Review article

# Modeling climatic effect on physiochemical parameters and microorganisms of Stabilization Pond Performance

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## ABSTRACT

The present study was carried out to evaluate the relationship between physiochemical parameters, microorganisms, wastewater and climate in Stabilization Pond Performance. This study performed as a post-treatment after the secondary wastewater treatment using extended aeration in Rashid city, Egypt. The model of the extended aeration as secondary wastewater treatment was developed based on the combination with lagoon after the secondary sedimentation basin. The Climatic functions have an important impact on the mechanism of ponds as it actuates vertical mixing of the pond contents. The interaction between bacteria, algae and other organisms are the main idea of oxidation pond treatment beside the relationship between the climatic functions, physiochemical parameters and microorganisms biomass. The removal of biodegradable organic loads specially nitrogen and phosphorous are perfectly happens in oxidation maturation ponds which reflects a higher treatment efficiency of the sewage by 98%–99% of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and heavy metals. The study included some recommendations aiming at improving both water quality and its recycling in plants irrigation.

## 1. Introduction

Freshwater represents about 3% of earth's water and is the source of all drinking water. This water is mainly obtained from rivers, underground water, streams and lakes; and these sources are strong sustainable to pollution [1]. The main aim of wastewater treatment is the reduction of microorganism contamination including coliform bacteria, suspended solids and organic loads. Wastewater stabilization ponds (WSPs) are an inexpensive and effective manner to treat wastewater. The ponds have been designed and classified in to three types according to its characteristics and usage as anaerobic, facultative and aerobic. Aerobic oxidation ponds have a distinguishing depth of 1–1.90 m, where the reduction of the organic loads in the sewage is carried out by algae –bacteria action [2]. The efficiency of the aerobic oxidation ponds depends on climatic conditions as rain, temperature, wind, sunlight…etc. These are used as a post-secondary treatment for out flowing from the classical systems [3, 4]. The maturation stabilization ponds show a Vital integration among many bacterial species [5], fungi [6], algae [7, 8], protozoa [9, 10] and viruses [11, 12, 13, 14]. It was believed that the commensally behavior between algae and bacteria was only responsible for the treatment of waste in stabilization ponds. In addition to that commensally behavior of

protozoa and algae, other organisms like viruses, rotifers, larvae of crustacean, insects, nematodes which combine and fight for food to turn hydrocarbons into simple substances. Due to nematode and coliform analyses, the Tunisian government has passed rules for the healthy reuse of agricultural streams [15, 16]. In both raw sewage and treated wastewater, "the biological oxygen demand BOD, chemical oxygen demand COD and suspended solid SS "levels are significantly sensitive to either or both of the following conditions: (a) seasons of the year (b) population activities [17, 18]. In Walkerton, Ontario, Canada, public water supply got infected by *Escherichia coli* bacteria "O157:H7 type "and campylobacteriosis cases have happened. As a result, in May 2000, about 2300 people died and about 2700 people suffered from infection [19]. Studies of a bacterial infections of an urban water well have shown that the common cause was the transfer of muck contamination to the water source by breakthrough, through surface oozing into the underground water and that would never be excluded [20]. Sewage from farming processes may contain different species of bacteria, including pathogens such as enterohaemorrhagic and *Escherichia coli* [21, 22]. Cows animals are considered a major *Escherichia coli* intermediate host [23], these pathogens may be transferred by the infection of cattle waste sources to drinking water [24]. Infections are commonly linked with the use of food
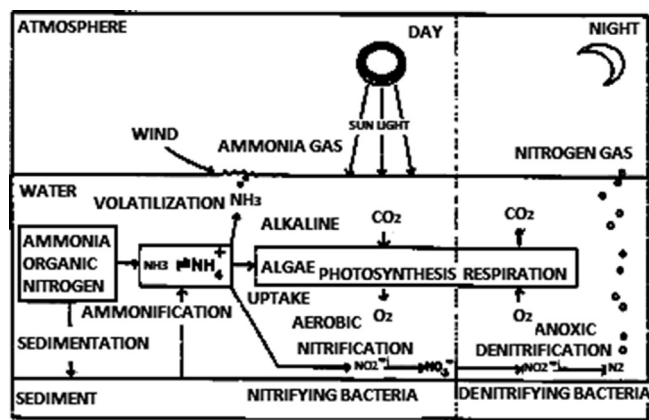
**Figure 1.** Principal biochemical and physical pathway for nitrogen removal in waste stabilization ponds.

