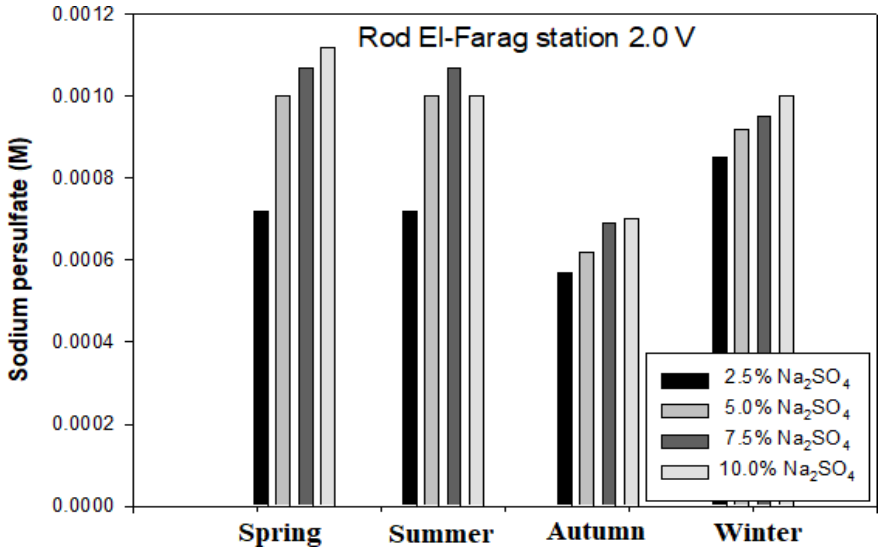


Figure (5): Relationship between Sodium Persulfate (M) production and initial sulfate concentration for Rod El-Farag Drinking Water Station at potential voltage 2.0 V along different seasons.

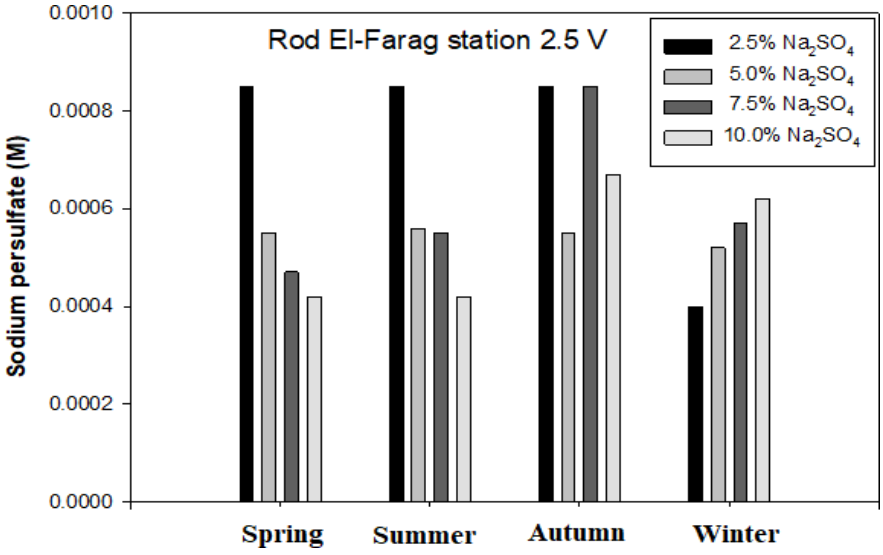


Figure (6): Relationship between Sodium Persulfate (M) production and initial sulfate concentration for Rod El-Farag Drinking Water Station at potential voltage 2.5 V along different seasons

Through the study along the two studied drinking water stations, the efficiency of different concentrations of Sodium Persulfate disinfectant (2.5%, 5.0%, 7.5%, and 10%) was investigated on raw water and the water laden by algae. It was appeared that 10% concentration of $Na_2S_2O_8$ was the best and effective concentration to be chosen for raw water at optimum current potential 2 V. For the second disinfectant (H_2O_2) 2.5% concentration with 1.2 V potential current was considered to be the optimum condition for raw water.

B. Impacts of operating conditions of Sodium Persulfate and Hydrogen Peroxide on Physico- chemical characteristics of water :

Physical parameters

1- **Turbidity** :

Turbidity values during the study period at El-Amyria drinking water station for raw water recorded a value of 8.07 (Nephelometric Turbidity Unit) (NTU) during spring and 3.19 NTU in winter.

Its value for the disinfectant Sodium Persulfate was for the spring for a concentration of 10% estimated at 5.4 NTU, and its value for the winter was 7.4 NTU.

As for the turbidity values for the Hydrogen Peroxide disinfectant, the value for the spring season was equal to 16.4 NTU, and the value for the winter season was equal to 8.4 NTU.

As for Rod El-Farag drinking water station, the value of turbidity for raw water for the spring season was equal to 10.20 NTU, and the value for the winter season was estimated at 2.03 NTU. The value of Sodium Persulfate disinfectant for a concentration of 10% for the spring season was estimated at 8.4 NTU and its value for the winter was 10.3 NTU As for the value of Hydrogen Peroxide, it was 3.3 NTU for the spring season, and its value during the winter season was equal to 7.4 NTU, as shown in Table 9.

Table (9). Turbidity values (NTU) of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El-Amyria & Rod El-Farag Drinking Water Stations.

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amyria	8.07	5.4	16.4	3.19	7.4	8.4
Rod El-Farag	10.20	8.4	3.3	2.03	10.3	7.4

Chemical parameters:

1- Electrical conductivity (EC) mS/cm:

The EC values during the study period at El-Amyria drinking water station for raw water were 499.0 mS /cm for the spring season and 499.0 mS/cm for the winter season.

Its value for the disinfectant Sodium Persulfate was for the spring for a concentration of 10% estimated at 91200.0 mS/cm, and its value for the winter was 91300.0 mS/cm.

As for the (EC) values for the Hydrogen Peroxide disinfectant, the value for the spring season was 866.0 mS/cm, and the value for the winter was 871.0 mS/cm.

As for Rod El-Farag drinking water station, the value of (EC) for raw water in the spring season was equal to 500 mS/cm, and the value for the winter season was estimated at 495.0 mS/cm.

The value of Sodium Persulfate disinfectant at a concentration of 10% for the spring was estimated at 84600.0 mS/cm, and its value for the winter was 84600.0 mS/cm. As for the value of Hydrogen Peroxide, it was 819.0 mS/cm for the spring, and its value during the winter was 819.0 mS/cm (Table 10).

Table (10). Electrical Conductivity (Ec) values, microsiemens per centimetre (mS/cm) of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El-Amyria & Rod El-Farag Drinking Water Stations.

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amyria	499.0	91200.0	866.0	499.0	91300.0	871.0
Rod El-Farag	500	84600.0	819.0	495.0	84600.0	819.0

2- Hydrogen Ion Concentrations (pH):

The pH values recorded during the study period at El-Amyria drinking water station for raw water were 7.6 for the spring season and 6.9 for the winter season.

Its value for the disinfectant Sodium Persulfate was for the spring season for a concentration of 10% estimated at 2.7, and its value for the winter season was 2.7.

As for the pH values for the Hydrogen Peroxide disinfectant, the value for the spring season was 6.2 and the value for the winter season was 6.2.

As for the Rod El-Farag drinking water station, the pH value of raw water for the spring season was 8.27, and its value for the winter season was estimated at 7.7.

The value of Sodium Persulfate disinfectant at a concentration of 10% for the spring season was estimated at 2.7, and its value for the winter season was 2.7. As for the value of Hydrogen Peroxide, it was 6.9 for the spring season, and its value during the winter season was equal to 6.6 (Table 11).

Table (11). Hydrogen ion concentrations (pH) values of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El -Amyria & Rod El-Farag Drinking Water Stations

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amyria	7.6	2.7	6.2	6.9	2.7	6.2
Rod El-Farag	8.27	2.7	6.9	7.7	2.7	6.6

3- Alkalinity:

The total alkalinity of water is characterized by the concentrations of carbonate (CO_3^{--}) and bicarbonate (HCO_3^{-}). Since the carbonate concentration in the water of both stations was too low to be detected by the method used in this study, its value was neglected, and the alkalinity of the water was determined depending on the bicarbonate concentration.

The values of bicarbonate during the study period at El- Amyria drinking water station for raw water during the spring season recorded a value of 241.1 mg/L and its value for winter was 239.1 mg/L.

Its value for the disinfectant Sodium Persulfate was for the spring season for a concentration of 10% estimated at Nil, and its value for the winter season was Nil.

As for the values of Bicarbonate for the Hydrogen Peroxide disinfectant, the value for the spring season was equal to 85.4 mg/l, and the value for the winter season was equal to Nil.

As for Rod El-Farag drinking water station, the value of Bicarbonate for raw water in spring was 95.16 mg/l, and its value for winter was estimated at 247.7 mg/l.

The value of Sodium Persulfate disinfectant for the concentration of 10% for the spring season was estimated at Nil, and its value for the winter season was Nil. As for the value of Hydrogen Peroxide, it was 75.4 mg/l for the spring season, and its value during the winter season was equal to 93.9 mg/l, as shown in (Table 12).

Table (12). Bicarbonate (HCO_3^-) values (mg/l) of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El- Amyria & Rod El-Farag Drinking Water Stations

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amyria	241.1	Nil	85.4	239.1	Nil	85.4
Rod El-Farag	95.16	Nil	75.4	247.7	Nil	93.9

4- Total dissolved solids (TDS) mg /l :

The values of (TDS) during the study period in El-Amyria drinking water station of the raw water during the spring season recorded a value of 300.1 mg/l and its value for the winter season was 281.2 mg/l.

Its value for the disinfectant Sodium Persulfate was for the spring, for a concentration of 10%, estimated at 69570.5 mg/l, and its value for the winter was 69569.4 mg/l.

As for the (TDS) values for the Hydrogen Peroxide disinfectant, the value for the spring season was equal to 434.9 mg/l and the value for the winter season was equal to 427.8 mg/l.

As for Rod El-Farag drinking water station, the TDS value for raw water for the spring season was equal to 320 mg/l, and its value for the winter season was estimated at 341.1 mg/l.

The value of Sodium Persulfate disinfectant for the concentration of 10% for the spring season was estimated at 65265.4 mg/l, and its value for the winter season was 65268.4 mg/l. As for the value of Hydrogen Peroxide, it was 461.7 mg / l for the spring season, and its value during the winter season was equal to 461.7 mg / l (Table 13).

Table (13). Total Dissolved Solids (TDS) values (mg/l) of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El -Amyria & Rod El-Farag Drinking Water Stations

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amyria	300.1	69570.5	434.9	281.2	69569.4	427.8
Rod El farag	320	65265.4	461.7	341.1	65268.4	461. 7

5- Biological Oxygen Demand (BOD) mg /l :

During the study period, the values of (BOD) in El-Amyria drinking water station of the raw water recorded a value of 7.1 mg/l for the spring, and its value for the winter was 7.4 mg/l.

Its value for the disinfectant Sodium Persulfate was for the spring season for a concentration of 10% estimated at Nil, and its value for the winter season was Nil.

As for the (BOD) values for the Hydrogen Peroxide disinfectant, the value for the spring season was equal to 2.1 mg/l and the value for the winter season was equal to 2.1 mg/l.

As for Rod El-Farag drinking water station, the value of (BOD) for raw water in the spring was equal to Nil mg/l, and its value for the winter was estimated at 1.8 mg /l.

The value of Sodium Persulfate of 10% concentration for the spring season was estimated at Nil, and its value for the winter season was 2.4 mg/l. As for the value of Hydrogen Peroxide, it was for the spring season, Nil, and its value during the winter season was equal to 5.2 mg/l (Table 14).

Table (14). Biological Oxygen Demand (BOD) values (mg/l) of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El-Amyria & Rod El-Farag Drinking Water Stations

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amyria	7.1	Nil	2.1	7.4	Nil	2.1
Rod El-Farag	Nil	Nil	Nil	1.8	2.4	5.2

6- Dissolved Oxygen (DO) mg/l :

The values of (DO) during the study period in El-Amyria drinking water station of the raw water recorded a value of 9.50 mg/l for the spring, and its value for the winter was 9.54 mg/l.

Its values for the disinfectant Sodium Persulfate were for the spring, for a concentration of 10%, estimated at 0.73 mg/l, and for the winter, they were 0.78 mg/l.

As for the (DO) values for the Hydrogen Peroxide disinfectant, the value for the spring season was equal to 7.70 mg/l and the value for the winter season was equal to 7.78 mg/l.

As for Rod El-Farag drinking water station, the value of (DO) for raw water for the spring season was equal to 9.60 mg/l, and its value for the winter season was estimated at 9.62 mg/l.

The value of Sodium Persulfate disinfectant at a concentration of 10% for the spring season was estimated at 0.43 mg/l, and its value for the winter season was 0.43 mg/l. As for the value of Hydrogen Peroxide, it was 8.15 mg / l for the spring season, and its value during the winter was equal to 8.15 mg / l (Table 15).

Table (15). Dissolved Oxygen (DO) values (mg/l) of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El -Amyria & Rod El-Farag Drinking Water Stations

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amyria	9.50	0.73	7.70	9.54	0.78	7.78
Rad El-Farag	9.60	0.43	8.15	9.62	0.43	8.15

7- Chemical Oxygen Demand (COD) mg/l :

The values of **COD** during the study period in the El- Amyria drinking water station of the raw water recorded a value of 16.15 mg/l for the spring season and its value for the winter was 17.15 mg/l.

The values for the disinfectant Sodium Persulfate were for the spring, for a concentration of 10%, estimated at 5 mg/l, and the value for the winter was 5 mg/l.

As for the **COD** values for the Hydrogen Peroxide disinfectant, the value for the spring season was equal to 7.8 mg/l and the value for the winter season was equal to 7.8 mg/l.

As for Rod El-Farag drinking water station, the value of **COD** for raw water for the spring season was equal to 354.1 mg/l, and its value for the winter season was estimated at 11 mg/l.The value of Sodium Persulfate disinfectant for a concentration of 10% for the spring was estimated at 90 mg /l, and its value for the winter was 51 mg/l. As for the value of Hydrogen Peroxide, it was for the spring 20 mg/l, and its value during the winter was equal to 20 mg/l, as shown in the Table 16.

Table (16). Chemical Oxygen Demand (COD) values (mg/l) of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El-Amyria & Rod El-Farag Drinking Water Stations

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amyria	16.15	5	7.8	17.15	5	7.8
Rod El-Farag	354.1	90	20	11	51	20

8- Nitrite N-NO_2^- mg/l:

The values of N-NO_2^- during the study period at the EL-Amyria drinking water station of the raw water recorded a value of 0.114 mg/l for the spring and 0.116 mg/l for the winter.

Its value for the disinfectant Sodium Persulfate was for the spring season for a concentration of 10% estimated at Nil, and its value for the winter season was Nil.

As for the values of $N\text{-}NO_2^-$ for the Hydrogen Peroxide disinfectant, the value for the spring season was 0.035 mg/l, and the value for the winter season was 0.038 mg/l.

As for Rod El-Farag drinking water station, the value of $N\text{-}NO_2^-$ for raw water for the spring season was equal to 0.049 mg/l, and its value for the winter season was estimated at Nil.

The value of Sodium Persulfate disinfectant for the concentration of 10% for the spring season was estimated at Nil, and its value for the winter season was Nil. As for the value of Hydrogen Peroxide, it was Nil for the spring season, and its value during the winter season was equal to Nil (Table 17).

Table (17). Nitrite $N\text{-}NO_2^-$ values(mg/l) of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El -Amyria & Rod El-Farag Drinking Water Stations

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amyria	0.114	Nil	0.035	0. 116	Nil	0.038
Rod El-Farag	0.049	Nil	Nil	Nil	Nil	Nil

9- Nitrate $N\text{-}NO_3^-$, mg/l :

The values of $N\text{-}NO_3^-$ during the study period at the El- Amyria drinking water station of the raw water recorded a value of 28.35 mg/l for the spring season and its value for the winter was 32.34 mg/l.

Its values for the disinfectant Sodium Persulfate were for the spring, for a concentration of 10%, estimated at 14.15 mg/l, and their value for the winter was 16.17 mg/l.

As for the values of $N\text{-}NO_3^-$ for the Hydrogen Peroxide disinfectant, the value for the spring season was equal to 4.50 mg/l and the value for the winter season was equal to 4.62 mg/l.

As for Rod El-Farag drinking water station, the value of $N\text{-}NO_3^-$ for raw water in spring was 17.92 mg/l, and its value for winter was estimated at 49.28 mg/l.

The value of 10% Sodium Persulfate disinfectant for the spring season was estimated at 7.15 mg/l and its value for the winter season was 12.73 mg/l. As for the value of Hydrogen Peroxide, it was 3.50 mg/l for the spring season, and its value during the winter season was equal to 10.25 mg/l (Table 18).

Table (18). Nitrate N-NO_3^- values(mg/l) of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El- Amyria & Rod El-Farag Drinking Water Stations

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amiria	28.35	14.15	4.50	32.34	16.17	4.62
Rod El-Farag	17.92	7.15	3.50	49.28	12.73	10.25

10- Ammonia N-NH_4^+, mg/l

The values of NH_4^+ during the study period at the EL-Amyria drinking water drinking water of the raw water station recorded a value of 8.39 mg/l for the spring season and its value for the winter was 8.47 mg/l.

Its values for the disinfectant Sodium Persulfate were for the spring season for a concentration of 10% estimated at 1.50 mg/l and its value for the winter was 1.54 mg/l

As for the values of NH_4^+ for the Hydrogen Peroxide disinfectant, the value for the spring season was 3.03 mg/l, and the value for the winter season was 3.08 mg/l.

