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Treatment of Produced Water Using Microalgae

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ABSTRACT

Produced water is one of the key attractions in the oil fields, where formation water rises to the surface along with the crude oil and is then separated to prevent many problems that may arise during transportation. Nevertheless, the created water is occasionally injected into a man-made lake inside the fields. The sands, creatures, vegetation, and formation water are all contaminated by the lake's water. Because produced water contains minerals and inorganic salts, effective treatment of this water is crucial. This study was conducted to examine how treating produced water with organic elements like freshwater algae affected the amount of salts in the formation water. Two types of freshwater algae namely: Oedogonium algae , Zygnema algae, were used.

Electrical Conductivity (E.C), pH, total dissolved solids (TDS), and salinity were measured before and after the treatment at different times intervals (on day one, the fourth day, and the seventh day). The results showed that Oedogonium algae have positive effects on the first day, whereas TDS decreased from 5364 mg/l to 1381 mg/l, pH changed from 7.13 to 8.7, E.C decreased from 10.95 ms/cm to 2.818 ms/cm, and salinity decreased from 6.2 ppt to 1.6 ppt. The treated produced water was used for irrigation of plants and as a drinking water for animals without any detrimental effects.

معالجة المياه المنتجة باستخدام الطحالب الدقيقة

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الكلمات المفتاحية:
معالجة المياه
الطحالب الدقيقة
المياه المنتجة
الملوحة
Oedogonium algae
Zygnema algae

الملخص

تعتبر المياه المنتجة من أهم مواضيع الجذب في حقول النفط، حيث تأتي مياه التكوين إلى السطح مع النفط الخام ويتم فصلها لتجنب العديد من المشاكل التي قد تحدث أثناء النقل. ومع ذلك، فإن المياه المنتجة تضخها أحيانًا في بحيرة اصطناعية داخل الحقول. تتسبب مياه تلك البحيرة في تلوث الرمال والحيوانات والنباتات ومياه التكوين ونظرا لأن المياه المنتجة تحتوي على معادن وأملاح غير عضوية. لذلك فإن المعالجة الفعالة لهذه المياه مهمة جدا. نفذت هذه الدراسة لفحص كبفبة معالجة المياه المنتجة بعوامل مثل طحالب المياه العذبة وتأثير ذلك على كمية الاملاح. تم استخدام اثنان من الطحالب هما Oedogonium algae و.Zygnema algae سجلت قيم كل من pH، والتوصيل الكهربائي (E.C)، والمواد الصلبة الذائبة الكلية TDS، والملوحة قبل وبعد المعالجة على مدى فترات زمنية: اليوم الاول والرابع واليوم السابع.. بينت النتائج أفضل نتيجة واط في اليوم الأول، فيما يتعلق بـ Oedogonium ، حيث انخفض TDS من 5364 ملجم / لتر إلى 1381 ملجم / لتر ، وتغير الرقم الهيدروجيني من 7.13 إلى 8.7 ، وانخفض EC من 10.95 مللي ثانية / سم إلى 2.818 مللي ثانية / سم ، و انخفضت الملوحة من 6.2 جزء إلى 1.6 جزء من المليون ، كما انخفضت الأملاح الثقيلة معنوياً في عدة عناصر ، واستخدمت المياه المعالجة لري النباتات وسقاية الحيوانات و بدون أي تأثيرات ضارة. وبناءً على هذه

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النتائج يمكن أن نستخلص أن إمكانية الحد من التلوث الناجم عن المياه المنتجة صحبة العمليات النفطية وذلك بواسطة مواد عضوية أمنة وتحويلها إلى مياه مفيدة.