and water infected by animal waste pathogens or contaminated water used for irrigation [25, 26, 27, 28]. Ejecting sewage containing great limits of total phosphorus compounds, orthophosphorus compounds and organic and non organic nitrogen compounds can lead to water to acquire eutrophication, particularly in lakes and relatively slow rivers. In many countries, regulatory agencies have placed nutrient emission restrictions on sewage effluents to avoid these conditions. Dairy production activities are established as a significant potential source of pollution in groundwater with nitrate [29], and phosphorus [30, 31]. So, due to the environmental issues, recent limits on phosphorus compounds discharges have become stricter. It has been suggested that oxidation ponds are put after the electrically aerated lagoon to settle and stabilize the solids. Electrically aerated lagoon treatment system has been taken from conventional oxidation ponds, where electrical aeration was designed to raise the oxygen within the ponds. The existing inorganic elements will promote the algae in the maturation oxidation ponds to expand. Only algae and not the other organisms streamed from the oxidation ponds will affect the effluent biological oxygen demand (BOD) and total suspended solids (TSS) values. The combination between the electrical aerated ponds and oxidation ponds has approximately 40 percent of a conventional oxidation ponds area to handle the same wastewater amount. The aerated lagoons have more benefits to reduce smell disturbance and less area demand than conventional oxidation ponds [32, 33].

Figure 1 summarizes the relation between biological chemistry and biological physics functions for various nitrogen species of oxidation pond model, in terms of changes in water quality a rise in phytoplankton [34].

The greatest association between total ammonia removals and water dissolved oxygen limits was observed, according to temperature value in addition to pH values, they are strongly associated with nitrogen elimination percentage [34]. Temperature is considered to be the greatest obvious thermodynamic physical agent affecting the performance of the oxidation ponds and thus affecting the process of metabolism of the bacteria and algae and the level of destruction of organic matter and consequently stabilization of inorganic nutrients [35, 36]. Earlier research has revealed that the efficiency of stabilization pond was higher

in summer months than in winter ones [37, 38, 39]. Similarly, it has been claimed that the efficiency of removing total ammonia nitrogen in particular, Werribee oxidation pond plant nitrification process was stronger in summer season [40]. Scientists indicated an ammonia volatilization process that could be critical in the elimination of total nitrogen in oxidation ponds due to algal photosynthetic activity [38, 41, 42]. Algal stabilization ponds with the high influents rates can retain dissolved oxygen across the depth of the pond which is approximately from 30 cm to 45 cm. Photosynthetic activity provides oxygen during the day, while at night the wind generates aeration due to the shallow depth of the pond [43]. Aerobic ponds have high potential for elimination of the organic loads and are suitable for regions where lands are economically less. Another additional feature of oxidation ponds is providing a retention time from two to six days. It has been noticed that an amount between 112 and 225 kg/1000 $m^3$ day of load level of (BOD) has 95 percent of treatment efficiency of biological oxygen demand (BOD) [42, 44].

## 2. Experimental and method

### 2.1. Description of the wastewater plant under study and collected samples

Rashid (Rosetta) city was selected for implementing the research. It has a present population of approximately 118511 people [45]. People are almost citizen people and a few of them industrial residents. It is a port city of the Nile Delta, located 65 km east of Alexandria, in Egypt's Beheira governorate, coordinates: 31°24′16″N 30°24′59″E. The system was implemented and operated in Rashid waste water treatment plant. The influent raw sewage was an average of 17000 $m^3$/day. The Rashid waste water treatment plant WWTP Maturation Oxidation Ponds system consists of one or two ponds according to the load required. Each of them is respectively connected after the secondary clarifier basin stage. Each pond has a stretched area equals to 8 acre (1 acre = 4200 $m^2$). With a capacity depending on the depth of the pond (20–100) cm and the pond that has L shape. The pond will be filled with effluents from the secondary clarifier basin and retain for a time with the wind reactions and the algae effects. The samples were mixed and composed ones from out of two oxidation Ponds as shown in the following shape Figure 2 [46].