As for Rod El-Farag drinking water station, the value of NH_4 for raw water in spring was 4.48 mg/l, and its value for winter was estimated at 0.5 mg/l. The value of Sodium Persulfate disinfectant at a concentration of 10% for the spring season was estimated at 5.22

mg/l, and its value for the winter season was 3.85 mg/l. As for the value of Hydrogen Peroxide, it was 10.25 mg/l for the spring season, and its value during the winter season was equal to 6.16 mg/l, as shown in Table 19.

Table (19). Ammonia N- NH_4^+ values(mg/l) of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El- Amyria & Rod El-Farag Drinking Water Stations

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amyria	8.39	1.50	3. 03	8.47	1.54	3.08
Rod El-Farag	4.48	5.22	10.25	0.5	3.85	6.16

11- Phosphorus , mg/l :

Phosphorus values were <0.008 mg/l during the study period at El-Amyria drinking water station of the raw water for spring and <0.007 mg/l for winter.

Its values for the disinfectant Sodium Persulfate were for the spring, for a concentration of 10%, estimated at 2.150 mg/l, and the value for the winter was 2,156 mg/l.

As for the values of Phosphorus for the Hydrogen Peroxide disinfectant, the value for the spring season was <0.005 mg/l, and the value for the winter season was <0.007 mg/l.

As for the Rod El-Farag drinking water station, the value of Phosphorus for raw water for the spring season was equal to 1. 500 mg/l and its value for the winter was estimated at 1.406 mg/l. The value of 10% Sodium Persulfate disinfectant for the spring season was estimated at 1.064 mg/l and its value for the winter season was 1.736 mg/l. As for the value of Hydrogen Peroxide, it was <0.005 mg/l in the spring and its value during the winter was <0.007 mg/l (Table 20).

Table (20). Phosphorus values (mg/l) of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El -Amyria & Rod El-Farag Drinking Water Stations

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amyria	<0.008	2.150	<0.005	<0 .007	2.156	<0 .007
Rod El-Farag	1. 500	1.064	<0.005	1.406	1.736	<0 .007

12- Silicon mg/l:

Silicon values recorded during the study period at the El-Amyria drinking water station of the raw water during the spring a value of 0.0486 mg/l and its value for the winter was 0.0489 mg/l.

Its values for the disinfectant Sodium Persulfate were for the spring, for a concentration of 10%, estimated at 0.2905 mg/l, and the value for the winter was 0.2907 mg/l.

As for the silicon values for the Hydrogen Peroxide disinfectant, the value for the spring season was <0.07 mg/l, and the value for the winter season was <0.07 mg/l.

As for Rod El-Farag drinking water station, the value of silicon for raw water for the spring season was 0.8871 mg/l, and its value for the winter season was estimated at 0.0628 mg/l.

The value of Sodium Persulfate disinfectant for the concentration of 10% for the spring season was estimated at 0.2905 mg/l and its value for the winter season was <0.07 mg/l. As for the value of Hydrogen Peroxide, it was 0.1372 mg/l for the spring season, and its value during the winter season was equal to 0.1372 mg/l, as shown in Table 21.

Table (21). Silicon values (mg/l) of raw and treated water by the disinfectants ($Na_2S_2O_8$10%, H_2O_2) during spring and winter seasons in El -Amyria & Rod El-Farag Drinking Water Stations

Station	Spring			Winter		
	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%	Raw Water	$Na_2S_2O_8$ 10%	H_2O_2 2.5%
El-Amyria	0.0486	0.2905	<0.07	0.0489	0.2907	<0.07
Rod El-Farag	0.8871	0.2905	0.1372	0.0628	<0.07	0.1372

C. Algal Composition and Phytoplankton density of the investigated stations:

The algal composition of raw water collected from El-Amyria drinking water station belonged to 3 algal divisions (Cyanophyta , Chlorophyta , Bacillariophyta (Table 22). Concerning the phytoplankton density, it was observed that the highest phytoplankton density was detected during autumn season**,** while the lowest density were obtained in summer and spring seasons (Fig. 7).

The finding results were confirmed by the determination of chlorophyll content where the highest values of chlorophyll were obtained in autumn season followed by winter season and the lower chlorophyll contents were observed during spring and summer seasons respectively (Fig. 8).

Bacillariophyta was the highest division during the spring season in terms of cell density by 4040 individuals/l belonging to 6 genera, followed by Chlorophyta with 760 individuals/l belonging to 6 genera, and finally Cyanophyta with 160 individuals/l belonging to 4 genera.

In summer, Division Bacillaroiphyta was dominant division in terms of the number of individuals where 4120 individuals/l were determined, belonging to 7 genera, followed by Chlorophyta with 560 individuals belonging to 9 genera, then Cyanophyta by 160 individuals/l belonging to 3 genera **(Table 22).**

During autumn, Bacillaroiphyta still the dominant division with 97, 160 individuals/l belonged to 4 genera followed by Chlorophyta, with 2,020 individuals belonging to 10 genera and finally Cyanophyta with 1800 individuals/l belonging to 5 genera.

Similarly, in winter season, the phytoplankton dominancy was not changed as Bacillaroiphyta was dominated by 12,360 individuals belonging to 5 genera, followed by Chlorophyta by 960 individuals belonging to 10 genera then Cyanophyta, came in the last place by 600 individuals belonging to 6 genera.

Table (22). Algal composition and phytoplankton cell density (number of individuals/l) of raw water of El- Amyria Drinking Water Station at different seasons during 2021/2022.

Taxa	Spring	Summer	Autumn	Winter
Division : Cyanophyta				
Genus : *Anabaena* Bory de SainVincent ex				
Anabaena sphaerica Bornet & Flahault	40	40	40	40
Genus: *Gloeocapsa* Kützing				
Gloeocapsa decorticans (A.Braun) P.Richter	40		40	40
Genus: *Gomphosphaeria* Kützing				
Gomphosphaeria aponina Kütz.	40		200	40
Genus .*Merismopedia* Meyen				
Merismopedia tenuissima Lemm.	80		480	80
Merismopedia elengans (A.Braun ex Kützig)		40	400	
Genus: *Microcystis* Kützing				
Microcystis aeruginosa Kütz.		40	600	80
M. flos - aquae (Witlr.) Kirchner		40	40	120
Genus: *Oscillatoria* Vaucher				
Oscillatoria pseudogeminata G. Schmid				80
O. tenuis Ag. ex Gomont				40
O. subbrevis schmidle				80
Division: Chlorophyta				
Genus: *Actinastrum* Lagerheim				
Actinastrum Hantzchii Lagerheim			120	80
Genus: *Ankistrodesmus* Corda				
Ankistrodesmus falcatus (Corda) Ralfs.		40		
Genus: *Coelastrum* Nägeli				
Coelastrum microporum Nägeli	40	40	160	80
C. proboscideam Bohlin				

C. reticulatum (Dang.) Senn	40	40	200	40
Genus : *Crucigenia* Morren				
Crucigenia crucifera (Wolle) Collins				40
Genus: *Dictyosphaerium* Nägeli				
Dictyosphaerium pulchellum Wood	40	40	40	
Genus: *Golenkinia* Chodat				
Golenkinia radiata Chodat			200	40
Genus: *Kirchneriella* Schmidle				
Kirchneriella aeruginosa (Kützing) Henfrey			40	
K. lunris (Kirchner) Möbius		40	40	40
Genus: *Oocystis* Nägeli				
Oocystis borgei J.W.Snow		40	80	40
Genus: *Pediastrum* Meyen				
Pediastrum Boryanum (Turp.) Meneghini	40			
P. duplex var. gracillimum West & G. West		40		
P. simplex Meyen	120	40	160	80
P. simplex var. duodenarium (Bailey) Rabenhorst	80	160	140	200
P. tetras (Ehren.) Ralfs	80			
Genus: Scenedesmus Meyen				
Scendesmes acutus Meyen	40	40	200	
S. quadricauda Brebisson	40		240	40
S. acuminatus (lag .) Chodat			40	80
S. bijuga (Turpin) Lagerh.			40	40
Genus: *Staurastrum* Meyen				
Staurastrum elliptium West			40	
S. paradoxum Meyen	200	80	240	80
Genus :Tetraëdron Kützing				
Tetraëdron minimum (A.Braun)Hansgirg	40	40		
Genus:Schizochlamys Braun ex Kützing				
Schizochlamys gelatinosa A.Braun				80

Schizochlamys compacta Prescott			40	
Division : Bacillariophyta				
Genus: *Aulacoseira* Thwaites				
Aulacoseira granulata (Ehr.) Simonsen	1360	1000	6440	1880
A. granulata var. *angustissima* (O. F. Müller) Simonsen	520	800	2720	6680
Genus: *Asterionella* Hassall				
Asterionella formosa Hassall	80	40		
Genus: *Cyclotella* Kützing				
C. meneghiniana Kütz.	80	40	400	160
C. ocellata Pant.	600	120	3600	1520
Genus: *Cymbella* Agradh				
Cymbella affinis Kütz.		40		
Genus: *Navicula* Bory				
Navicula cryptocephala Kützing		40		
N. cuspidata Kützing	40	80	40	80
Genus: *Nitzschia* Hassal				
Nitzschia palea (Kütz.) W. Smith	960	40		40
Genus: *Synedra* Ehrenberg				
Synedra ulna (Nitzch.) Ehrenberg	400	1920	83960	2040
Total	**5000**	**4920**	**100980**	**06931**

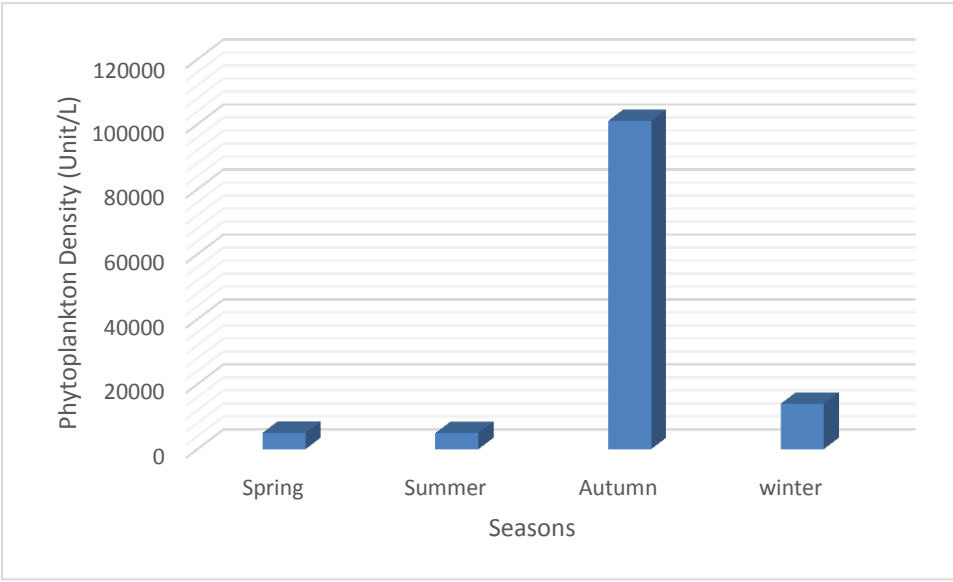


Figure (7): Phytoplankton Density (individuals/l) in raw water at EL-Amyria Drinking Water Station at different seasons during 2021-2022.

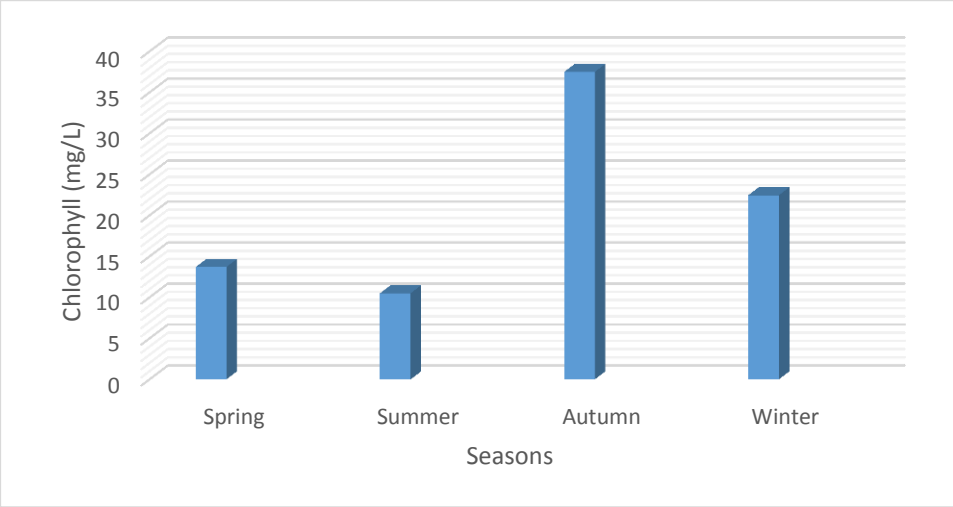


Figure (8): Chlorophyll (mg/L) in raw water at EL-Amyria Drinking Water Station at different seasons during 2021-2022.

Algae in raw water of Rod-El Farag drinking water station were belonged to Cyanophyta, Chlorophyta and Bacillariophyta algal divisions (Table 23). I t was found that the total algal cell density was the highest one during autumn season by 69800 units/l followed by spring season by 18480 units/l, then the winter season by 10720 units/l and finally the lower algal density was found during summer season by 3960 units/l (Fig. 9).

Regarding to the chlorophyll concentrations, it was observed that the higher chlorophyll concentration in the raw water were found during winter and autumn seasons by 21 and 14 mg/l respectively and decreased to reach its lower value during spring and summer seasons by 9 mg/l (Fig. 10).

In spring season Bacillariophyta was the dominance division in terms of numbers of individuals by 11,440 individuals/l belonging to 6 genera and 8 species, followed by division Chlorophyta with 5,200 individuals belonging to 12 genera and 19 species, and division Cyanophyta with 1,840 individuals/l belonging to 5 genera and 5 species.

During the summer season, Bacillaroiphyta also predominates in terms of number of species, with 3080 individuals/l belonging to 5 genera to 7 species, followed by Chlorophyta as the number of species of this division was 640 individuals belonging to 9 genera belonging to 13 species, then Cyanophyta came in the last place with 240 individuals belongs to 5 genera and 5 species.

Regarding the autumn season, the total number of individuals were increased to reach the highest algal density where Bacillaroiphyta was dominating the phytoplankton density with 6240 algal cells belonging to 6 genera out of 9 species, followed by division Chlorophyta, by 3560 individuals belonging to 9 genera and 17 species, while Cyanophyta was observed by 1720 individuals belong to 5 genera and 5 species.

In winter, the diatoms species dominated the phytoplankton flora with 7440 species belonging to 5 genera and 7 species, followed by the blue green algae by 2000 individuals belonging to 5 genera and 6 species, and green algae by 1160 algal cells related to 11 genera and 19 species.

Table (23). Algal composition and phytoplankton cell density (number of individuals/l) of raw water of Rod EL- Farag Drinking Water Station at different seasons during 2021/2022.