Introduction

In the contemporary epoch, petroleum assumes a seminal stature as a preeminent wellspring of energy and fiscal revenue for myriad nations, with its extraction being characterized as a paramount industrial undertaking within the ambit of the twenty-first century [1]. Since the inaugural drilling of the maiden oil well by Edwin Drake during the latter half of the 1850s, petroleum has sustained an unabated trajectory of burgeoning demand. Prognostications intimate an escalation in global daily petroleum consumption from 85 million barrels in 2006 to a projected 106.6 million barrels by the year 2030 [2]. Notwithstanding its indispensability, the petroleum production endeavor engenders substantial byproducts, and it is noteworthy that wastewater constitutes an excess of 80% of the aggregate liquid waste [3], a proportion that swells to nearly 95% in maturing oilfields [4]. The customary volumetric ratio of oil to water approximates 1:3 [5]. Designated as formation water, the subsurface aqueous entourage that ascends to the surface concomitant to oil and gas extraction, is fraught with a composite composition typified by constituents bifurcating into organic and inorganic moieties [7]. These encompass dissolved and dispersed hydrocarbons, adipose matter, heavy metallic entities, radionuclides, treating agents, solid components originating from the formation, salts, dissolved gases, scale derivatives, waxes, microorganisms, and dissolved oxygen [5-8]. Notably, the global daily production from oil and gas reservoirs yields an estimated 250 million barrels of water, a fraction exceeding 40% of which is disseminated into the surroundings. Within reservoirs, the co-presence of indigenous water, or formation water, is an established phenomenon contiguous to petroleum reservoirs. This aqueous contingent is sequestered beneath hydrocarbon reserves within porous reservoir matrices, characterized by a marginally acidic pH [6] (Figure 1).

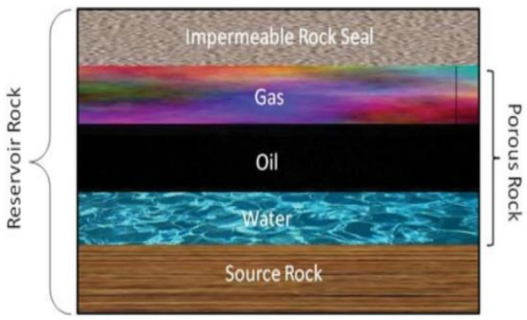

Fig 1: Sketch of a typical reservoir.

To sustain hydraulic reservoir pressure and ameliorate petroleum retrieval efficiencies, an augmented inflow of water is a conventional recourse subsequent to the diminution of reservoir pressure ensuing oil and gas extraction. In tandem with the progression of oil and gas production, a juncture arises when formation water, inherent to the subsurface, interfaces with production wells, thereby commencing a concomitant emergence of water alongside hydrocarbon extraction. Beyond introduced injection water; the potential exists for extraneous water incursions from the peripheries of the reservoir. Signifying a preponderant outcome of oil and gas extraction endeavors, this aqueous component is frequently termed as produced water or oilfield brine [9,10]. This composite manifestation, contingent on its origin, is commonly delineated into categories inclusive of oilfield-produced water, water generated through natural gas activities, or coal bed methane (CBM) production-derived water. It represents an amalgamation of injection water, formation water, hydrocarbon constituents, and ancillary treating agents [11]. Surpassing 60% of the globally generated daily produced water is attributed to oilfields [5]. Moreover, the trajectory of oilfield produced water output is anticipated to mount as the oilfields mature (Figure 2). Noteworthy is the assertion that diverse factors have been documented to exert influence upon the quantum of produced water amassed within an oilfield [9].

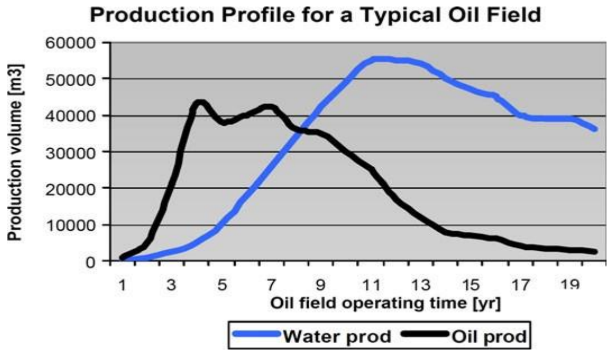

Fig 2: Typical production profile for an oil field[12].

The compositional constituents of produced water primarily encompass production chemicals, dissolved gases (including CO_2 and H_2S), generated solids, dissolved and dispersed hydrocarbon fractions, and solubilized formation minerals [13]. Variability in its organic and inorganic composition is notably pronounced, stemming from distinct geological strata, the reservoir's temporal longevity, and the nature of extracted hydrocarbons. Operators' objectives in treating produced water typically encompass de-oiling (removal of dispersed oil and grease), desalination, abatement of suspended particulates and sand, elimination of soluble organic components, mitigation of dissolved gases, attenuation of naturally occurring radioactive materials (NORM), disinfection, and softening (to ameliorate water hardness) [13]. The amalgam may encompass reservoir water, injection water, and assorted chemicals employed across drilling, production, and treatment processes, thereby encapsulating the multifaceted nature of produced water [6], interchangeably referred to as "brine," "saltwater," or "formation water" [6].