The present study was carried out to investigate the water quality of Rashid waste water oxidation pond treatment plant in Rashid city – EL-Beheira governorate –Egypt, coordinates: 31°24′16″N 30°24′59″E (physiochemical and climatic measurements) and to investigate the bioaccumulation of toxic trace metals (Cu, Pb, Mn and Fe) by Planting Bean plant with the effluent of Rashid oxidization pond. And that will be as a wastewater reuse in irrigation and a substantial resource for agricultural production. And another bean plant irrigated with canal water will be compared to the previous one.

### 2.2. Physiochemical and climate parameters measurements

Physical and chemical parameters as (BOD, COD, TSS and total phosphorus, DO pH value and Temperature measurements) and climatic considerations as (wind speed and pressure) were considered to prove the relation function affecting the pond efficiency. The experimental work of this study was performed in Rashid city – EL- Beheira governorate –Egypt, coordinates: 31°24′16″N 30°24′59″E. And the
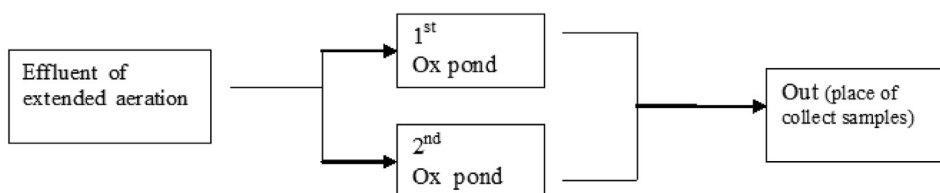


**Figure 2.** Rashid oxidation pond diagram.

**Table 1.** Characteristics Wastewater influent and effluent quality at Rashid aerated oxidation pond WWTP (milligram per Liter).

| Parameter | COD (Milligram per Liter). | | BOD (Milligram per Liter). | | TSS (Milligram per Liter). | | Temp. (C⁰) | | pH value | | DO (Milligram per Liter). | | T. phosphorus (Milligram per Liter). | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Out | In | Out | In | Out | In | In | Out | In | Out | In | Out | In | out |
| Max. | 72 | 114 | 40.1 | 64 | 52 | 104 | 30 | 31 | 7.67 | 7.65 | 3.69 | 18.5 | 4.8 | 3.2 |
| Min | 34 | 22 | 15 | 13 | 15 | 17 | 28 | 25 | 6.92 | 6.98 | 1 | 4 | 2.2 | 2 |
| Average | 45 | 60 | 26.4 | 35.3 | 35.8 | 41.5 | 24 | 22 | 7.2 | 7.4 | 3.6 | 8.2 | 3.4 | 3.01 |
| Median | 44 | 50 | 25.5 | 28 | 36 | 40 | 24 | 26 | 7.1 | 7.3 | 3.2 | 9 | 3.3 | 2 |
| N | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 | 123 |