Taxa	Spring	Summer	Autumn	Winter
Division : Cyanophyta				
Genus : *Anabaena* Bory de SainVincent ex				
Anabaena sphaerica Bornet &Flahault	80	40	40	
Genus: *Gloeocapsa* Kützing				
Gloeocapsa decorticans (A.Braun) P.Richter	80	40	40	40
Genus: *Gomphosphaeria* Kützing				
Gomphosphaeria aponina Kütz.	520	40	200	80
Genus .*Merismopedia* Meyen				
Merismopedia tenuissima Lemm.	1000	80	1000	1680
M. glauca (Ehrenb)				40
Genus :*Microcystis* Kützing				
Microcystis flos - aquae (Witlr.) Kirchner	160	40	440	80
Genus: *Oscillatoria* Vaucher				
Oscillatoria princeps Vaucher *ex* Gomont				80
Division: Chlorophyta				
Genus: *Actinastrum* Lagerheim				
Actinastrum Hantzchii Lagerheim		40	280	40
Genus: *Ankistrodesmus* Corda				
Ankistrodesmus falcatus (Corda) Ralfs.	1200	40	40	
Genus: *Characium* A. Braun in Kützing				
Characium Ornithocephalum A.Braun				40
C. gracilipes lamhert				40
Genus: *Coelastrum* Nägeli				
Coelastrum microporum Nägeli	80	40	520	120
C. reticulatum (Dang.) Senn	40	80	40	40
Genus : *Crucigenia* Morren				
Crucigenia crucifera (Wolle) Collins	160			40
C. quadrata Morren				40
Genus: *Dictyosphaerium* Nägeli				
Dictyosphaerium pulchellum Wood	80		120	120
Genus: *Golenkinia* Chodat				
Golenkinia radiata Chodat	40	40		80
G. paucispina West &West (lemm)				80
Genus: *Kirchneriella* Schmidle				
Kirchneriella lunris Kirchner Möbius	120	40	240	
Genus : Lagerheimia Chodat				

Lagerheimia citriformis (J.W snow) collins	40			
Genus: *Oocystis* Nägeli				
Oocystis borgei J.W.Snow	40	40	560	80
Genus: *Pediastrum* Meyen				
Pediastrum Boryanum (Turp.) Meneghini	240			
P. duplex var. gracillimum West & G. West	40	80	200	
P. simplex Meyen	640	80	80	
P. simplex var. duodenarium (Bailey) Rabenhorst	560	40	40	40
P. tetras (Ehren.) Ralfs	400		40	40
Genus: Scenedesmus Meyen				
Scendesmes *acutus* Meyen	240	40	40	
S. quadricauda Brebisson	160	40	240	80
S. acuminatus (lag .) chodat			80	40
S. bijuga J.W.Snow	40		280	40
Genus: *Staurastrum* Meyen				
Staurastrum elliptium west			40	40
S. paradoxum Meyen	1000	40	720	40
Genus :Tetraëdron Kützing				
Tetraëdron minimum (A.Braun)Hansgirg	80			120
Division : Bacillariophyta				
Genus: Asterionella Hassall				
Asterionella formosa Hassall	240			120
Genus: *Aulacoseira* Thwaites				
Aulacoseira granulata (Ehr.) Simonsen	2720	1320	1960	760
A. granulata var. *angustissima* (O. F. Müller) Simonsen	1840	40	1800	2800
Genus: *Cyclotella* Kützing				
C. meneghiniana Kütz.	1040	80	40	120
C. ocellata Pant.	2000	120	2360	2400
Genus: *Navicula* Bory				
Navicula cuspidata Kutzing	80	40	40	40
Genus: *Nitzschia* Hassal				
Nitzschia palea (Kütz.) W. Smith	1920	40		200
Genus: *Synedra* Ehrenberg				
Synedra ulna (Nitzch.) Ehrenberg	1600	1440	58320	1120
Total/L	**18480**	**3960**	**69800**	**10720**

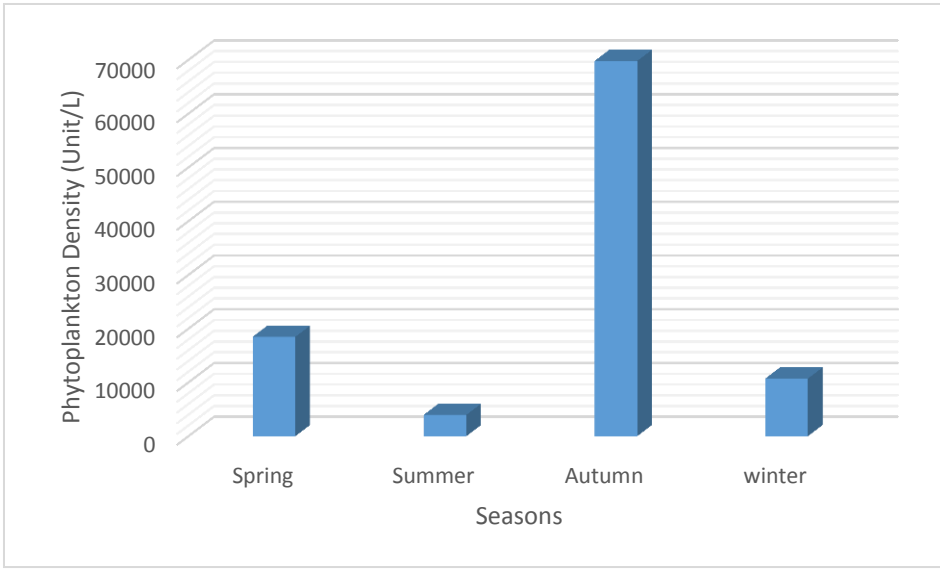


Figure (9): Phytoplankton Density (individuals/l) in raw water at Rod EL- Farag Drinking Water Station at different seasons during 2021-2022.

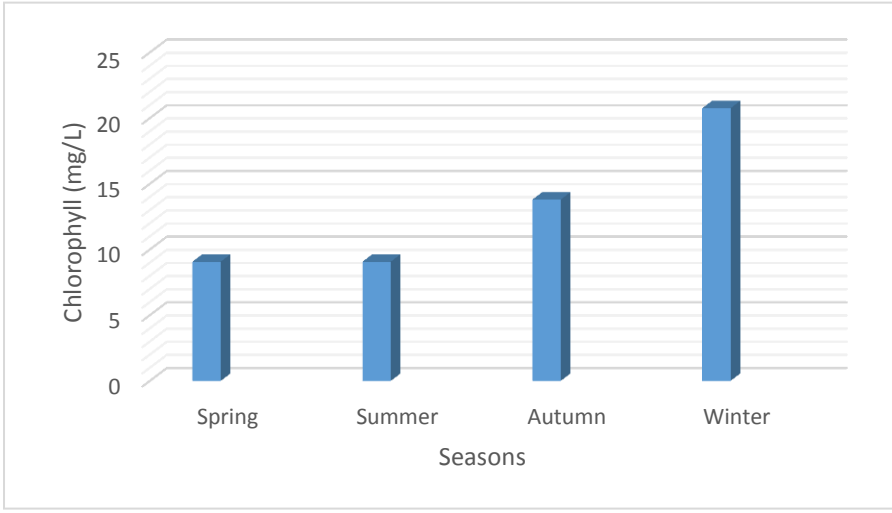


Figure (10): Chlorophyll (mg/L) in raw water at Rod EL- Farag Drinking Water Station at different seasons during 2021-2022.

D. The effects of Sodium Persufate and Hydrogen Peroxide on algal composition of water at the investigated stations:

D.1. El-Amirya Drinking Water Station

The results in **Table 24** showed that the algae cell density during the spring season after treatment with Sodium Persulfate disinfectant was 690 units/l at 2.5% concentration and of 2.5 volt current potential , while for a voltage of 2.0 volts was 580 units/l. At a concentration of 5.0% for a voltage of 2.5 volts, the total number did not exceed 430 units/l and for a voltage of 2.0 volts, the total number of algae was 460 units/l. At the concentration of 7.5%, the total numbers of algae for a voltage of 2.5 volts was 930 units/l and for a voltage of 2.0 volts the number was 370 units/l. At a 10% concentration of Sodium Persulfate for a voltage of 2.5 V, the numbers did not exceed 260 units/l, while for a voltage of 2.0 V, the total was 180 units/l. For Hydrogen Peroxide disinfectant the number was 250 units/l for concentration 2.5% for voltage 1.2 V.

From **Table 25,** during summer season after treatment with Sodium Persulfate, at concentration of 2.5% for the voltage of 2.5 V the total cell density was 590 units/l, while for the voltage of 2.0 V the total was 440 units/l. At a concentration of 5.0% for a voltage of 2.5 V, the total did not exceed 620 units/l, and at voltage of 2.0 V the total algal density was 600 units/l. For concentration of 7.5%, it was found that the total density for a voltage of 2.5 V was 480 and for a

voltage of 2.0 V the number was 360 Units/l. At a 10% concentration for a voltage of 2.5 V, the total did not exceed 480 units/l, while for a voltage of 2.0 V, the total was 260 units/l. As for H_2O_2 disinfectant the algal density was 290 units/l for a concentration of 2.5% for a voltage of 1.2 V.

The results in **Table 26**, shows the phytoplankton density during autumn season after treatment with Sodium Persulfate and Hydrogen Peroxide disinfectant, where the rate of preparation for the concentration was 2.5% for the voltage 2.5 V the total number of individuals was 610 units/l, while for the voltage 2.0 V, the number was 420 units/l. At a concentration of 5.0% for a voltage of 2.5 V, the number did not exceed 300 mg/l, and for a voltage of 2.0 V, the number of algae species was 530 units/l. Concentration of 7.5%, for the voltage 2.5 V the algal numbers was 630 units/l and for the voltage 2.0 V the number was 470 units/l. At a concentration of 10% phytoplankton density was the lowest one as for the voltage of 2.5V, it was not exceed 270 units/l, while for the voltage of 2.0 V the numbers were 160 units/l. For H_2O_2 the average number of algal cell was 340 units/l for concentration 2.5% for voltage 1.2V.

In winter, after the treatment with Sodium Persulfate, at concentration of 2.5% for the voltage 2.5 V the total algal density was 280 units/l, while for the voltage 2.0 V the it was 310 units/l. For the concentration of 5.0% at a voltage of 2.5 V, the algal cell count did not exceed 260 units/l, and at voltage of 2.0 V it was found to be

380 units/l. For 7.5% concentration at 2.5V and 2.0V voltage the total cell count was 290 units/l and 400 units/l respectively (**Table 27**). At 10% concentration for a voltage of 2.5 V, phytoplankton cell density was 300 units/l, while for a voltage of 2.0 V the numbers of individuals were decreased to reach 110 units/l. After the treatment by H_2O_2 disinfectant, it was found that the total algal cell reach 260 units/l for concentration 2.5% for voltage 1.2 V.

Through the study along the El- Amyria drinking water stations, 10% concentration of $Na_2S_2O_8$ was the best and effective concentration to be chosen for raw water laden by algae at optimum current potential 2.0 V. For the second disinfectant (H_2O_2) 2.5% concentration with 1.2 V potential current was considered to be the optimum condition for removing of algae (Fig. 11). These results were confirmed with the chlorophyll concentrations after the treatment with Sodium Persulfate and Hydrogen Peroxide disinfectants (Fig.12).

Table (24). Algal composition and phytoplankton cell density (number of individuals/l) of treated water by different disinfectants concentrations of Sodium Persulfate and Hydrogen Peroxide at El-Amyria Drinking Water Station during Spring season.

Taxa	Spring 2.5 % 5.2V	Spring 2.5% 2.0V	Spring 5.0% 2.5V	Spring 5.0% 2.0V	Spring 7.5% 2.5V	Spring 7.5% 2.0V	Spring 10% 2.5V	Spring 10% 2.0V	H_2O_2 2.5 % 0.5V
Division : Cyanophyta									
***Genus : Anabaena* Bory de Saint-Vincent ex**									
Anabaena sphaerica Bornet &Flahault	20				20			10	
Division : Chlorophyta									
Genus: Coelastrum Nägeli									
Colastrum microporum Nägeli	10	20							
C. reticulatum (Dang.) Senn		10			30				
Genus: Dictyosphaerium Nägeli									
Dictyosphaerium pulchellum Wood									10
Genus :Pediastrum Meyen									
P. simplex var. duodenarium (Bailey)	10								
P. simplex Meyen							40		70
***Genus: Staurastrum* Meyen**									
Staurastrum paradoxum Meyen						10			
***Genus:Scenedesmus* Meyen**									
Scendesmes acutus Meyen	10			20	10	60		20	
Division : Bacillariophyta									

Genus : Aulacoseira Thwaites									
Aulacoseira granulate (Ehr) Simonsen	100	160	40	60	50	70	70	30	80
A. granulata var. *angustissima* (O. F. Müller) Simonsen	220	110	160	50	10	20	50	40	10
Genus: Asterionella Hassall									
Asterionella formosa Hassall					40		10	30	10
***Genus: Cyclotella* Kützing**		10							
Cyclotella menghiniana Kutz	80	70	20	50	20				
***Genus: Nitzschia* Hassal**									
Nitzschia palea (Kütz.) W. Smith	10					10	20		
***Genus: Synedra* Ehrenberg**									
Synedra ulna (Nitzshia) Lange - Bertalot	230	200	210	280	200	200	100	50	70
TOTAL/L	**690**	**580**	**430**	**460**	**380**	**370**	**290**	**180**	**250**

Table (25). Algal composition and phytoplankton cell density (number of individuals/l) of treated water by different disinfectants concentrations of Sodium Persulfate and Hydrogen Peroxide at El-Amyria Drinking Water Station during Summer season.

Taxa	Summer 2.5 % 5.2V	Summer 2.5% 2.0V	Summer 5.0% 2.5V	Summer 5.0% 2.0V	Summer 4.5% 2.5V	Summer 7.5% 2.0V	Summer 10% 2.5V	Summer 10% 2.0V	H2O2 2.5% 1.2V
Division : Cyanophyta									
Genus : *Anabaena* Bory de Saint-Vincent ex									
Anabaena sphaerica Bornet &Flahault						10	10		
Genus : Gloeocapsa kützing									
Gloeocapsa decorticans (A. Braun)		20		10		10			30
Genus : Merismopedia Meyen									
Merismopedia tenuissima Lemm							10		
Genus: **Microcystis** kützing									
Microcystis areuginosa kütz	10		10	10		10	10		
M.flo-aquae (Witlr.) Kirchner			10				50		
Division :Chlorophyta									
Genus: *Ankistrodesmus* (Corda) Ralfa									
Ankistrodesmus fatcatus (**Corda) Ralfa**		10							
Genus: *Coelastrum* Nägeli									
Colastrum microporum Nägeli		20	10			10			
C. reticulatum (Dang.) Senn								10	
Genus: Dictyosphaerium Nägeli									
Dictyosphaerium pulchellum Wood		10	10						
Genus: Kirchneriella Schmidle									

Kirchneriella lunris (Kirch.) moebius	10		10						
Genus :Oocystis Nägeli									
Oocystis borgei . J.W.Snow					10				
Genus :Pediastrum Meyen									
Pediastrum. simplex var. duodenarium (Bailey**)**				20				10	
P. *simplex* Meyen	10								
P.*duple*x var.gracilli mum w.et.G.s.wet						10	10		
Genus: *Staurastrum* Meyen ex Ralfs									
Staurastrum paradoxum Meyen ex Ralfs		20					20	10	
Genus:*Scenedesmus* Meyen									
Scendesmes acutus meyen						10			
Genus :*Tetraëdron* Kützing									
Tetraëdron minimum (A.Braun)Hansgirg	60		60	20		20	10		
Genus :*Golenkinia* Chodat									
Golenkinia radiata choda				10	10				
Division :Bacillaroiphyta									
Genus : *Aulacoseira* Thwaites									
Aulacoseira granulata (Ehr) Simonsen	140	120	150	200	190	100	150	50	80
A.granulata var.angustissima (O.f mulre simones**)**	100	120	80	240	80	100	100	80	20
Genus: *Cyclotella* Kützing									
Cyclotella menghiniana Kutz	20	20			60		40		10
C.ocellata Pant	80		60		70	30	20		
Genus :*Navicula* Bory									
Navicula cuspidate Kutzing			10		40				
Genus: *Synedra* Ehrenberg									
Synedra ulna (Nitzshia) Lange -Bertalot	160	100	210	90	20	50	50	100	150
TOTAL/L	**590**	**440**	**620**	**600**	**480**	**360**	**480**	**260**	**290**

Table (26). Algal composition and phytoplankton cell density (number of individuals/l) of treated water by different disinfectants concentrations of Sodium Persulfate and Hydrogen Peroxide at El-Amyria Drinking Water Station during Autumn season .

Taxa	Autumn 2.5 % 5.2V	Autumn 2.5% 2.0V	Autumn 5.0% 2.5V	Autumn 5.0% 2.0V	Autumn 7.5% 2.5V	Autumn 7.5% 2.0V	Autumn 10% 2.5V	Autumn 10% 2.0V	H2O2 2.5 % 1.2 V
Division : Cyanophyta									
Genus : Anabaena Bory de Saint-Vincent ex									
Anabaena sphaerica Bornet &Flahault			10	10	20			10	
Genus : ***Gomphosphaeria* kützing**									
Gomphosphaeria aponina kütz.	10					20		20	
Genus : *Merismopedia* Meyen									
Merismopedia tenuissima Lemm	10	30				10	10		
M. elegans A.Braun ex kützing				40					
Genus: ***Microcystis*** kützing									
Microcystis flo-aquae (Witlr.) Kirchner	10	30	10	20	10	20	10		
Division :Chlorophyta									
Genus: *Actinasrtrum* Lagerheim									
Actinasrtrum hantzchii Lagerheim	10			10	30	10	10		
Genus: *Coelastrum* Nägeli									
Colastrum microporum Nägeli	20		10	50		20			20
C. reticulatum (Dang.) Senn			10						
Genus: *Dictyosphaerium* Nägeli									
Dictyosphaerium pulchellum Wood	10				10	10			

Genus :*Oocystis* Nägeli									
Oocystis borgei . J.W.Snow	10	10		40	30	30		10	20
Genus: *Staurastrum* Meyen ex Ralfs									
Staurastrum paradoxum Meyen ex Ralfs		50		50	10	50	60		10
S.elliptium west						10	10		
Genus:*Scenedesmus* Meyen									
Scendesmes acutus meyen			10			60		10	
S. quadricauda Brebisson				40				10	20
S. acuminatus (lag .) Chodat		10		20	10		30	10	20
S. bijuga J.W.Snow	10	10		20					
Genus:*Schizochlamys* Braun ex Kützing									
schizochlamys compacta Prescott								10	
Division :Bacillaroiphyta									
Genus : Aulacoseira Thwaites									
Aulacoseira granulate (Ehr) simonsen	90	60			40	20	10	20	110
A.granulate var.angustissima (O.f mulre simones)									20
Genus: Cyclotella Kützing									
Cyclotella menghiniana Kutz		50		60	20		10		30
C.ocellata Pant	20	20	20	20	20		20	10	70
Genus: Synedra Ehrenberg									
Synedra ulna (Nitzshia) Lange - Bertalot	410	150	230	150	450	200	100	50	20
Total/L	**610**	**420**	**300**	**530**	**630**	**470**	**270**	**160**	**340**

Table (27). Algal composition and phytoplankton cell density (number of individuals/l) of treated water by different disinfectants concentrations of Sodium Persulfate and Hydrogen Peroxide at El-Amyria Drinking Water Station during Winter season.