An array of factors exerts considerable influence upon the physicochemical attributes of generated water, encompassing:
1. Geographic situs of the oilfield.
2. Geological configuration from which it emanates.
3. Type of hydrocarbon derivative undergoing production. Importantly, produced water's properties and volume often exhibit dynamic fluctuations over the reservoir's lifecycle [6].
The economic viability of oil and gas production is intricately tied to the management expenditure associated with produced water. The cumulative outlay, spanning a range from fractional cents per barrel to surpassing five US dollars per barrel, incorporates:
1. Establishment costs of treatment and disposal infrastructure, encompassing equipment procurement.
2. Operational expenses tied to these facilities, embracing chemical adjuncts and utilities.
3. Management costs linked to byproducts arising from produced water treatment.
4. Costs affiliated with permitting, monitoring, and regulatory reporting.
5. Transportation costs. Typically, well shutdown becomes a recourse when the expense of produced water management surpasses the value of the extracted hydrocarbon [6].

2.Experimental Part

two beakers with a combined capacity of 1000 ml to begin the experiment. Each cup contains roughly 30 grams of algae, 100 milliliters of algae water, and 800 millilitersof produced water were treated for 1,4 and 7 days,After 24 hours(1day), we used the beaker, funnel, and filter paper to complete the water filtration process.We

took 20 ml of water after treating it for 24 hours(1day), and took the results, as well as the same steps after 4 days and 7 days. and we did an experiment using algae, but without fresh algae water, and it was separated with a manual filter, but it did not produce any results.
(treated water) that could be used to demonstrate the treatment process's effectiveness, the level of pollution, and its effects on the environment.

(a) (b) (c)

Fig 3:(a) processing experience, (b)filtration process, (c) sampleafter processing.

3. Results and Discussion

3.1 PH Results

Through the results as shown in the table (1,2),The average pH content in the oil well water before and after the treatment process was discovered by the results, which are depicted in figure (4). The PH values were discovered to vary throughout the treatment procedure; the samples under study had PH values between 7.13 and 8.64. The values of the function were specified by the classification used by the World Health Organization (WHO, 2006) [14]. According to these criteria, water with a PH of (6.5-8.5) can be used for both agricultural and human purposes without causing any issues. When the treatment time is between 1 and 4 days, it was seen that the PH is higher than permitted levels. The pH number should be high or excessively low to signal that the water is unsafe for use. While a high pH makes the water taste bitter, a low pH results in the corrosion and disintegration of minerals and other elements [15].

Table 1: Results of pH analysis of pre-treatment water samples

PH	7.13

Table 2: Results of pH analysis of post-treatment water samples

Algae species	odogonium algae	zygenem algae
1 day	8.17	8.12
4 day	8.26	7.92
7 day	7.14	7.22

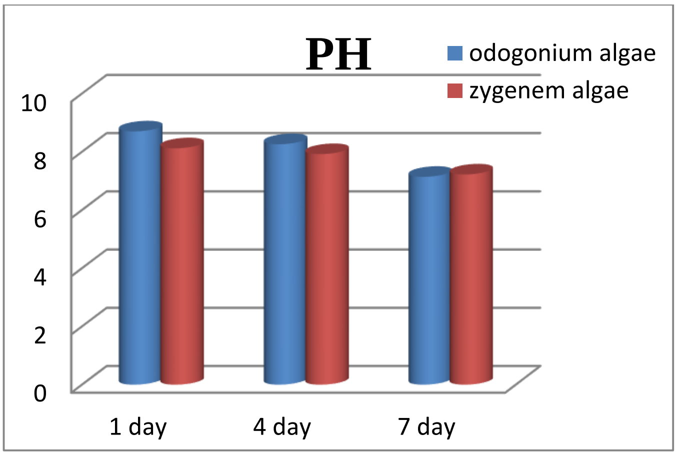

Fig 4: Results of pH analysis of post-treatment water samples

3.2Electrical Conductivity (E.C) Results

Figure (5) shows that the level of electrical conductivity in water after addition was less than the permissible limit (where all samples fall within a range greater than (32.00) (mc/cm), and on the approved classification of the World Health Organization (WHO, 2006), as well as the Public Health Standards of the United States of America (APHA, 1975), as well as on Specifications and Standards of the Libyan National Center for Drinking Water (LNCSDWS, 1992)[14,16,17]. The amount of material ions that carry positive and negative electric charges that are dissolved in water determines the electrical conductivity of water. To some extent, temperature has an impact on electrical conductivity as it increases with increasing heat [18]. The degree of electrical conductivity is directly proportional to the increase in the amount of these ions.