In = influent of Rashid aerated oxidation pond WWTP, Out = effluent of Rashid aerated oxidation pond Waste Water Treatment Plant.
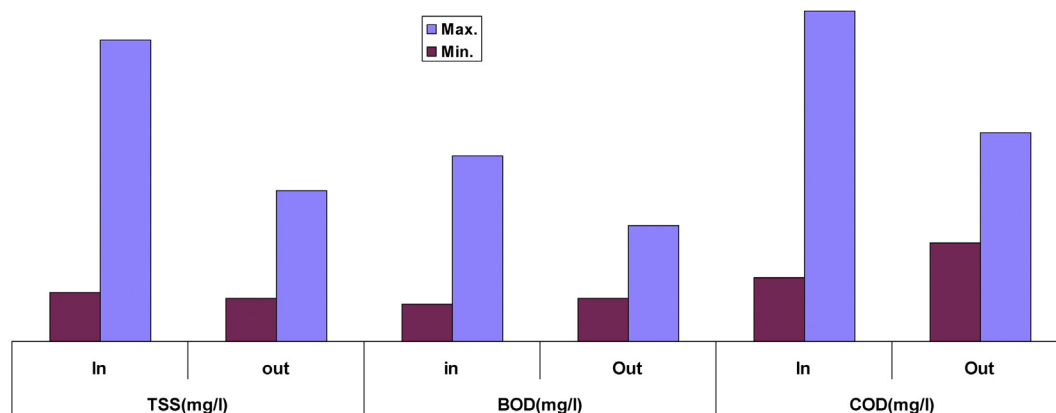


**Figure 3.** Max and min of TSS, BOD and COD in out (effluent) and influent of Rashid.

experimental work was conducted between 07/05/2019 and 07/08/2019, according to APHA [47].

### 2.3. Beans plant digestion

Digestion of beans plant was carried out by well suspension of 1 g of the dry sample in 100 ml of distilled water. Three milliliter of conc. HNO3, and the mixture was evaporated cautiously to 4 ml, then 5 ml of conc. HNO3 (15.8M) was added and refluxed for one hour. The mixture was cooled then solution of (15 ml of HCl (11.65 M) + 15 ml H2O) was added heated again for 15 min then cooled. Finally 100 ml of distilled water was added, the mixture was filtered and the heavy metal was estimated on ICP (ICP-MS-1) [48].

#### 2.3.1. Bioaccumulation coefficient

Bioaccumulation coefficient in the bean plant/waste water environments was calculated to qualify the toxic elements accumulation in the plant biomass over metal content in the source of irrigation [35].

### 3. Results and discussion

#### 3.1. Physiochemical operation parameters

The operating parameters for the oxidation ponds are sunlight penetration, air as a wind speed, pond engineering parameters, temperature, organic loads, dissolved oxygen and pH values.

#### 3.1.1. Biochemical oxygen demand (BOD)

is the quantity of dissolved oxygen required by aerobic organisms to consume organic material present in water sample at specific temperature and time period, which can digest or oxidize the organic compounds for energy and growth, if done in the presence of oxygen to produce carbon dioxide. Organic loads have a biochemical oxygen demand, that oxygen required by aerobic bacteria to oxidize them. In the Oxidation

pond system, the $BOD_5$ Average inlet 35. 3 mg/l and outlet 26.4 mg/l due to the presence of algae and it has led to 25.2% efficiency, chemical oxygen demand (COD) Average inlet 60 mg/l and outlet 45 mg/l due to the presence of algae and it has led to 25 % efficiency. The $BOD_5$ was removed faster in the hot seasons than winter and low temperatures and absence of sun light, the total suspended solids (TSS) Average inlet 41.5 mg/l and outlet 35.8 mg/l due to the presence of algae and it has led to 13.7 % efficiency as mentioned in Table 1 and Figure 3.