Taxa	Winter 2.5 % 5.2v	Winter 2.5% 2.0V	Winter 5.0% 2.5V	Winter 5.0% 2.0V	Winter 7.5% 2.5V	Winter 7.5% 2.0V	Winter 10% 2.5V	Winter 10% 2.0V	H2O2 2.5 % 1.2 V
Division : Cyanophyta									
Genus : **Anabaena Bory de Saint-Vincent ex**									
Anabaena sphaerica Bornet &Flahault		10							
Genus : Gloeocapsa kützing									
Gloeocapsa decorticans (A. Braun)						10			
Genus : Gomphosphaeria kützing									
Gomphosphaeria aponina kütz.				10		20			
Genus : Merismopedia Meyen									
Merismopedia tenuissima Lemm	20	40	10	40	30	30	10		10
M. glauca (Ehrenb)									
Genus: **Microcystis kützing**									
Microcystis areuginosa kütz									
M. flo-aquae (Witlr.) Kirchner	20	10	30	80	50	10	30	40	
Genus : **Oscillatoria Vaucher**									
Oscillatoria subbrevis schmidle									10
O. tenuis Ag. ex Gomont				30		40			10
O. agardhii Gomont		10							
Division :Chlorophyta									
Genus: *Actinasrtrum* Lagerheim									

Actinasrtrum hantzchii Lagerheim	40	40	40	40	40	40	40		10
Genus: *Coelastrum* Nägeli									
Colastrum Microporum Nägeli				10					
C. reticulatum (Dang.) Senn			10						
Genus: Kirchneriella Schmidle									
Kirchneriella lunris (Kirch.) moebius						10			
Genus :Oocystis Nägeli									
Oocystis borgei . J.W.Snow	10				20		10		
Genus :Pediastrum Meyen									
Pediastrum simplex var. duodenarium (Bailey**)**			10						
***P. Simplex* Meyen**						10			10
Genus: Staurastrum Meyen ex Ralfs									
Staurastrum paradoxum Meyen ex Ralfs	10	40	10	10	30	10	20		
S.elliptium west									
Genus: *Scenedesmus* Meyen									
Scendesmes quadricauda Brebisson									
S. acuminatus (lag .) Chodat	20				10				30
S. bijuga J.W.Snow		10	10	20	10		10		
Genus: Schizochlamys Braun ex Kützing									
Schizochlamys gelatinosa	10								
Genus: *Crucigenia* Morren									
Crucigenia crucifera (Wolle) Collins				10		10			
Genus :*Golenkinia* Chodat									
Golenkinia radiata **Choda**			10			10			10
Division :Bacillaroiphyta									
Genus : *Aulacoseira* Thwaites									
Aulacoseira granulata (Ehr) Simonsen	10	30	40			40	30	20	60

A.granulata var.angustissima (O.f mulre simones**)**	30		40		10		10		60
Genus: *Cyclotella* Kützing									
Cyclotella menghiniana **Kutz**	10		20			40	10	10	
***C.ocellata* Pant**	80	100	30	90	40	80	60	10	40
Genus :*Navicula* Bory									
Navicula cuspidata Kutzing	20			20					
Genus: *Nitzschia* Hassal									
Nitzschia palea (Kütz.) W. Smith					40		20		
Genus: *Synedra* Ehrenberg									
Synedra ulna (Nitzshia) Lange -Bertalot		20		20	10	40	50	30	10
Total/L	**280**	**310**	**260**	**380**	**290**	**400**	**300**	**110**	**260**

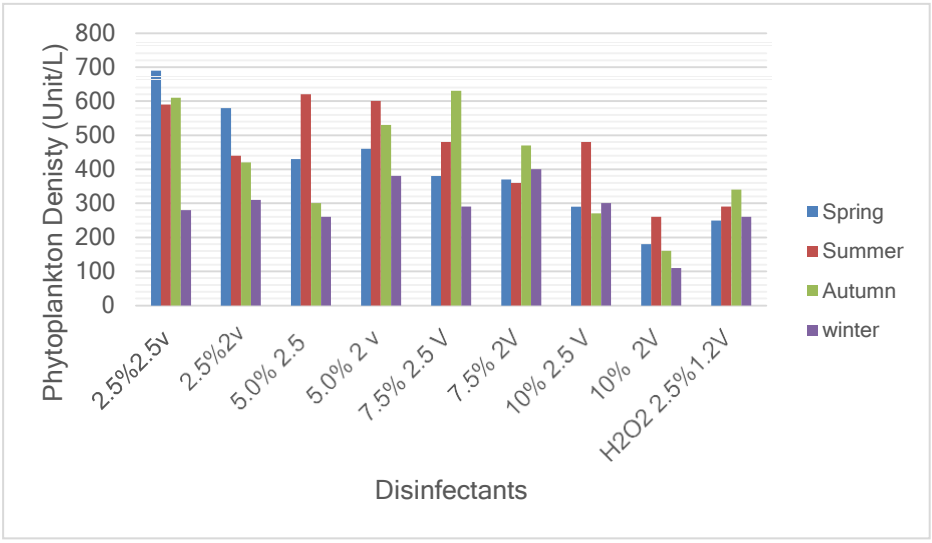


Figure (11): Phytoplankton Density (individuals/l) after treatment of water by Sodium Persulfate and Hydrogen Peroxide at different voltage of EL-Amyria Drinking Water Station during different seasons

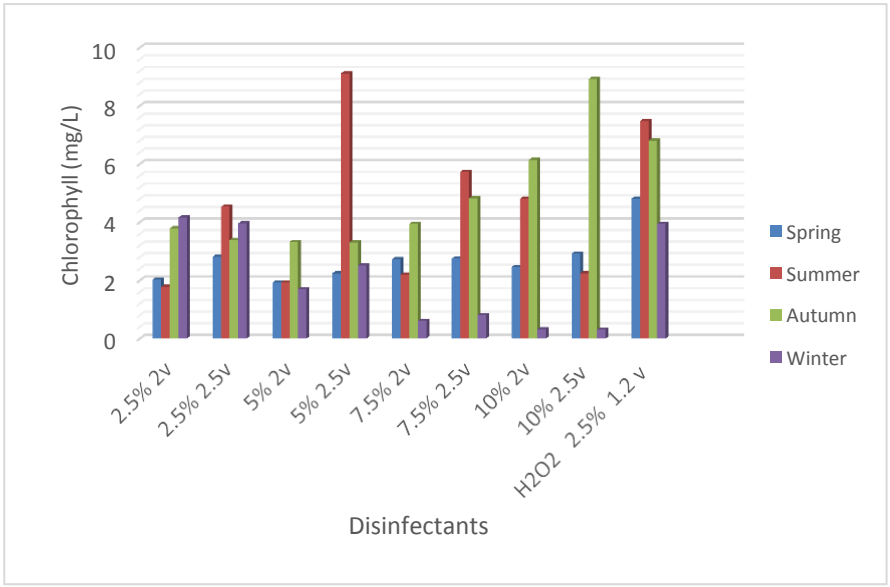


Figure (12): Chlorophyll (mg/l) after treatment of water by Sodium Persulfate and Hydrogen Peroxide at different voltage of EL-Amyria Drinking Water Station during different seasons

D.2. Rod El-Farag Drinking Water Station

Table (28) showed the algal count during the spring season after treatment with Sodium Persulfate and Hydrogen Peroxide disinfectant, where the total algal count at 2.5% of Sodium Persulfate for the voltage 2.5 volts was 490 units /l, while for the voltage 2.0 volts it was 370 units /l. At a concentration of 5.0% for a voltage of 2.5 V, the total number of algae did not exceed 430 units/l, and for a voltage of 2.0 V, the total number of algae was 290 units / l. By increasing the Sodium Persulfate concentration to 7.5%, the total number of algae for the voltage 2.5V was 360 and for the voltage 2.0 V the total was 310 units/l. At 10% concentration for a voltage of 2.5 V, the phytoplankton cell density was 510 units/l, while for a voltage of 2.0 V it was 180 units/l. For the second disinfectant (H_2O_2) total algal count was 240 units/l for a concentration of 2.5% for 1.2 V.

During summer season after treatment with disinfectants, the total algal cell density was 580 units /l after treatment with Sodium Persulfate at concentration of 2.5% for the voltage 2.5 volts, while for the voltage 2.0 volts it decreased to 440 units/l. At a concentration of 5.0% for a voltage of 2.5 V, the total algal count was 450 units/l, and for a voltage of 2.0 V, the total algae was 570 units/l. For The concentration of 7.5% at voltage 2.5 V the algal cells were 460 units/l, and for the voltage 2.0 V they were 540 units/l. At the higher concentration of Sodium Persulfate of 10% concentration for a voltage of 2.5 V, the total algal density reach its lower value as they did not exceed 430 units/l, while for a voltage of 2.0 V, the total was decreased to 220 units/l. By the treatment with

H_2O_2 disinfectant the mean number of algal cells were 330 units/l for concentration 2.5% for voltage 1.2 V (**Table 29).**

From the results observed in **Table (30)**, during autumn season after treatment with Sodium Persulfate disinfectant, the total algal cell count at concentration of 2.5% for the voltage 2.5 volts was 870 units/l, while for the voltage 2.0 volts the total was 940 units/l. At a concentration of 5.0% for a voltage of 2.5 V, the total did not exceed 430 units/l, and for a voltage of 2.0 V, the total algae was 620 units/l. For 7.5% concentration, the total algal cell was 860 units /l and 470 units/l for 2.5V voltage and for 2.0V respectively. The total algal count decreased to its lower values at 10% concentration for a voltage of 2.5 V, as it did not exceed 520 units/l, while for a voltage of 2.0 V, the total was 110 units/l. In case of H_2O_2 disinfectant, the mean number of algal cells after treatment were 110 units/l for concentration 2.5% for 1.2V.

In winter, the mean frequencies of algal cell count after treatment with Sodium Persulfate disinfectant, where 560 units/l at concentration of 2.5% for the voltage 2.5 volts while for the voltage 2.0 volts it was 590 units/l **(Table 61**). At a concentration of 5.0% for a voltage of 2.5 V, the algal cell count was 810 units/l, and for a voltage of 2.0 V, the total algae was 500 units/l. At the concentration of 7.5%, the average number of algae was 330 and 310 units/l for the voltage 2.5 volts and 2.0 volts respectively . At a 10% concentration for a voltage of 2.5 V, the total did not exceed

230 units/l, while for a voltage of 2.0 V, the total was 130 units/l. After the treatment by H_2O_2 disinfectant, the mean algal frequencies in water were 290 units/l for a concentration of 2.5% to a voltage of 1.2 V.

Regarding the previous results, it was found that the electrochemical treatment of raw water laden by algae with 10% concentration of Sodium Persulfate at voltage of 2.0 V was the optimum concentration and voltage that succeeded in reducing algal cell count (Fig. 13). In relevancy with the results obtained from the determination of chlorophyll concentrations after the treatment by the two electrochemical disinfectants confirmed the efficacy of the optimum conditions as recorded before (Fig. 14).

Table (28). Algal composition and phytoplankton cell density (number of individuals/l) of treated water by different disinfectants concentrations of Sodium Persulfate and Hydrogen Peroxide at Rod EL- Farag Drinking Water Station during spring season.

Taxa	Spring 2.5 % 5.2V	Spring 2.5% 2.0V	Spring 5.0% 2.5V	Spring 5.0% 2.0V	Spring 7.5% 2.5V	Spring 7.5% 2.0V	Spring 10% 2.5V	Spring 10% 2.0V	H_2O_2 2.5 % 0.5V
Division : Cyanophyta									
Genus : *Anabaena* Bory de SainVincent ex									
Anabaena sphaerica Bornet &Flahault				20					
Genus: *Gloeocapsa* Kützing									
Gloeocapsa decorticans (A.Braun) P.Richter		10							
Genus .*Merismopedia* Meyen									
Merismopedia tenuissima Lemm.	10	10		20	20				
Genus :*Microcystis* Kützing									
Microcystis flos - aquae (Witlr.) Kirchner				10		20	50		
Division: Chlorophyta									
Genus: *Coelastrum* Nägeli									
Coelastrum microporum Nägeli	10		20	10		10	30		
C. reticulatum (Dang.) Senn	10			10	20	10			
Genus: *Oocystis* Nägeli									
Oocystis borgei J.W.Snow			10	10					
Genus: *Pediastrum* Meyen									

Pediastrum Boryanum (Turp.) Meneghini						10			
P. duplex var. gracillimum West & G. West	10				20		20		
P. simplex Meyen	20		10	10				20	
P. simplex var. duodenarium (Bailey) Rabenhorst	60	10	10	10	30	30	30	10	
Genus: Scenedesmus Meyen									
Scendesmes acutus Meyen		10	10						30
Genus: *Staurastrum* Meyen									
S. paradoxum Meyen	70	40		40	20	10	20	10	
Division : Bacillariophyta									
Genus: *Asterionella* Hassall									
Asterionella formosa Hassall			10						
Genus: *Aulacoseira* Thwaites									
Aulacoseira granulata (Ehr.) Simonsen	100	120	90	50	140	60	80	50	30
A. granulata var. *angustissima* (O. F. Müller) Simonsen	90	70	160	40	70	80	130	20	20
Genus: *Cyclotella* Kützing									
C. ocellata Pant.	40	20	10	10	20	10	50	10	20
Genus: *Navicula* Bory									
Navicula cuspidata Kutzing					20				
Genus: *Nitzschia* Hassal									
Nitzschia palea (Kütz.) W. Smith		10		10		80			
Genus: *Synedra* Ehrenberg									
Synedra ulna (Nitzch.) Ehrenberg	70	70	100	40		60	100	60	170
Total	**490**	**370**	**430**	**290**	**360**	**310**	**510**	**180**	**240**

Table (29). Algal composition and phytoplankton cell density (number of individuals/l) of treated water by different disinfectants concentrations of Sodium Persulfate and Hydrogen Peroxide at Rod EL- Farag Drinking Water Station during Summer season.

Taxa	Summer 2.5% 5.2V	Summer 2.5% 2.0V	Summer 5.0% 2.5V	Summer 5.0% 2.0V	Summer 7.5% 2.5V	Summer 7.5% 2.0V	Summer 10% 2.5V	Summer 10% 2.0V	H_2O_2 2.5% 0.5V
Division : Cyanophyta									
Genus : *Anabaena* Bory de SainVincent ex									
Anabaena sphaerica Bornet &Flahault			10	10					
Genus: Gloeocapsa Kützing									
Gloeocapsa decorticans (A.Braun) P.Richter	20		20	30	20			10	
Genus: *Gomphosphaeria* Kützing									
Gomphosphaeria aponina Kütz.		20							
Genus: *Merismopedia* Meyen									
Merismopedia tenuissima Lemm.						10			
Genus *:Microcystis* Kützing									
Microcystis flos - aquae (Witlr.) Kirchner	20			20	10	30	10		
Division: Chlorophyta									
Genus: *Actinastrum* Lagerheim									
Actinastrum Hantzchii Lagerheim	30	20	30	30	10	20		10	
Genus: *Ankistrodesmus* Corda									
Ankistrodesmus falcatus (Corda) Ralfs.						10	20		
Genus: *Coelastrum* Nägeli									
Coelastrum microporum Nägeli			20	10					
C. reticulatum (Dang.) Senn				10		30	20		
Genus: *Golenkinia* Chodat									
Golenkinia radiata Chodat				10					

Genus: *Kirchneriella* Schmidle									
Kirchneriella lunris Kirchner	20	10	30		10		10	20	
Genus: *Oocystis* Nägeli									
Oocystis borgei J.W.Snow	20		10		10	20	10	10	
Genus: *Pediastrum* Meyen									
Pediastrum . duplex var. gracillimum West & G. West				10			10		
P. simplex Meyen				10			2		
P. simplex var. duodenarium (Bailey) Rabenhorst	30	30	10	10	20	20	10	10	
Genus: *Scenedesmus* Meyen									
Scendesmes acutus Meyen			10	20			10		
Genus: *Staurastrum* Meyen									
Staurastrum elliptium West					10				
S. paradoxum Meyen	10	10			10	10	10		
Division : Bacillariophyta									
Genus: *Aulacoseira* Thwaites									
Aulacoseira granulata (Ehr.) Simonsen	150	130	30	30	150	150	100	50	70
A. granulata var. *angustissima* (O. F. Müller) Simonsen	100	100	150	150	90	100	80	40	100
Genus: *Cyclotella* Kützing									
C. meneghiniana Kütz.							20		
C. ocellata Pant.	70	20	30	40	40	20	30	40	20
Genus: *Navicula* Bory									
Navicula cuspidata Kutzing	10					10			20
Genus: *Nitzschia* Hassal									
Nitzschia palea (Kütz.) W. Smith				30		10			
Genus: *Synedra* Ehrenberg									
Synedra ulna (Nitzch.) Ehrenberg	100	100	100	150	80	100	90	30	120
Total	**580**	**440**	**450**	**570**	**460**	**540**	**430**	**220**	**330**

Table (30). Algal composition and phytoplankton cell density (number of individuals/l) of treated water by different disinfectants concentrations of Sodium Persulfate and Hydrogen Peroxide at Rod EL- Farag Drinking Water Station during Autumn season.