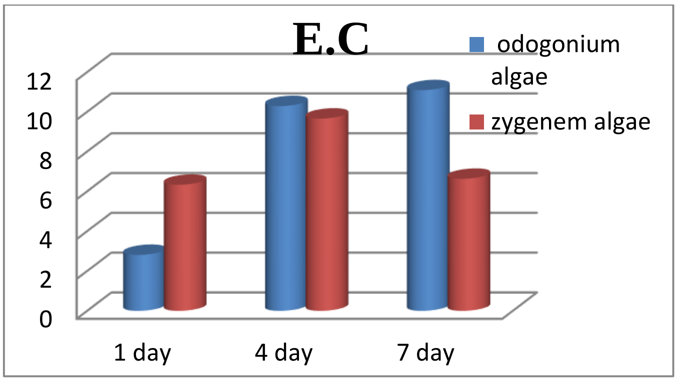

Fig 5: Electrical Conductivity analysis results of post-treatment water samples

3.3 Total Dissolved Solids (TDS) Results

It is a measurement of the amount of inorganic compounds dissolved in water, according to Figure (6). Dissolved salts are primarily composed of chlorides and sulfates, nitrates, carbonates, bicarbonates, sodium, calcium, and magnesium. Inorganic secondary components, such as aluminum, copper, and iron, are present in low amounts in natural waters.Total dissolved salts are a measure of the amount of inorganic substances dissolved in water. According to the World Health Organization (WHO), the permissible limit for total dissolved salts is between (500-1000) mg/L. The results obtained by total dissolved salts are higher than the permissible limit (values range from 1100 to 5000 mg/L), where high TDS values give the water a bitter taste and make it unpalatable.

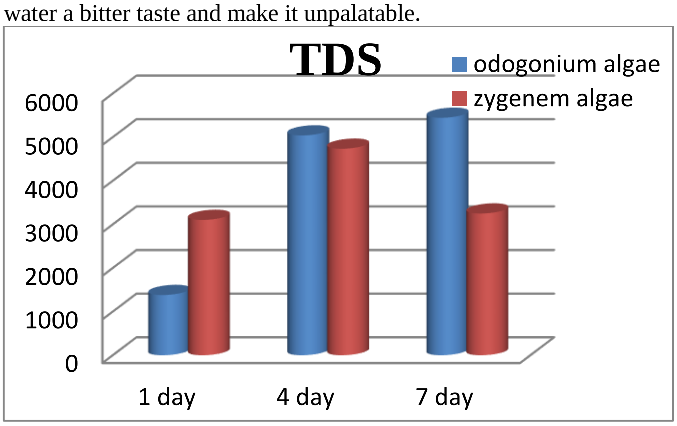

Fig 6: Total Dissolved Solids (TDS) analysis results of post-treatment water samples.

3.4 Salinity Results

Table (3,4) indicates the Salinity analysis results, we notice through the results that the first days of treatment, the salinity decreased to 80%, meaning that the algae showed a clear effect.
On day 4, the salinity rate increased to 70%, and this indicates that the algae had died. 7day, the salinity rate decreased to 15% compared to day 4, and this indicated that the algae had begun to decompose.according to Figure (7).

Table 3: Salinity analysis results of pre-treatment water samples

Salinity	6.2 ppt

Table 4: Salinity analysis results of post-treatment water samples

Algae species	odogonium algae	zygenem algae
1 day	1.6 ppt	3.6 ppt
4 day	5.8 ppt	5.4 ppt
7 day	6.3 ppt	3.6 ppt

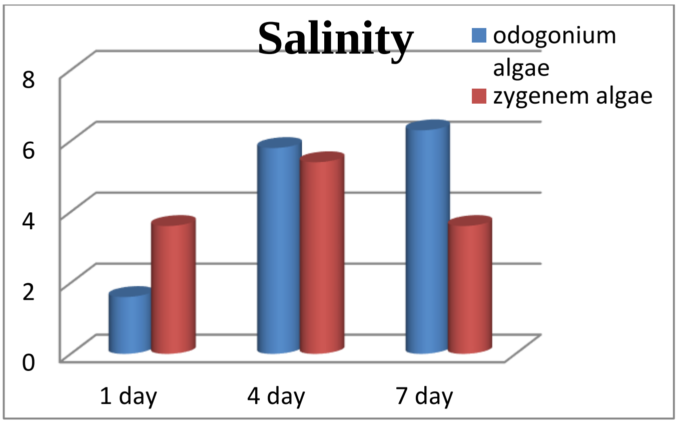

Fig 7: Salinity analysis results of post-treatment water samples

3.5 Results of Heavy Salt Elements

Through the results as shown in the table (5),Figure (8) indicates the results of heavy salts elements of the treated water sample usingOedogonium algae.