The efficiency of total phosphorus removal in the Pond depends on the pond water column. This occurs due to its accumulation as organic phosphorus in the algal biomass and precipitation as inorganic phosphorus depending on pH values. The removal of Total phosphorus was from average inlet 3.4 mg/l to outlet 3.01 mg/l due to the presence of algae and it has led to 11.5 % efficiency. The physiochemical parameter reported that the factors affecting the treatment are the substrate content, temperature, DO and pH as mentioned in Table 1. Table 1 also shows the median of N = 123 observation measurements of COD, BOD, TSS, Temperature, pH value, Dissolved Oxygen DO and Total phosphorus and it was (50 mg/l, 28 mg/l, 40 mg/l, 24 °c, 7.1, 3.2 mg/l, 3.3 mg/l) for the influent of Rashid oxidation pond respectively and was (44 mg/l, 25.5 mg/l, 36 mg/l, 26 °c, 7.3, 9 mg/l, 2 mg/l) for the effluent of Rashid oxidation pond. This reflected and emphasized the efficiency of the Rashid oxidation pond. The range of pH value for normal domestic influent waste is (6.8–7.5), depending on alkalinity and hardness of the water. The pH is a good indicator of the soundness of the pond system. Table 1 shows that the maximum value of effluent pH of Rashid was 7.67 and the minimum value was 6.98 where the average inlet 7.2 and outlet 7.4 due to the presence of algae and its biochemistry pathways reactions, also the average temperature in the pond (24 °C) decreased than it was in the influent because of the stretched surface area of oxidation pond. According to growth of algae that has an evidence of it by $O_2$ dissolved values. The closed respiration system between $CO_2$, $O_2$ and Photosynthesizing process in which carbon dioxide is created by organic decomposition and is released to hydrolyzed with ammonia and other

**Table 2.** Average heavy metals concentration in bean plant and its water quality at Rashid aerated oxidation pond WWTP and its canal (mg/L).

| Heavy metals (average) parameters | Pii (mg Kg$^{-1}$) | wii (mg L$^{-1}$) | pi (mg Kg$^{-1}$) | wi (mg L$^{-1}$) |
|---|---|---|---|---|
| Cu | 0.275 | 0.01 | 0.249 | 0.041 |
| Fe | 39.51 | 0.503 | 46.73 | 0.58 |
| Mn | 0.879 | 0.196 | 1.026 | 0.247 |
| Pb | 0.122 | 0.077 | 0.133 | 0.074 |

Where: Pii: bean's plant irrigated with oxidation Pond, Pi: bean's plant irrigated with canal Water, Wi: water of the canal, Wii: the water of oxidation pond.
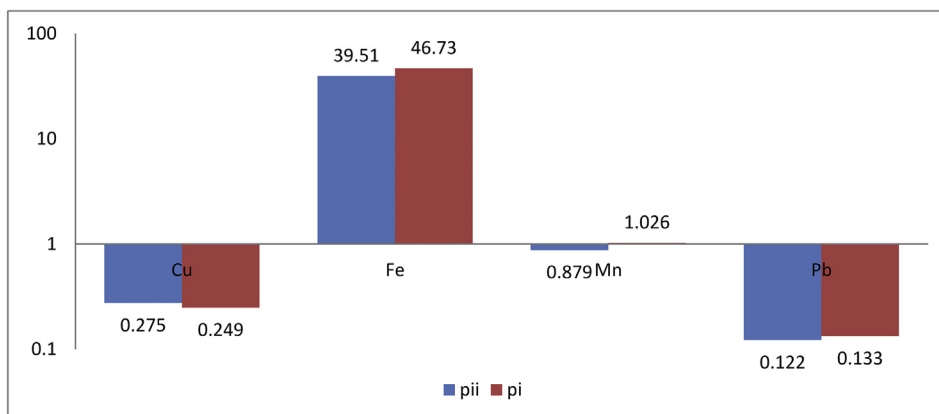