Taxa	Summer 2.5% 5.2V	Summer 2.5% 2.0V	Summer 5.0% 2.5V	Summer 5.0% 2.0V	Summer 7.5% 2.5V	Summer 7.5% 2.0V	Summer 10% 2.5V	Summer 10% 2.0V	H_2O_2 2.5% 0.5V
Division : Cyanophyta									
Genus : *Anabaena* Bory de SainVincent ex									
Anabaena sphaerica Bornet &Flahault	10	10			10	10	10		
Genus: *Gloeocapsa* Kützing									
Gloeocapsa decorticans (A.Braun) P.Richter					10		20		
Genus: *Gomphosphaeria* Kützing									
Gomphosphaeria aponina Kütz.		80					30	20	
Genus .*Merismopedia* Meyen									
Merismopedia tenuissima Lemm.	10	20		50	70	40	100	20	10
Genus *:Microcystis* Kützing									
Microcystis *flos - aquae* (Witlr.) Kirchner		20	10	10	40	10	10	10	
Division: Chlorophyta									
Genus: *Actinastrum* Lagerheim									
Actinastrum Hantzchii Lagerheim	10	70		40	20	20	30	10	
Genus: *Ankistrodesmus* Corda									
Ankistrodesmus falcatus (Corda) Ralfs.		10					10		
Genus: *Coelastrum* Nägeli									
Coelastrum microporum Nägeli	20	30		10	20		20	20	
C. reticulatum (Dang.) Senn		10		20	10		10		

Genus: *Dictyosphaerium* Nägeli									
Dictyosphaerium pulchellum Wood			10		10	20			
Genus: *Oocystis* Nägeli									
Oocystis borgei J.W.Snow		10	10	20		30	10	10	
Genus: *Pediastrum* Meyen									
Pediastrum . simplex Meyen					10		20	20	10
P. simplex var. duodenarium (Bailey) Rabenhorst				30				10	10
P. tetras (Ehren.) Ralfs									20
Genus: *Scenedesmus* Meyen									
Scendesmes acutus Meyen	10	10		10					
S. quadricauda Brebisson		40		40	20	10		10	
S. acuminatus (lag .) chodat	20	30	30	40	40		40	10	20
S. bijuga (Turp) Layer		20			10		20	10	
Genus: *Staurastrum* Meyen									
Staurastrum elliptium west					10				
S. paradoxum Meyen	20	50	20	30	80		60	20	10
Division : Bacillariophyta									
Genus: *Aulacoseira* Thwaites									
Aulacoseira granulata (Ehr.) Simonsen	70	20		10					
A. granulata var. *angustissima* (O. F. Müller) Simonsen	30		10		10				
Genus: *Cyclotella* Kützing									
C. meneghiniana Kütz.	10	10	20	20	30	30	30	10	
C. ocellata Pant.	60	60		10	10			20	10
Genus: *Synedra* Ehrenberg									
Synedra ulna (Nitzch.) Ehrenberg	600	440	320	280	450	300	100	100	20
Total	**870**	**940**	**430**	**620**	**860**	**470**	**520**	**110**	**110**

Table (31). Algal composition and phytoplankton cell density (number of individuals/l) of treated water by different disinfectants concentrations of Sodium Persulfate and Hydrogen Peroxide at Rod EL- Farag Drinking Water Station during Winter season.

Taxa	Winter 2.5% 5.2V	Winter 2.5% 2.0V	Winter 5.0% 2.5V	Winter 5.0% 2.0V	Winter 7.5% 2.5V	Winter 7.5% 2.0V	Winter 10% 2.5V	Winter 10% 2.0V	H_2O_2 2.5% 0.5V
Division : Cyanophyta									
Genus: *Gloeocapsa* Kützing									
Gloeocapsa decorticans (A.Braun) P.Richter			10						
Genus: *Gomphosphaeria* Kützing									
Gomphosphaeria aponina Kütz.			20						10
Genus .*Merismopedia* Meyen									
Merismopedia tenuissima Lemm.	20	40	60	40	10	40	10	20	10
M. glauca (Ehrenb)	10								
Genus :Microcystis Kützing									
Microcysti. flos - aquae (Witlr.) Kirchner	10	20	100	40	40	30	10		40
Genus: *Oscillatoria* Vaucher									
Oscillatoria princeps Vaucher *ex* Gomont	20			10					
Division: Chlorophyta									
Genus: *Actinastrum* Lagerheim									
Actinastrum Hantzchii Lagerheim	10	10	30	20	20	20	20	10	10
Genus: *Characium* A. Braun in Kützing									
Characium Ornithocephalum	10						20		
Genus: *Coelastrum* Nägeli									
Coelastrum microporum Nägeli					20				

Genus : *Crucigenia* Morren									
Crucigenia quadrata Morren	10		10				10		
Genus: *Dictyosphaerium* Nägeli									
Dictyosphaerium pulchellum Wood		20	10	10	10				
Genus: *Golenkinia* Chodat									
Golenkinia radiata Chodat		10	20	10	10				
G. paucispina West &West (lemm)		20		60					20
Genus: *Oocystis* Nägeli									
Oocystis borgei J.W.Snow			30	10					
Genus: *Pediastrum* Meyen									
Pediastrum . simplex var. duodenarium (Bailey) Rabenhorst	10	10	10				10		
P. tetras (Ehren.) Ralfs			10						
Genus: *Scenedesmus* Meyen									
Scendesmes quadricauda Brebisson	10	20	40	20	40	40	10		10
S. acuminatus (lag .) Chodat					20				
S. bijuga (Turp) Layer	10	10	30	20	10	10		20	
Genus: *Staurastrum* Meyen									
Staurastrum . paradoxum Meyen	10	10		10			10		
Genus :Tetraëdron Kützing									
Tetraëdron minimum (A.Braun)Hansgirg			20						
Division : Bacillariophyta									
Genus: *Aulacoseira* Thwaites									
Aulacoseira granulata (Ehr.) Simonsen	50	30	80	70	30	30			50
A. granulata var. *angustissima* (O. F. Müller) Simonsen	40	50	70	70	70	30		40	80

Genus: *Cyclotella* Kützing									
Cyclotella meneghiniana Kütz.	30	20	20	20	40	20	20		30
C. ocellata Pant.	190	210	120	50	70	50	60	10	10
Genus: *Navicula* Bory									
Navicula cuspidata Kutzing	10								
Genus: *Nitzschia* Hassal									
Nitzschia palea (Kütz.) W. Smith	80	110	70	30	30	30	50		10
Genus: *Synedra* Ehrenberg									
Synedra ulna (Nitzch.) Ehrenberg	30		50	10	10	10		30	10
Total	**560**	**590**	**810**	**500**	**330**	**310**	**230**	**130**	**290**

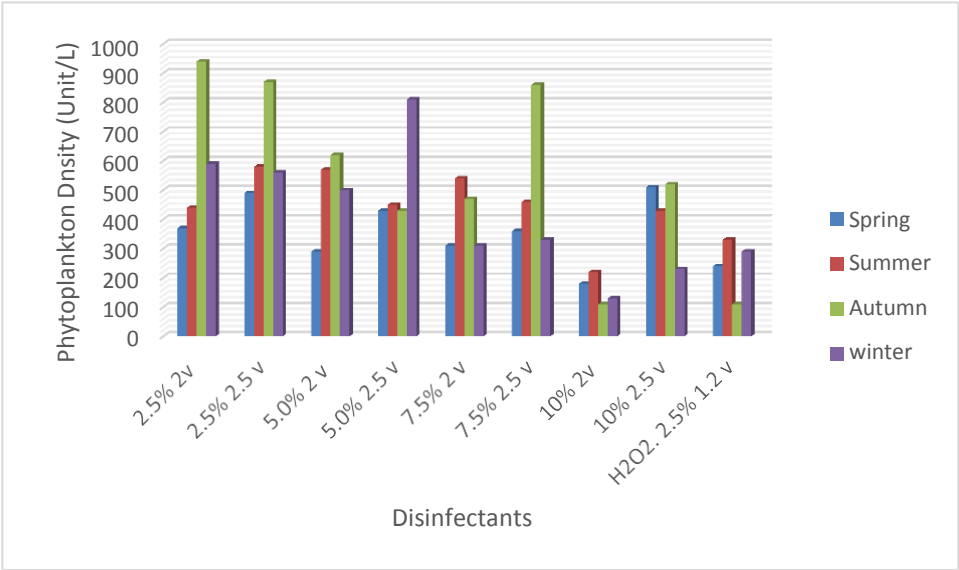


Figure (13): Phytoplankton Density (individuals/l) after treatment of water by Sodium Persulfate and Hydrogen Peroxide at different voltage of Rod El- Farag Drinking Water Station during different seasons

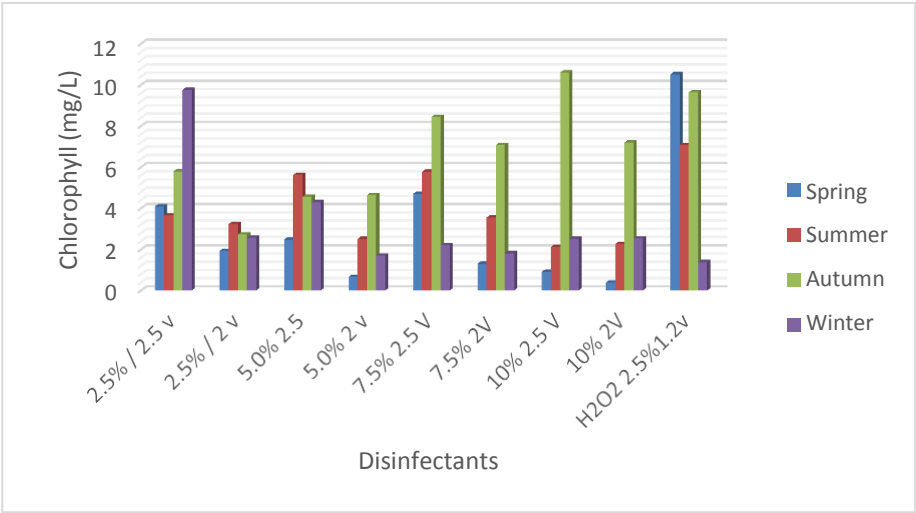


Figure (14): Chlorophyll (mg/l) after treatment of water by Sodium Persulfate and Hydrogen Peroxide at different voltage of Rod El- Farag Drinking Water Station during different seasons

E. Removal of Algae:

The results showed the removal percentage of the algal cells /chlorphyll present in water samples after treatment with Sodium Persulfate disinfectant at El- Amyria drinking water station during different seasons **(Table 32),** with a removal rate in the range 81-99% in some concentrations used.

Through Figures (15,16) it was found that the percentage of algal removal values during spring ranged between 94.40% as the highest concentration of 10% for the 2.0V voltage used for the Sodium Persulfate disinfectant. The chlorophyll removal percentages were 97%, the highest removal value for a concentration of 10% was for a voltage of 2.0V, and the highest value for a voltage of 2.5V was 93%. In summer, the higher value of algal removal was observed at concentration of 10% for a voltage of 2.0V of 71.94% for removal, while the higher removal rate for chlorophyll was 79% and the lowest value 46% at 2.5V (Fig. 15,16).

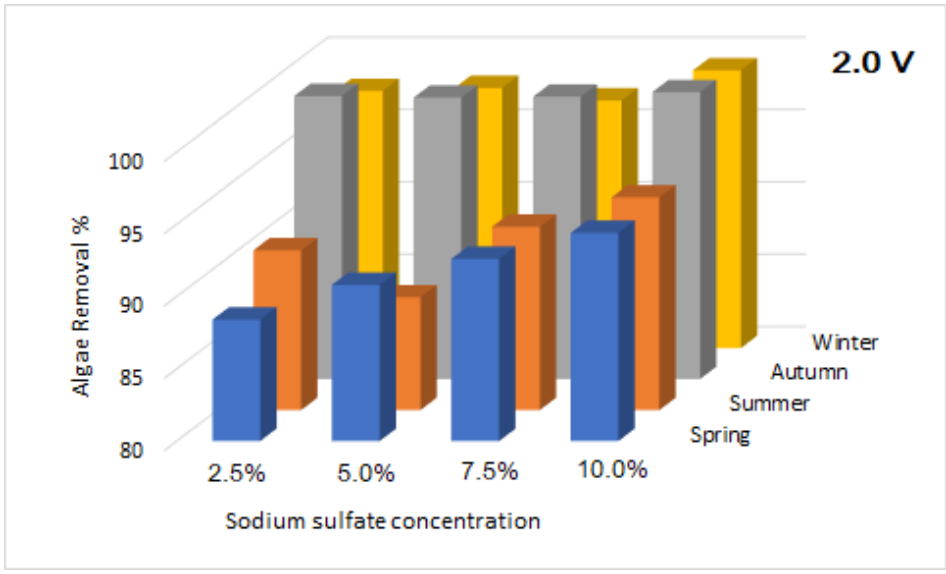
During autumn the percentage of algal removal were ranged between 99.4 – 99.8% 99.3 – 99.7% for different concentration at 2.0V and 2.5V respectively. The highest value of removal was observed at a concentration of 10% for a voltage of 2.0V with a value of 99.8% (Fig.15,16).

Similarly, in winter season the highest algal removal percentage was found at concentration of 10% of Sodium Persulfate

disinfectant of 99.2% at 2.0V. While the chlorophyll removal rates were 91%, 56% through different concentrations.

Table (32). The effectiveness and percentage of removal of Sodium Persulfate on cell density/chlorophyll of phytoplankton in El-Amyria Drinking Water Station in relevancy with voltage and different concentrations along different seasons.

Sodium Persulfate concentrations	Removal% of Algal cell				Removal% of Chlorophyll			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
2V								
2.5%	88.40	91.05	99.58	97.78	85.91	69.23	92.72	88.42
5.0%	90.80	87.80	99.47	97.99	95.18	76.09	87.62	92.43
7.5%	92.60	92.68	99.53	97.13	90.51	66.19	81.06	91.98
10.0%	94.40	94.71	99.84	99.21	97.15	78.47	81.05	88.87
2.5V								
2.5%	86.20	88.00	99.39	97.99	70.14	65.23	84.53	56.81
5.0%	91.40	87.39	99.70	98.13	81.97	46.47	88.00	80.85
7.5%	92.40	90.24	99.37	97.92	65.69	44.95	77.6	90.20
10.0%	94. 20	90.24	99.73	97.85	93.35	79.81	71.73	88.87



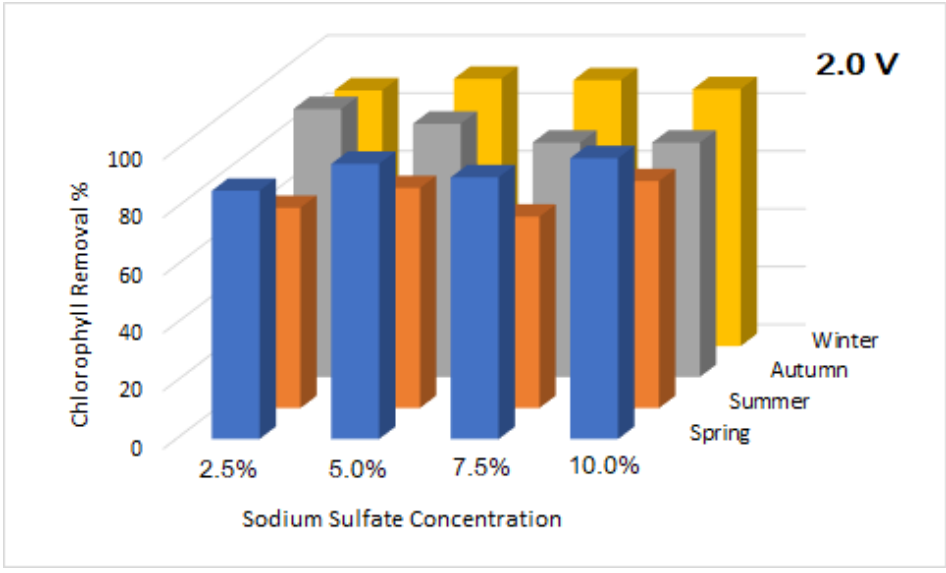
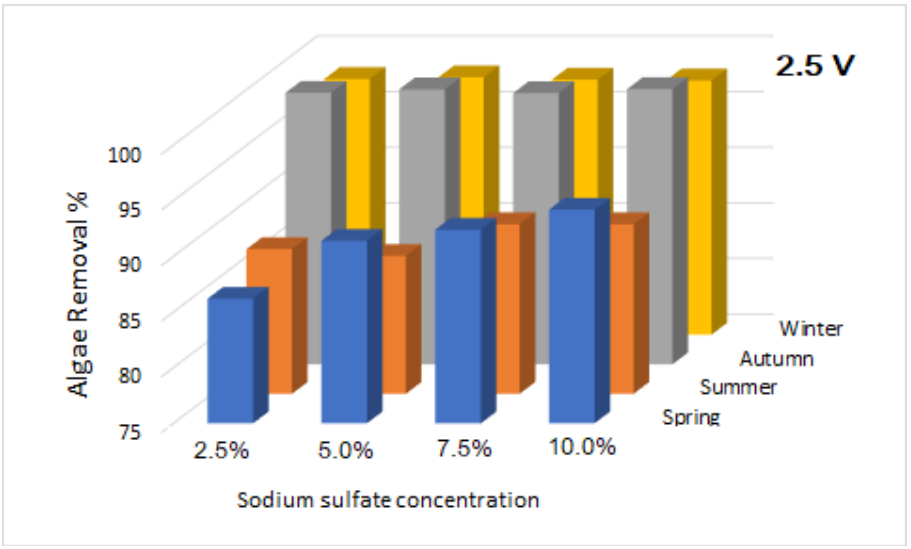


Figure (15): Percentage of algal & chlorophyll removal after treatment of water by Sodium Persulfate at 2.0 voltage of El-Amyria Drinking Water Station along different seasons



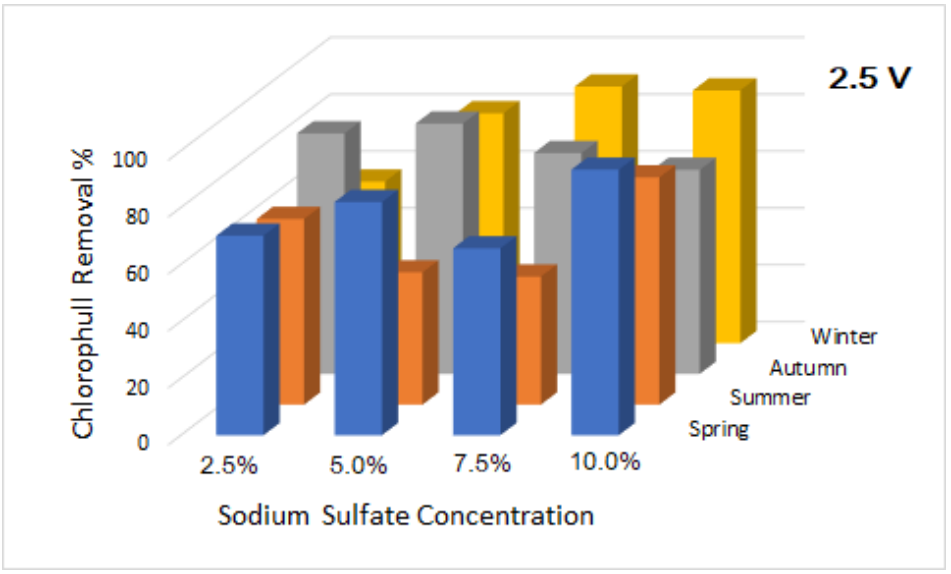


Figure (16): Percentage of algal & chlorophyll removal after treatment of water by Sodium Persulfate at 2.5 voltage of El-Amyria Drinking Water Station along different seasons

From the results shown in Table (**33**) at Rod Al-Farag drinking water station it was found that during spring, the highest value of algal removal was obtained at a concentration of 10% for a voltage of 2.0V of 99%, while the removal rate for chlorophyll was ranged between 69 -77%, %.