Table 5:Results of heavy salts elements of the treated water sample Oedogonium algae.

Elements	before treating the produced water	After treatment of the produced water
Calcium	441.36	113.616
Magnesium	176.544	45.446
sodium	1011.45	260.37
Potassium	107.275	27.615
Bicarbonate	2318.36	596.799
Sulfate	245.2	63.12
Chlorides	1042.1	268.26

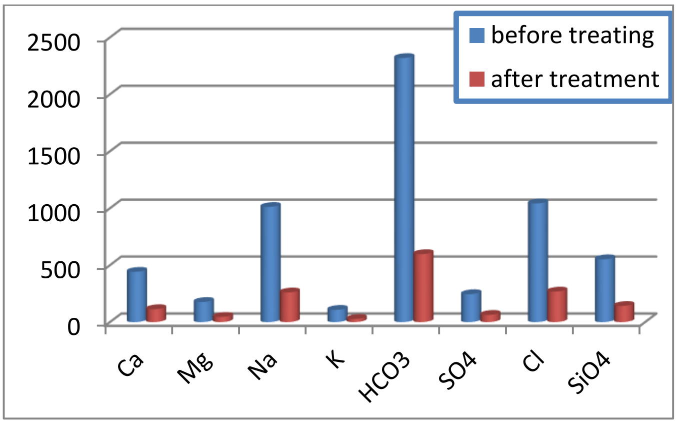

Fig 8: Results of heavy salt elements

As can be seen from Fig. 3.4, noticeable reduction in the amount of heavy salt elements (e.g. Ca, Mg, Na, K, HCO_3, SO_4, Cl, SiO_4) occurred after treatment of produced water. The highest reduction occurred in HCO_3 element, reaching74 % from the initial value (before treatment).

3.6 The Process of Using the Produced Water after Treatment

Plant irrigation can be carried out using the treated generated water. A comparison was done between the produced water's quality before and after the treatment process. Two distinct varieties of seedlings were employed, and the irrigation procedure went on for seven days**:**

1.Dadonia seedlings: As shown in Figure (9), Dadonia seedlings were irrigated with post-treatment water.It was green for seven days.

Fig 9: Dadonia seedlings with water after treatment.

2.Alunca seedlings: Alunca seedlings were irrigation with post-treatment water.It remained green for seven days, as shown in Figure (10) below.

Fig 10: Alonca seedlings with water after treatment

Additionally, the treated water was given to the animals as drinking water. For instance, it was tried on homing pigeons, which survived for 7 days and were unaffected by the treated water, as shown in Figure (11).

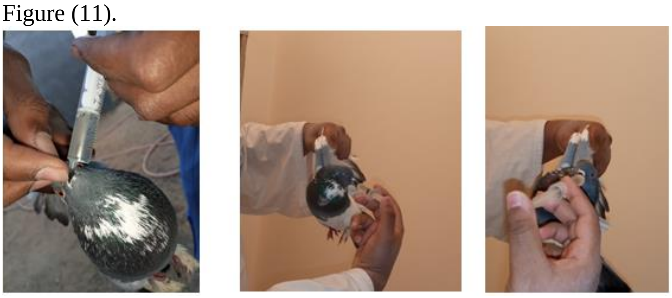

Fig 11: Post-treatment homing pigeons

Conclusions

1. The findings of this study led to the conclusion that Oedogonium is the best type of algae, that it was beneficial right away, and that the percentage of TDS that decreased following treatment was 74%.
2. It was determined that there is a factor, namely temperature that influences how effective algae are. At low temperatures between 15-20C, algae do not produce any results because they are in a growth phase, but at medium temperatures between 25-30C, algae produce results because their growth has stopped.
3. Due to the salinity rising the following days as a result of the death, it was clear that the treatment process only requires one day.
4. The treated water is safe to use for irrigation of plants and animals, for example, and it can be released into the environment because no negative effects were observed when we used it after treatment for irrigation. However, it is not acceptable for human consumption because the permitted TDS level was not reached.

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