**Figure 4.** The concentration of heavy metals (Fe, Cu, Mn and Pb mg/l) in bean plant irrigated with pond and canal water (Where: Pii: bean plant irrigated with oxidation pond,Pi: bean plant irrigated with canal water).
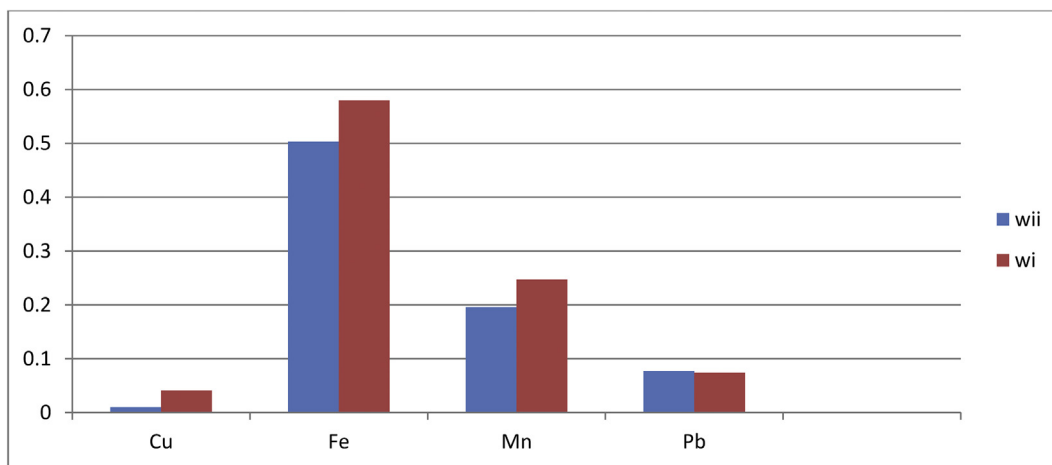


**Figure 5.** The concentration of heavy metals (Fe, Cu, Mn and Pb mg/l) in water of oxidation pond and canal (Where: Wi: water of the canal, Wii: the water of oxidation pond).

nitrogen-containing compounds [49]. Table 1 shows the average DO value of the effluent was 8.2 mg/l and influent value was 3.6 mg/l due to the presence of algae and it has led to 128 % efficiency.

**Table 3.** The calculated bioaccumulation coefficients in order to compare heavy metal contents in the bean plant biomass at the different samples of its irrigated Water.

| Heavy metals | Bioaccumulation coefficients | |
|---|---|---|
| | Pii | Pi |
| Cu | 27.50 | 6.07 |
| Fe | 78.55 | 80.57 |
| Mn | 4.48 | 4.15 |
| Pb | 1.58 | 1.80 |

### 3.1.2. Heavy metals

High concentrations of heavy metals can have significant effects on the ecological properties, man's health, give rise to further harm to the urinary system, nervous system, reproductive system, gastrointestinal system, kidney and skin. The heavy metal impact depends on the type and concentration of the metal itself [50, 51, 52]. So ponds increase heavy metals treatment, from the results in Table 2 and Figures 4 and 5) which showed that the concentration of (Cu, Pb, Mn and Fe) in bean plant irrigated with oxidation pond, bean plant irrigated with canal water, water of the canal and the water of oxidation pond. As shown the concentration of heavy metal decreased in oxidation pond that may be by:

A Heavy metal sedimentation.
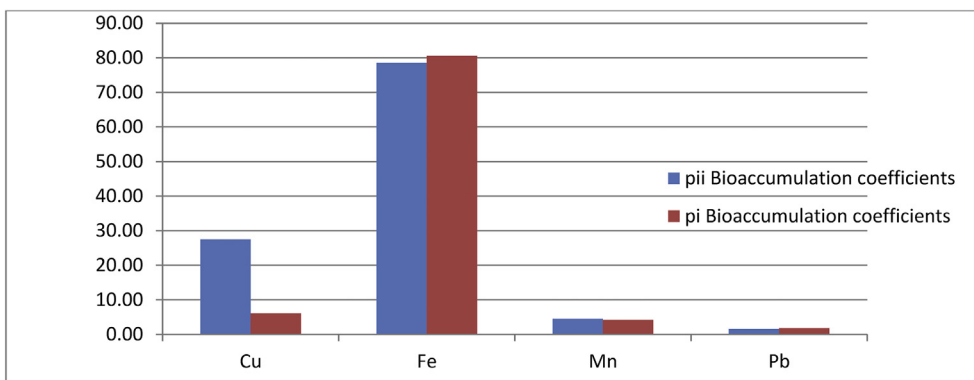B Absorbed by algae and bacteria.

**Figure 6.** The heavy metals (Fe, Cu, Mn and Pb mg/l) bioaccumulation coefficients in the bean plant `biomass at the different samples of its irrigated Water (Where: Pii: bean plant irrigated with oxidation pond, Pi: bean plant irrigated with canal water).