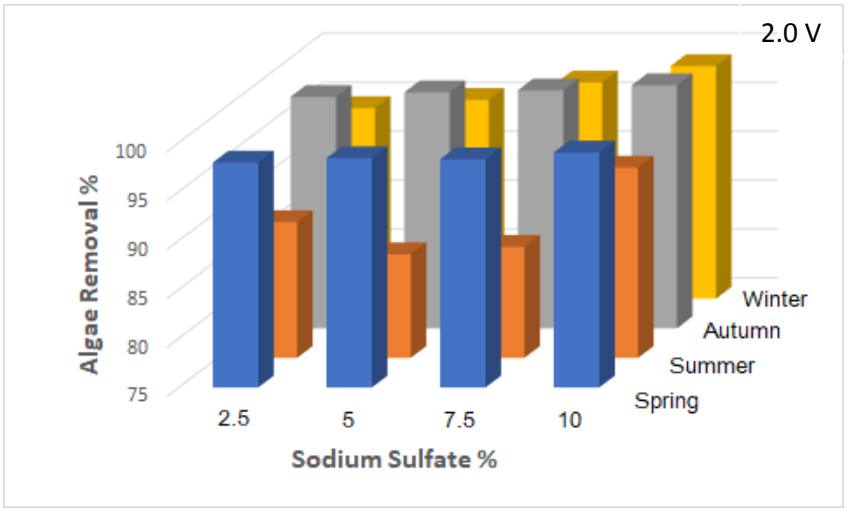
In summer the highest value of algal removal was obtained at a concentration of 10% for a voltage of 2.0V with a value of 44.94%, while the higher removal rate of chlorophyll was 80% at concentration of 2.5% at 2.5V and the lower value was 0.44% at concentration 5% at 2.5V.

During autumn season, the algal removal were ranged between 98.6 -99.8% and 98.7 – 99.3% at 2.0V and 2.5V respectively. The highest value at a concentration of 10% for a voltage of 2.0 volts with a value of 99.84% for removal (Fig. 17,18). The removal rate for chlorophyll was ranged between 35.36 - 75.94% at different concentration using different voltages.

In winter, the highest value of algal removal was reached at a concentration of 10% for a voltage of 2.0V with a value of 78.98%, while the removal rate for chlorophyll was ranged between 79.95 - 98.50%.

Table (33). The effectiveness and percentage of removal of Sodium Persulfate on cell density/chlorophyll of phytoplankton in Rod EL-Farag Drinking Water Station in relevancy with voltage and different concentrations along different seasons.

Sodium Persulfate concentrations	Removal% of Algal cell				Removal% of Chlorophyll			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
2V								
2.5%	97.99	88.88	98.65	94.49	77.61	80.37	75.43	79.95
5.0%	98.43	85.60	99.11	95.33	78.83	78.72	75.94	91.80
7.5%	98.32	86.36	99.32	97.10	69.90	75.74	71.44	97.11
10.0%	99.02	94.44	99.84	98.78	72.87	46.96	55.50	98.45
2.5V								
2.5%	97.34	85.35	98.75	94.77	69.01	50.05	75.43	80.91
5.0%	97.67	88.63	99.38	92.44	75.30	0.44	76.08	95.18
7.5%	98.05	88.38	98.76	96.92	69.68	36.82	65.21	96.09
10.0%	97.24	89.14	99.25	97.85	69.80	75.30	35.36	98.50



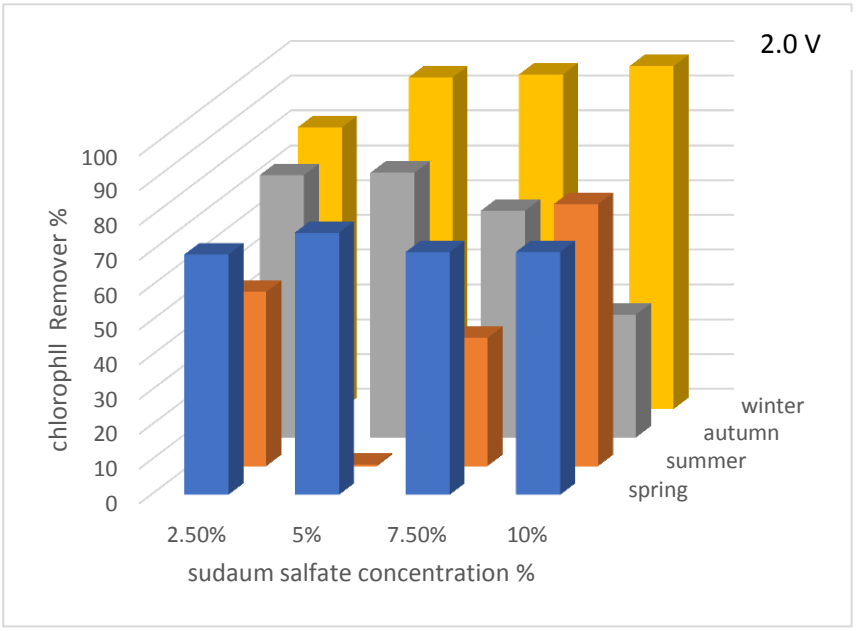
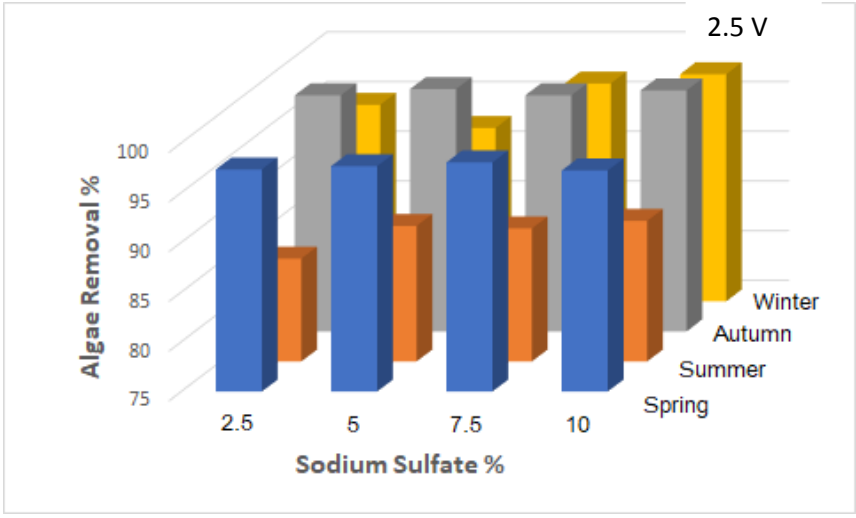


Figure (17): Percentage of algal & chlorophyll removal after treatment of water by Sodium Persulfate at 2.0 voltage of Rod EL-Farag Drinking Water Station along different seasons



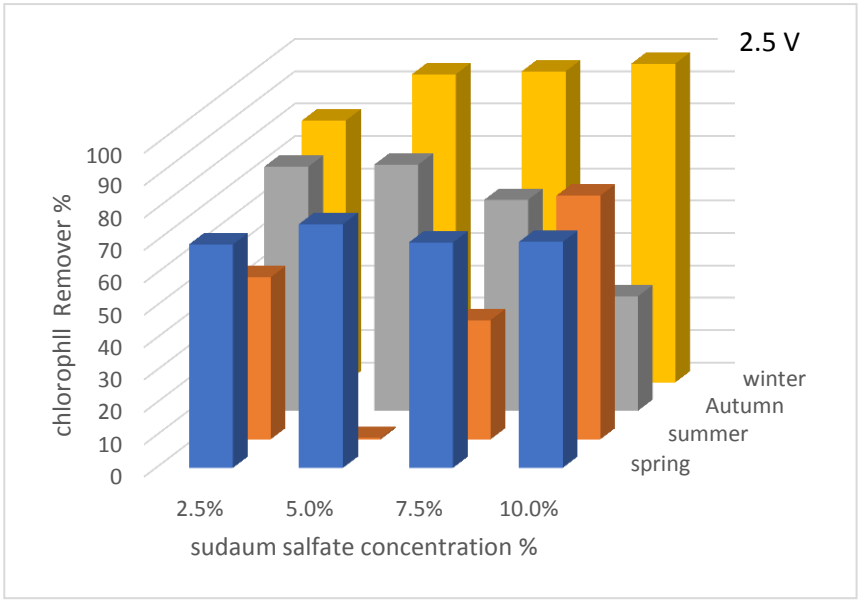


Figure (18): Percentage of algal & chlorophyll removal after treatment of water by Sodium Persulfate at 2.5 voltage of Rod EL-Farag Drinking Water Station along different seasons

The results in **Table (34)** and Fig. (19) show the percentage of algal and chlorophyll removal of the Hydrogen Peroxide disinfectant for El -Amyria drinking water station during different seasons. It was observed that the removal rate of algal cell was of 95.00% during spring season and 94.10% at summer season and the percentages were increase during autumn and winter seasons to reach 99.74 and 98.13% respectively. As for chlorophyll, the lower value of removal was obtained at autumn season by 74.29% and the higher value was found during winter by 93.85%

Table (34). The effectiveness and percentage of removal of Hydrogen Peroxide on cell density/chlorophyll of phytoplankton in El-Amyria Drinking Water Station at different seasons.

seasons	Removal% of Algal cell	Removal% of Chlorophyll
Spring	95.00	87.73
Summer	94.10	90.66
Autumn	99.74	74.29
Winter	98.13	93.85

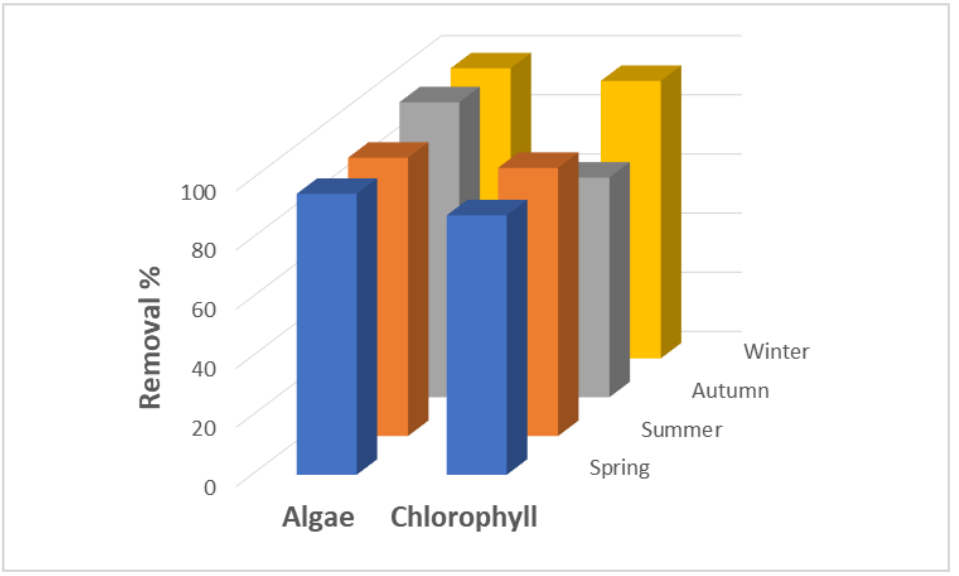


Figure (19): Percentage of algal and chlorophyll removal after treatment of water by Hydrogen Peroxide of EL- Amyria Drinking Water Station along different seasons

For Rod El-Farag drinking water station the removal percentage of algal cells and chlorophyll using the Hydrogen Peroxide disinfectant was shown in **Table. (35)** and Fig. (20). The percentages of algal removal were ranged between 91.66 - 99.84% along different seasons. The chlorophyll removal rate also ranged between 17.64 – 81.01% along different seasons.

Table (35). The effectiveness and percentage of removal of Hydrogen Peroxide on cell density/chlorophyll of phytoplankton in Rod El-Farag Drinking Water Station at different seasons.

seasons	Removal% of Algal cell	Removal% of Chlorophyll
Spring	98.70	46.96
Summer	91.66	17.64
Autumn	99.84	50.72
Winter	97.29	81.01

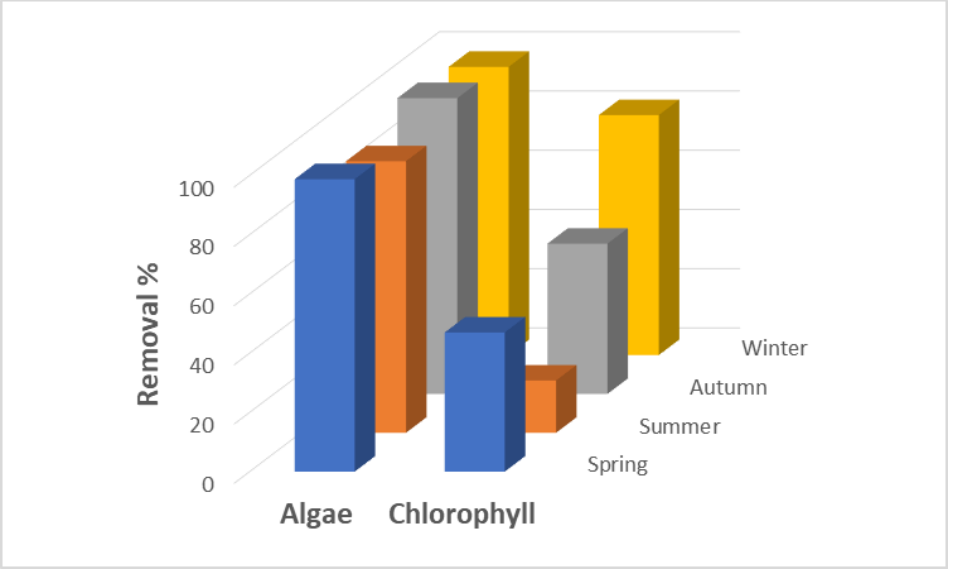


Figure (20): Percentage of algal and chlorophyll removal after treatment of water by Hydrogen Peroxide of Rod El-Farag Drinking Water Station along different seasons

Discussion

Physico- Chemical Characteristics of Water:

Algae in water are of great concern because they adversely affect drinking water quality and water treatment processes. (**Dittmann & Wiegand ., 2006**; **Ma & Liu., 2002).** In particular, in tropical and semi-tropical zones, algae can grow excessively under high nutrient contents in surface water due to contamination by agricultural activity, domestic wastewater discharge and industrial effluents **Gao et al., (2009), Zheng et al., (2012).** The high concentrations of nitrogen and phosphorous can provide the ideal medium for the excessive growth of algae, which is detrimental not only from an environmental point of view but also for human health. **Gao et al., (2010)**

Moreover, the presence of algae in water treatment plants interferes with physical and/or chemical water purification processes. **Henderson et al., (2008),** in particular, fouling and clogging of filtration membranes have been observed even when the coagulation and sedimentation processes removed more than 90% of the algae in the influent .**Liang et al., (2005)**

Only a few studies exist in the literature on the use of electrolysis for the *in situ* generation of oxidants to control algal biomass in aqueous media. **Xu et al., (2007**), demonstrated that the growth of *Microcystis aeruginosa* could be inhibited by an

electrochemical treatment with Ti–RuO_2 anodes due to the generation of active oxidants. The use of boron doped diamond (BDD) anodes has been proposed for the treatment of pond water containing humic acids and algae. **Liao et al., (2008).** Although the study was mainly devoted to the removal of organic load, the decrease in chlorophyll-*a* indicated that the process was also effective towards algae. The mechanism of the algae's inactivation during electrolysis is still not well understood; the action of free radicals and long-life oxidants electrogenerated, as well as the effect of the electric field on the cell membrane, are considered as possible algicidal actions. **Vacca et al., (2011).** In the presence of chlorides, the electrolysis may produce a mixture of oxidants mainly constituted by active chlorine species**. Bergmann, & Rollin., (2007), Polcaro et al., (2009),** In any case, the different mechanisms may have the same preoxidative effect as the chemical treatment traditionally proposed in algae removal plants.