Numerous researches have been conducted in the treatment of heavy metals to examine the outcomes measures of oxidation ponds [51,52]. And showed that the oxidation ponds effluent has enhanced beside the soil quality and increased plant growth potential which had been irrigated by it.

By the performance data mentioned in Table 2, the calculated bio-accumulation coefficients in order to compare heavy metal contents in the bean plant biomass at the different irrigated samples can be obtained in Table 3. Bioaccumulation coefficients in correlated bean plant/water environments have been calculated to qualify the toxic elements accumulation efficiency of bean plant by dividing metal content in bean plant biomass over metal content in the irrigation water as listed in Table 2. The high bioaccumulation abilities of bean plant for selected metals have been confirmed according to the result obtained in Table 3 and Figure 6.

The magnitude of Fe, Mn, Pb and Cu metal bioaccumulation was found to be (78.55, 4.48, 1.58 and 27.50 times, respectively) in samples of Pii: bean plant irrigated with oxidation Pond when compared with metals collected from oxidation pond water (Table 2). This high accumulative ability indicates that bioavailability of these metals at this bean plant. Especially it has the lowest concentrations of Cu metals in its water samples. On the other hand, samples of Pi: bean plant irrigated with canal Water when compared with metals collected from the canal water (Table 2). Bioaccumulation of Fe, Mn, Pb and Cu metal as found to be (80.57, 4.15, 1.80 and 6.07 times, respectively). These results indicate that bioavailability of Fe, Cu and Mn metals. Where bioaccumulation of Pb in bean plant tissues collected from different sources indicating lower concentration and lower bioavailability as illustrated in Table 3 and Figure 6.

## 3.2. Climatic operation parameters

The principle climatic factors which affect oxidation ponds efficiency follow.

**Table 4.** Illustrates the maximum, minimum and average of some climate parameters at Rashid oxidation pond.

| Parameter | Wind Speed (mph) | Pressure (Hg) | Dew Point (° F) |
|---|---|---|---|
| Max | 28 | 30.09 | 105 |
| Min | 0 | 29.56 | 62 |
| Average | - | - | 65.3 |

1. The life cycle of algae greatly influences water biology and chemistry, where algae rate of growth is affected by the beam of light, temperature, Nutrient presence, pH values and other environmental conditions where pond average PH value is 7.7.
2. Energy of Light factor has a directly effects on algae growth.
3. Temperature parameter also affects algae directly [53].

### 3.2.1. The temperature

The $BOD_5$ was removed faster in the hot seasons due to the presence of algae than in winter and low temperatures and absence of sun light. The temperature of the influent wastewater can be used to detect inflow and infiltration and some industrial wastes. A sudden increase in temperature may indicate the presence of warm industrial wastes. On the other hand, influent temperatures may be cool rapidly in late fall and early winter. Temperature can also be used to predict treatment efficiency. The operator of a mechanically aerated pond system may choose to remove an individual unit from the operation to prevent a possible algal overgrowth condition (see Figure 7).
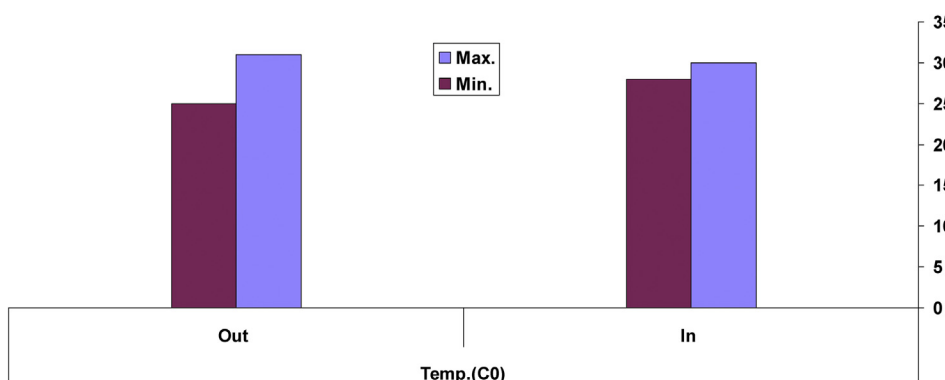