Consequences of the effects of electrochemical disinfectants on the physico-chemical characteristics of water and algae in the investigated drinking water stations:

1- **Turbidity.** Turbidity is the measure of fine matter suspended in water, which is mostly caused by mud, silt, non-living organic particles, plankton and other microorganisms, as well as suspended organic and inorganic matter. The degree of turbidity of colloidal particles such as stream water is a rough measure of

the severity of contamination. **El-Manawy and Amin,** (**2004**), The turbidity of raw water shows the highest values during spring season due to the activity and increase in the numbers of phytoplankton in particular the dominancy of diatoms. This is in agreement with **AbdEl-Hady and Hussian (2012), Ezzat et al (2012) Croteau et al (2022).** The turbidity values of treated water by the electrochemical disinfectant of Sodium Persufate 10 % were decreased during spring season owing to the efficacy of removing of algae at optimum operating condition of potential current 2.0 V. In winter season, the turbidity of the treated water by the two disinfectants (Sodium persulfate 10 %, Hydrogen peroxide) was increased, this may be due to the increasing of timing of the operating electrolysis. **Contreras et al,** (**2009).**

2- **Electric conductivity.** Electric conductivity is the ability of water to conduct an electrical current. The increasing in the dissolved salts in water leads to an increase in its electrical conductivity. **Belov et al., (2019)**, The electric conductivity of the treated water by persulfate disinfectant 10 % was attained the highest values where the EC readings of the raw water were within the fresh water range and substantially shifted to saline water range after the treatment. While the EC values of the treated water by Hydrogen Peroxide disinfectant were slightly increased, but within the fresh water ranges. Generally, an increasing in EC readings may be correlated with operating

conditions concerning timing and preparation of electrolyte. **(Abdo, 2010).**

3- **Hydrogen ion concentration.** The hydrogen ion concentration of raw water were within neutral to slightly alkaline range. The previous studies (**Stahl and Ramadan 2008; Abdo and El-Nasherty 2010; Abd El-Hady and Hussein 2012;Khalil et al. 2012; Abd El-Hady 2014; Korium and Toufeek 2015) ,** pointed out that the pH values were in the range of 6.5 to 9.0, which is permissible for Nile River water. The alkalinity may be increased as a result of the chemical composition of water, in addition to the photosynthetic activities of algae and aqutic flora. **Yusuf (2019).** The pH of treated water by Sodium persulfate 10 % was substantially decreased to acdic range (pH 2.7), this is consistence with the results of **Sharma et al., (2014).** At acidic pH, the persulfate ion slowly hydrolyzes and forms peroxymonosulfate or hydrogen peroxide, where the rate of reaction increases with decreasing pH. **Siegrist, et al., (2011).** Algae removal is greatly affected by the pH of the treated water. The acidic pH of the solution promotes the production of hydroxide radicals, which leads to an increase in the oxidation potential of the hydroxide radicals. Since there are more OH radicals accessible for the decomposition process in an acidic environment, this finally reveals the amount of algae removal. Thus the highest efficiency occurs at lower pH **Gogate and Patil, (2015); Thanekar and Gogate, (2018); Innocenzi**

et al., (2018). The results show that when the pH of the solution decreases after treatment, the algae removal value increases. This is consistent with **Kim et al., (2018), Laszakovits and MacKay, (2019), Mukherjee et al., (2020); Askarniya et al., (2020); Zampeta et al., (2022).** The optimum operating conditions in relevancy with low current potential (2V) and the concentration of electrochemical disinfectant (10 %) were found to be the main factors contributed in algae removing. These findings were parallel with those obtained by **Bashir et al. (2011); Gore et al., (2014); Kuldeep & Saharan (2016); Saxena et al. (2018); Thanekar and Gogate, (2018); Lalwania et al., (2020).** In addition**,** algae removal efficacy improved over time of electrolysis. This agrees with. **Wu et al., (2012), Randhavan and Khampet, (2018); Mukherjee et al., (2020); and Zhou et al. (2022)**. Regarding to the effect of Hydrogen Peroxide disinfectant on pH of water, it was found that the hydrogen ion concentration was slightly decreased to slightly acidic range (pH 6.2-6.9). This pH condition together with 2.5 % Hydrogen Peroxide and 1.2 V current potential were contributed together in removing of algae in a certain level somewhat relatively less efficiency than that obtanined by Sodium persulfate condition.

4- Alkalinity. Alkalinity, which is determined by the concentration of bicarbonates, carbonates, and hydroxides in water, is a measure of the capacity of water to neutralize acids. Since

carbonate levels were occasionally non existed , bicarbonate ion concentrations were used in this study to express the alkalinity **Ali, (2008); Abdo and El-Nasharty, (2010); Abdo, (2013).** According to the available data, bicarbonate concentrations in the two investigated drinking water stations were relatively high. This finding can be attributed to the presence of a large amount of organic matter that is available for bacterial fermentation **Abdo, (2013)**. The treated water by Sodium persulfate disinfectant, **b**icarbonate was not present in the water's alkalinity. The absence of bicarbonate leads to the increasing of efficacy of Sodium persulfate to remove algae and other contaminants, where, higher carbonate and bicarbonate concentrations showed inhibitory effect on the activity of persulfate degradation **(Ji, et al., 2014),** On the other hand , the alkalinity was obviously decreased in the case of treating water by Hydrogen Peroxide disinfectant.

5- **Total Dissolved Salts**. The total dissolved salts reflecting the summation of total cations and anions dissolved in water. The TDS of raw water before the treatment of freshwater range (281.2-341.1 mg/l), while after treatment by persulfate disinfectant its value was increased and reached to hyper saline level. This condition together with the generation of the oxidative radicles of sulfate and hydroxides making the strongest efficiency for removing algae. The reaction mechanism of persulfate can be led either by sulfate or hydroxyl

radical, depending on the contaminant degradation mechanism. It has been proposed that sulfate radical preferably removes electrons from an organic molecule to produce an organic radical cation, whereas hydroxyl radical adds to carbon double bond, aromatic rings or abstracts hydrogen from the carbon hydrogen bond **(Antoniou, et al., 2010; Mahdi Ahmed, et al., 2012).**

6- **Biological Oxygen Demand**. BOD describes the amount of oxygen needed to break down organic matter in water **Hussain, et al. (2021).** The results of BOD readings reflecting the effectiveness of disinfectants to remove algal cells from the water sample, as the values decreased significantly to be non existed especially in the case of Sodium persulfate after the treatment. According to **Kadhum et al. (2021b)**, the pH value, the type of electrode, and the period of the electrochemical process may all have an impact on how effectively algae are removed from the water by reducing biological oxygen demand.

7- **Dissolved oxygen**. Dissolved oxygen is essential for the survival of aquatic organisms **Herbig (2019)**, and a decrease in its level can lead to serious consequences **(Elsheekh., 2016; Díaz et al., 2012).** The dissolution of oxygen in water is strongly influenced by biological processes, respiration, and remineralization of organic matter, and is not solely dependent on the presence of contaminants **Desmet et al, (2011); Rajwa-Kuligiewicz et al, (2015).** Dissolved oxygen in the raw water were ranged between

9.5 and 9.62 mg/l along the investigated drinking water stations. Electrochemical disinfectants when used can lead to a decrease in dissolved oxygen levels and this is consistent with the results obtained after the treatment especially under Sodium persulfate condition where DO values were obviously decreased (DO: 0.43-0.78 mg/l). On the other hand, the treated water by Hydrogen Peroxide disinfectant showed a slightly decreasing in the dissolved oxygen level (DO: 7.70-8.15 mg/l).

8- **Chemical Oxygen Demand**. COD can be used as a marker of organic pollution in surface waters. According to **Nemerow et al. (2009)**, COD is the amount of oxygen (mg/l) required chemically for the oxidation of molecules in both organic and inorganic components. COD is the most important indicator of the water quality index (**Mahmoud et al., 2020)**. The values of COD recorded in raw water were in between 11-354.1 mg/l. The COD value decreased after treatment, and this is consistent with the results of the study of **Kadhum et al., (2021a).** Through the study, the removal of COD is the ratio of its removal after treatment depends on the concentrations and the used time, as time increase the COD values decrease, as well as the type of electrodes used. This is confirmed with the results obtained by the studies of **Zexu et al., (2017), Sahu, (2019), Kadhum et al., (2021a), and Kadhum et al ., (2021b).**

9- **Nitrite, Nitrate, Ammonia Nitrogen**. The values of nitrite and nitrate nitrogen in raw water of the two investigated drinking

water stations were ranged between 0.049-0.114 mg/l and 17.92-49.28 mg/l respectively. The removal of nitrite by the action of Sodium persulfate electrochemical disinfectant is a promising method for water treatment. This method has been shown to effectively remove nitrite from water samples., making its potential solution for water treatment facilities. The electrochemical disinfection process involves the use of an electric current to generate reactive species that can oxidize and degrade organic and inorganic pollutants. Sodium persulfate is a strong oxidizing agent that can be used in this process to remove nitrite from water. **Kadhum et al, (2021a). The** use of Hydrogen Peroxide with a concentration of 2.5 % and a potential current of 1.2 has proven to be effective in reducing nitrate levels in treated water. This method has shown significant decline in nitrate levels, making it a promising solution for water treatment. The electrochemical disinfectants Sodium persulfate and Hydrogen Peroxide were effective in decreasing ammonia levels in treated water at El-Amyria drinking water station. However their actions were insignificant at Rod El Farag drinking water station. Ammonium in solution can also be oxidized to nitrite and nitrate. The direct oxidation of ammonia to elemental nitrogen is highly favorable over nitrogen oxyanions at lower electrode potentials. However, while nitrogen oxyanions may be produced at the anode depending on operating conditions, subsequent reduction at the

cathode is also common. Under such conditions, produced nitrate and nitrite can be sequentially or directly denitrified at the cathode to elemental nitrogen or directly from nitrate to elemental nitrogen. These interpretations explained how electrochemical disinfectants worked to reduce the amount of dissolved inorganic nitrogen. **Steven and Ronald, (2021).**

10- **Phosphorus and silica** Phosphorus and silicate dissolved in water were detected in very low concentrations in raw water samples for the two investigated drinking water stations. The application of Sodium persulfate disinfectant of 10 % concentration at 2V potential and Hydrogen Peroxide of 2.5 % at 1.2 V current potential resulting in slight increasing in the concentrations. These may be due to the effectiveness of these disinfectants to disintegrate the algal cells, releasing their components (in particular silica frustules of diatoms) in the medium. **Abdo, (2013).**

11- **Algal Composition**. Algal composition of raw water was determined qualitatively and quantitatively along different seasons from the two investigated drinking water stations. The cell density (number of individuals/l) and chlorophyll content for each water sample collected were determined. The raw water sample laden by algae was subjected under the influence of electrochemical disinfectant to study its effectiveness for removing algal cells. The percentage of removal was determined in terms of the determination of cell density and

chlorophyll content of the sample after the treatment. Generally, the algal composition of water samples collected from the two investigated drinking water stations showed number of species of blue-green algae, green algae and diatoms. Such finding confirmed the results of the previous studies on algae of River Nile **(Shehata et al 2009., Abd El-Hady and Hussein 2012., Abd El-Hady, 2014., Badr El-Din et al., (2015); and Yusuf, (2019).** The operating conditions (type of the disinfectant used, the concentration of the disinfectant, the potential current) were applied on water sample laden by algae and the results were highlighted about the efficacy of electrochemical disinfectant for removing algal cells. From the results obtained, some concluding remarks were summarized as follows:

1- The optimum operating conditions for removing of algae form drinking water through providing the Sodium persulphate disinfectant of 10% concentration at 2V current potential.

2- In aqueous solution, at room temperature and at neutral pH persulfate ion is quite stable. The persulfate ion slowly hydrolyzes and forms peroxymonosulfate or Hydrogen Peroxide at acidic pH. The rate of reaction increases with decreasing pH. **Siegrist, et al., (2011).**

3- There is an optimum persulfate concentration. Exceeding the optimum concentration, the contaminant degradation is inhibited by the reaction of excess persulfate with persulfate

radicals, e.g. the excessive persulfate competes with contaminant **(Lin & Wu, 2014; Moussavi, et al., 2016; Wang & Liang, 2014).**

4- The activation energy depends on pH conditions. At neutral pH conditions the activation energy is 119-129 kJ/mol, at alkaline pH conditions it is 134-139 kJ/mol and at acidic conditions it is 100-116 kJ/mol **(House, 1961).** Therefore, it can be concluded that preferred environment is acidic or neutral. The rate constant of sulfate radical formation at pH 1.3 varies from 1.0 × 10−7 s −1 at 25°C to 5.7 × 10−5 s −1 at 70°C **(House, 1961**).

5- The reaction mechanism of persulfate

Persulfate salts dissociate in aqueous solutions to form the persulfate anion ($S_2O_8^{2-}$). The decomposition of the persulfate anion in aqueous solution involves the following reactions (Kolthoff & Miller, 1951)

$$S_2O_8^{-2} + H_2O \rightarrow 2HSO_4^- + ½\ O_2 \quad (1)$$

$$H_2O_2O_8 + H_2O \rightarrow H_2SO_5 + H_2SO_4 \quad (2)$$

$$H_2SO_5 + H_2O \rightarrow H_2O_2 + H_2SO_4 \quad (3)$$

Persulfate decomposes in dilute acid, neutral and alkaline solutions according to reaction Eq. (1). Reactions Eq. (2) and Eq.(3) apply for strongly acid solutions **(Kolthoff & Miller, 1951).** Persulfate anion is a strong oxidant, with the oxidation potential of 2.01 V **(House, 1961):**

$$S_2O_8^{-2} + 2H^+ + 2e^- \rightarrow 2HSO_4^- \quad (4)$$

Therefore, it can degrade many environmental contaminants. However, the persulfate anion typically has slow oxidative kinetics at ordinary temperatures for most contaminant species and really can only be applied to a limited number of contaminants, such as TCE or xylene, to be effective. In these circumstances persulfate is typically activated for oxidizing most contaminants or concern. In the presence of various reactants it can be catalyzed to form more powerful oxidant, the sulfate free radical ($SO^{-\bullet}_4$), with the oxidation potential of 2.6 V:

$$S_2O_8^{-2} + \text{activator} \rightarrow SO_4^{-\bullet} + (SO_4^{-\bullet} \text{ or } SO^{-\prime}_4) \quad (5)$$

Catalysis of persulfate anion and sulfate radical can be achieved at elevated temperatures (35 – 40 °C), with ferrous ion, by photo activation, with elevated pH, or with hydrogen peroxide. In addition to ferrous ion, the activators can include also ions of copper, silver, manganese, cerium and cobalt. Under acidic conditions persulfate anion can hydrolyze to form Hydrogen Peroxide **(Kolthoff & Miller, 1951):**

$$S_2O_8^{-2} + 2H_2O \rightarrow H_2O_2 + 2HSO_4^- \quad (6)$$

Hydrogen Peroxide has the oxidation potential of 1.77 V and in the presence of various activators, can form the hydroxyl radical, with the oxidation potential of 2.8 V. It is the strongest available oxidant for remediation applications. In addition, also hydroxyl radicals are generated when sulfate radicals react with water. Under

stronger conditions, persulfate can form peroxymonopersulfate anions, with the oxidation potential of 1.44 V

$$S_2O_8^{-2} + H_2O \rightarrow HSO_5^- + HSO_4^- \quad (7)$$

In this context, persulfate solutions may contain several different oxidant and radical species. This increases the probability of reducing the target contaminant's concentration as mixture of oxidizing species may cause multiple pathways for degradation of the contaminant. However, such diversity of oxidant species makes the assessment of the stoichiometric amount of persulfate needed to decompose the contaminants problematic, and thus it is common practise to revert back to the basic, two electron transfer associated with the persulfate anion (Eq. (4)) to determine the stoichiometric persulfate demand. In addition, under certain conditions persulfate can also generate the reductive species, super oxide. Under alkaline activation conditions through the addition of hydrogen radical, persulfate generates both sulfate radicals and superoxide **(Furman, et al., 2010)**

$$2S_2O_8^{-2} + 2H_2O \rightarrow 3SO_4^{-2} + SO_4^{-\bullet} + O_2^{-\bullet} + 4H^+ \quad (8)$$

Under highly alkaline conditions sulfate radical can react with hydroxide ion to form hydroxyl radicals (**Watts & Teel, 2006):**

$$SO_4^{\bullet-} + OH^- \rightarrow SO_4^{-2} + OH^{\bullet} \quad (9)$$

6- . Persulfate has many advantages over the other well-known oxidants. The following describes advantages resulting from persulfate physical properties. An important advantage is

1- High aqueous solubility (saturated solution: 2.5M $Na_2S_2O_8$ at 20 °C) (**Ji, et al., 2014; Liang, et al., 2006).**

2- Persulfate also has no odour and due to its powder form and stability is also easy to transport.

3- Also due to the previously mentioned properties persulfate can be transferred more effectively to the contaminated zones to react with the contaminants. **Huang, et al., (2002).**

The following describes advantages resulting from persulfate chemical properties. One of the most important property is effectiveness of oxidation. Persulfate has the redox potential of 2.01V over a wide range of pH. **Liang, et al., (2006).** Activating persulfate results to forming of sulfate and hydroxyl radicals, which have even more higher redox potential, 2.6V and 2.7V, respectively. In most cases the sulfate radical is predominant radical. Nonetheless hydroxyl radical has a slightly higher redox potential than sulfate radical, the hydroxyl induced oxidation is unselective, For example, with increasing pH hydroxyl radicals may be completed and thereby lowering the treatment rate by many other co-existing species, like bicarbonate and carbonate. **Tan, et al., (2012).** Some studies compared persulfate to other common oxidants as Hydrogen Peroxide and ozone and found persulfate more stable in the

subsurface **(Huang, et al., 2002; Huling & Pivetz, 2006)**. This is due to the fewer mass transfer and mass transport limitations (**Huling & Pivetz, 2006).** Also the natural oxidant demand for persulfate is low. The stability of the persulfate also allows it to be injected at high concentrations, storage and transport it easily, even to contamination in hard to reach places **(Huling & Pivetz, 2006; Waldemer, et al., 2007; Ji, et al., 2014).** Persulfate will undergo density-driven and diffusive transport into low permeability materials **(Huling & Pivetz, 2006).** In practical application, Hydrogen Peroxide activation is short-lived as the Hydrogen Peroxide rapidly decomposes, often with considerable off-gassing.

SUMMARY

Algae in water are of great concern because they adversely affect drinking water quality and water treatment processes. The presence of algae in water treatment plants interferes with physical and/or chemical water purification processes.

This study is concerned with the treatment of drinking water laden by algae by the production of electrochemical disinfectants represented by Sodium persulfate and Hydrogen Peroxide.

The objective of this study is to determine the efficacy of the electrochemical disinfectant for removing of algae in terms of cell density and chlorophyll content.

Water and algal samples were collected seasonally from the waterways feeding the drinking water stations (El- Amyria and Rod El-Farag) during 2021-2022. Physico-chemical parameters were determined before and after the treatment. Four concentrations of Sodium persulfate were prepared (2.5%, 5.0%, 7.5%, and 10%) at two different potential current 2.0V and 2.5 V. For hydrogen peroxide disinfectant, only 2.5 % concentration at 1.2 V potential was applied during the study.

Through the study along the two studied drinking water stations, the efficiency of different concentrations of Sodium persulfate disinfectant was investigated on raw water and the water laden by algae. It was appeared that 10% concentration of $Na_2S_2O_8$ was the best and effective concentration to be chosen for raw water at optimum potential 2.0V.

The consequences of the treatment of raw water by the electrochemical disinfectants on its physico-chemical characteristics were obviously indicated for changing these characters by lowering their values mostly throughout the study.

Generally, the algal composition of water samples collected from the two investigated drinking water stations showed number of species of blue-green algae, green algae and diatoms.

The number of algae during the study ranged from 94 species belonging to 3 division of algae. Diatoms were predominant throughout the study, followed by green algae and blue-greens.

The operating conditions (type of the disinfectant used, the concentration of the disinfectant, the potential) were applied on water sample laden by algae and the results were highlighted about the efficacy of electrochemical disinfectant for removing algal cells.

From the results obtained, some concluding remarks were summarized as follows:

1- The optimum operating conditions for removing of algae form drinking water through providing the Sodium persulphate disinfectant of 10% concentration at 2.0V potential.

2- In aqueous solution, at room temperature and at neutral pH persulfate ion is quite stable. The persulfate ion slowly hydrolyzes and forms peroxymonosulfate or hydrogen peroxide at acidic pH.

3- The action mechanism of electrochemical disinfectant of Sodium persulfate on removing of algae weas due to the production of oxidative radicals as sulfate free radical (SO^{2-}_4) and also under acidic conditions persulfate anion can hydrolyze to form Hydrogen Peroxide. In addition, also hydroxyl radicals are generated when sulfate radicals react with water. Under stronger acidic conditions, persulfate can form peroxymonopersulfate anions. In this context, persulfate solutions may contain several different oxidant and radical species. This increases the probability of reducing the target contaminant's concentration as mixture of oxidizing species may cause multiple pathways for degradation of the contaminant.

4- Persulfate has many advantages over the other well-known oxidants. An important advantage is high aqueous solubility (saturated solution: 2.5M $Na_2S_2O_8$ at 20°C) also persulfate has no odour and due to its powder form and stability is also easy to transport. Also due to the previously mentioned properties persulfate can be transferred more effectively to the contaminated zones to react with the contaminants. One of the most important property is effectiveness of oxidation. Persulfate has the redox potential of 2.01V over a wide range of pH.

5- For Hydrogen peroxide disinfectant, hydroxyl radicals were formed and be effective for algal removing.

6- Finally it was concluded that, the implementation of these novel methods requires follow up studies that should verify their usefulness for promoting effective persulfate degradation and advanced process characteristics for practical application, especially for upscaling the applications and the cost-effectiveness. Based on the studies examined, persulfate has a great potential as a novel oxidant in treatment of the contaminated water and wastewater, but more research is necessary to confirm that.

Conclusion and Recommendations

It could be concluded that the proposed methods for electrochemical production of water disinfectants are simple and effective for removal of algae and from raw water. The production of Sodium persulfate and Hydrogen peroxide is easy, fast and cost effective as the voltage needed for it is very low and could be applied by a solar cell.

For the final conclusion, the implementation of these novel methods requires follow up studies that should verify their usefulness for promoting effective Sodium persulfate degradation and advanced process characteristics for practical application, especially for upscaling the applications and the cost-effectiveness. Based on the studies examined, Sodium persulfate has a great potential as a novel oxidant in treatment of the contaminated water and wastewater, but more research is necessary to confirm that.

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الملخص العربى

تعتبر الطحالب الموجودة في المياه مصدر قلق كبير لأنها تؤثر سلبًا على جودة مياه الشرب وعمليات معالجة المياه. يسبب وجود الطحالب في محطات معالجة المياه في عدم كفاءة العمليات الفيزيائية والكيميائية لتنقية المياه.

تهتم هذه الدراسة بمعالجة مياه الشرب المحملة بالطحالب بإنتاج المطهرات الكهروكيميائية المتمثلة في بيرسلفات الصوديوم وبيروكسيد الهيدروجين.

الهدف من هذه الدراسة هو تحديد كفاءة المطهر الكهروكيميائي لإزالة الطحالب من حيث كثافة الخلايا ومحتوى الكلوروفيل.

جمعت عينات المياه والطحالب موسميا من المصادر المائية المغذية لمحطتي مياه الشرب (الأميرية و روض الفرج) خلال الفترة ٢٠٢١-٢٠٢٢. تم تحديد المعلمات الفيزيائية والكيميائية قبل وبعد المعالجة. تم تحضير أربعة تراكيز من بيرسلفات الصوديوم (٢.٥٪ ، ٥.٠٪ ، ٧.٥٪ ، ١٠٪) عند جهدين محتملين مختلفين ٢ فولت و ٢.٥ فولت لمطهر بيروكسيد الهيدروجين ، تم تطبيق تركيز ٢.٥٪ فقط عند جهد تيار ١.٢ فولت أثناء الدراسة. .

من خلال الدراسة على طول محطتي مياه الشرب اللاتى تحت الدراسة ، تم فحص كفاءة تراكيز مختلفة من مطهر بيرسلفات الصوديوم على الماء الخام والمياه المحملة بالطحالب. اتضح أن تركيز ١٠٪ من $Na_2S_2O_8$ كان أفضل تركيز وأكثر فاعلية ليتم اختياره للمياه الخام عند الجهد الحالي الأمثل ٢ فولت.

تمت الإشارة بوضوح إلى نتائج معالجة المياه الخام بواسطة المطهرات الكهروكيميائية على خصائصها الفيزيائية والكيميائية لتغيير هذه الصفات عن طريق خفض قيمها على الأغلب طوال فترة الدراسة.

بشكل عام ، أظهر تكوين الطحالب لعينات المياه التي تم جمعها من محطتي مياه الشرب الخاضعين للفحص عدد أنواع الطحالب الخضراء المزرقة والطحالب الخضراء والدياتومات. تراوح عدد الطحالب خلال الدراسة من ٩٤ نوعًا تنتمي

إلى ٣ أقسام من الطحالب. كانت الدياتومات هي السائدة خلال الدراسة ، تليها الطحالب الخضراء والخضر الزرقاء.

تم تطبيق ظروف التشغيل (نوع المطهر المستخدم ، تركيز المطهر ، التيار المحتمل) على عينة ماء محملة بالطحالب وتم إبراز النتائج حول فعالية المطهر الكهروكيميائي في إزالة الخلايا الطحلبية.

ومن النتائج التي تم الحصول عليها تتلخص على النحو التالي:

١- ظروف التشغيل المثلى لإزالة الطحالب من مياه الشرب من خلال توفير مطهر كبريتات الصوديوم بتركيز ١٠٪ بجهد تيار ٢ فولت.

٢- في محلول مائي ، عند درجة حرارة الغرفة وعند درجة حموضة متعادلة أيون بيرسلفات ، يكون مستقرًا تمامًا. يتحلل أيون بيروكبريتات ببطء ويشكل بيروكسيمونوسلفات أو بيروكسيد الهيدروجين عند درجة الحموضة الحمضية.

٣- آلية عمل المطهر الكهروكيميائي لبيرسلفات الصوديوم على إزالة نوى الطحالب بسبب إنتاج أيونات المؤكسدة مثل أيونات الحرة للكبريتات (SO_4^{2-}) وأيضًا في الظروف الحمضية يمكن أن يتحلل أنيون بيرسلفات الصوديوم لتكوين بيروكسيد الهيدروجين. بالإضافة إلى ذلك ، يتم أيضًا إنشاء أيونات الهيدروكسيل عندما تتفاعل أيونات الكبريتات مع الماء. في ظل ظروف حمضية أقوى ، يمكن أن يشكل بيروكسيونات أنيون بيروكسيمونوبرسلفات. في هذا السياق ، قد تحتوي محاليل بيرسلفات على عدة أنواع مختلفة من المؤكسدات والايونات. هذا يزيد من احتمال تقليل تركيز الملوث المستهدف حيث أن خليط الأنواع المؤكسدة قد يتسبب في مسارات متعددة لتحلل الملوثات.

٤- يحتوي البرسلفات على العديد من المزايا مقارنة بالمؤكسدات المعروفة الأخرى. ميزة مهمة هي الذوبان المائي العالي (محلول مشبع: ٢.٥ M $Na_2S_2O_8$ عند ٢٠ درجة مئوية) كما أن البيرسلفات الصوديوم ليس له رائحة وبسبب شكله المسحوق واستقراره سهل النقل أيضًا. أيضًا بسبب الخصائص

المذكورة سابقًا ، يمكن نقل البيرسلفات الصوديوم بشكل أكثر فعالية إلى المناطق الملوثة للتفاعل مع الملوثات. من أهم الخصائص فعالية الأكسدة. يحتوي بيرسلفات على إمكانات الأكسدة والاختزال عند جهد ٢.٠١ فولت على نطاق واسع من الأس الهيدروجيني.

٥- بالنسبة لمطهر بيروكسيد الهيدروجين ، تم تكوين ايونات الهيدروكسيل الفعالة في إزالة الطحالب.

٦- أخيرًا ، تم التوصل إلى أن تنفيذ هذه الأساليب الجديدة يتطلب دراسات متابعة يجب أن تتحقق من فائدتها في تعزيز التحلل الفعال للبيرسلفات وخصائص العملية المتقدمة للتطبيق العملي ، خاصة لتوسيع نطاق التطبيقات والفعالية من حيث التكلفة. بناءً على الدراسات التي تم فحصها ،يحتوي الكبريتات على إمكانات كبيرة كعامل مؤكسد جديد في معالجة المياه الملوثة ومياه الصرف الصحي ، ولكن يلزم إجراء المزيد من الأبحاث لتأكيد ذلك.

المستخلص العربي

المستخلص العربي

تمت دراسة إزالة الطحالب بالمعالجة الكهروكيميائية من خلال تحضير مطهرات كهروكيميائية من بيرسلفات الصوديوم وبيروكسيد الهيدروجين. تم تجهيز الخلية بقطبين كهربائيين (قطبين متطابقين من الجرافيت). تم تقييم تأثير عوامل التشغيل المختلفة، مثل الجهد المطبق وكمية كبريتات الصوديوم الأولية المضافة في حالة إنتاج بيرسلفات. تم فحص تأثير فرق الجهد أيضًا في حالة إنتاج بيروكسيد الهيدروجين. تم تجربة المطهرين وجد انهما فعالين في إزالة المياه المحملة بالطحالب عند تطبيقهما على العينات المأخوذة من محطتي مياه الشرب في الامرية وروض الفرج. تم العثور على نظام pro-type المستخدم مع الطرق المقترحة ليكون بسيطًا وسريعًا وفعالًا لإزالة الطحالب.

الكلمات المفتاحية: إزالة الطحالب، المطهرات الكهروكيميائية، بيرسلفات الصوديوم، بيروكسيد الهيدروجين.

جامعة عين شمس
كلية العلوم
قسم النبات

دراسة تأثير المطهرات الناتجة بالعمليات الكهروكيميائية على نمو الطحالب في مياه الشرب

رسالة
مقدمة للحصول على درجة الدكتوراه الفلسفة في العلوم
علم النبات
كلية العلوم - قسم النبات - جامعة عين شمس
للباحثة

انتصار كريم عبدالحسن
(ماجستير نبات/ ٢٠١٥)
كلية التربية للعلوم الصرفة /ابن الهيثم - جامعة بغداد
تحت أشراف

أ.د/ عادل فهمي حامد
أستاذ علم الطحالب - قسم النبات
كلية العلوم جامعة عين شمس

د.هشام محمد عبدالفتاح
أستاذ علم الطحالب المساعد - قسم النبات
كلية العلوم - جامعة عين شمس

أ.د/ جمال عويس السيد
أستاذ علم الكيمياء - قسم الكيمياء
كلية العلوم جامعة بنها

٢٠٢٣

دراسة تأثير المطهرات الناتجة بالعمليات الكهروكيميائية على نمو الطحالب في مياه الشرب

للباحثة

انتصار كريم عبدالحسن

المشرفون **التوقيع**

١- **أ.د/ عادل فهمي حامد** .....

أستاذ علم الطحالب - قسم النبات
كلية العلوم جامعة عين شمس

٢- **د.هشام محمد عبدالفتاح** .....

أستاذ علم الطحالب المساعد - قسم النبات
كلية العلوم - جامعة عين شمس

٣- **أ.د/ جمال عويس السيد** .....

أستاذ علم الكيمياء - قسم الكيمياء
كلية العلوم جامعة بنها

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الشكر

اللهم لك الحمد حتى ترضى ولك الحمد اذا رضيت ولك الحمد بعد الرضا اللهم يا من قرب من خطرات الظنون وبعد عن لحظات العيون وعلم بما كان قبل ان يكون يا من أرقدني بمهاد آمنه وأمانه وأيقظني الى ما منحني به من مننه وإحسانه وكف اكف السوء عني بيده وسلطانه صلِّ اللهم على الدليل اليك بالليل الأليل والماسك من اسبابك بحبل الشرف الأطول والناصح الحسب في ذروة الكاهل الاعبل والثابت القدم على زحاليفها في الزمن الاول وعلى آله الاخيار المصطفين الابرار.

أتقدم بالشكر والتقدير لجامعة ديالى / كلية التربية الأساسية لإتاحة الفرصة لي لإكمال دراستي.

كما أتقدم بالشكر والتقدير لجامعة عين شمس ورئاسة قسم النبات/ كلية العلوم لتسهيلها كل المعوقات أمام أستكمال دراستي في كليتهم الموقرة.

كما أتقدم بخالص شكري إلى أستاذي ومشرفي **الأستاذ الدكتور عادل فهمي حامد** أستاذ الطحالب بقسم النبات بكلية العلوم جامعة عين شمس لاقتراح وجهة البحث والمساعدة التي قدمها لي طوال فترة دراستي، له كل المودة والاحترام والتقدير.

و أقدم شكري وأمتناني لاستاذي ومشرفي **الأستاذ الدكتور جمال عويس السيد** أستاذ الكيمياء قسم الكيمياء جامعة بنها على الجهد الذي بذله معي طوال فترة دراستي فيما يتعلق بالجزء الكهروكيميائي من أُطرُوحَتي، له مني كل الشكر والتقدير.

كما أود أن أشكر أستاذي ومشرفي **الدكتور هشام محمد عبدالفتاح** أستاذ الطحالب المساعد بقسم النبات بكلية العلوم جامعة عين شمس للجهد الذي بذله طيلة فترة دراستي. وتوجيهاته القيمة لجعل هذا العمل يخرج بهذه الطريقة ، له كل الشكر والتقدير .

و أشكر **زوجي الحبيب حيدر** الذي تحمل كل المصاعب معي له مني كل الحب والاحترام

كما أشكر **امي وخالتي جنان** على دعائهما المتواصل لي ودعمهم .

وأشكر اولادي **(حسين وامامي وزينب وزهراء)** لتحملهم معي مشاق السفر والغربة .

كما أود أن أشكر كل من وقف معي ودعمني ليخرج هذا العمل بهذا الإنجاز العلمي.

انتصار كريم عبدالحسن

جامعة عين شمس
كلية العلوم

اسم الطالب : انتصار كريم عبدالحسن

عنوان الرسالة : دراسة تأثير المطهرات الناتجة بالعمليات الكهروكيميائية على نمو الطحالب في مياه الشرب

اسم الدرجة : دكتوراه الفلسفة في العلوم (نبات)

القسم التابع له : النبات

اسم الكلية : العلوم

اسم الجامعة : جامعة عين شمس

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