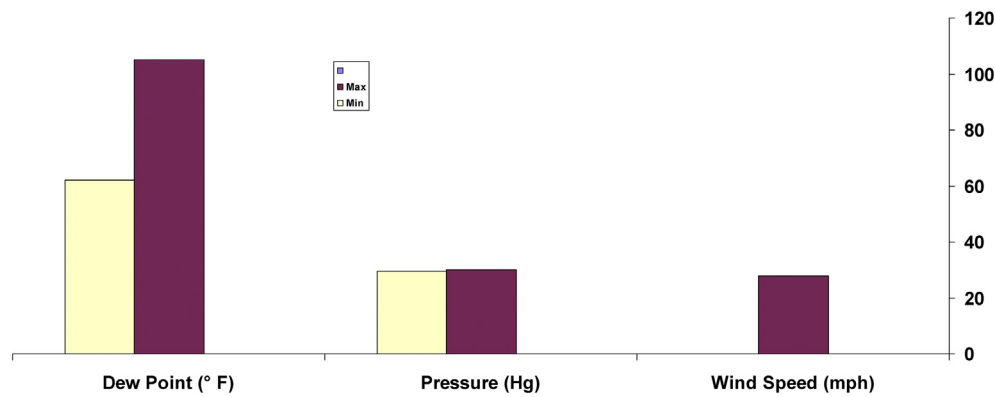**Figure 7.** Maximum and minimum of temperature of the effluent (out) and the influent (in) of Rashid oxidation pond.

**Figure 8.** The maximum, minimum of dew point (F$^{\circ}$), pressure (Hg) and wind speed (mph) in out (effluent) and influent of Rashid.

### 3.2.2. Light penetration

The depth of the pond ranges from 20 cm to100 cm for each one, with a capacity depending on the depth of the pond which equals 33600 *d m$^3$/day/pond, where d = (depth m). The optimum operational depth is 0.35 m so the capacity is 11760 m$^3$/day/pond. The tendency of organisms to absorb sun rays at certain wave number or the number of wavelengths per unit distance (cm$^{-1}$). The visible light wavelength range is the optimal for photosynthetic process, called photosynthetic active radiation (PAR) [49]. The suspended substances in the pond, the weather and geographic position of the pond will aid the activity of the treatment [42]. However, due to water properties, the nature of light particles dispersion and the subsistence of organisms can affect the usefulness of the sun rays entering the pond [49].

### 3.2.3. Wind

Air is necessary when mixing water warmer layers and water cooler layers [42,54] to prevent anaerobic cases. This mixing action also helps disperse microorganisms and augments the movement of algae, particularly green algae. Prevention of short circuiting and reduction of odor occurrence by giving Care during designing the position of the pond inlet/outlet axis. These axes must be perpendicular to the direction of prevailing winds to reduce short circuiting, which is the most common cause of poor performance.

Table 4 shows the maximum and minimum of wind speed which was 28 and zero mph so, the agent associated with the removal of bacteria includes wind direction, wind speed and the subsistence of barriers, especially L-form designed barriers. Wind can swirl parallelly to the pond's L-shaped inlet-outlet yield weaker results which has opposed to the pond of orthogonal orientation. Nonetheless however, the measurements can differ with higher wind speeds [55]. Algae produce a 20 cm thick layer in the presence of wind. Without the wind that layer expands across 50 cm of the water. This results illustrated in an effluent of variable quality [56,57] (see Figure 8).

## 4. Conclusion

The oxidation ponds treatment based on the Bacteria actions that convert hydrocarbons into carbon dioxide, water, phosphorus, and ammonia in the presence of oxygen. Beside the algae role to use carbon dioxide produced by bacteria and water in the presence of sunlight to produce new oxygen gas and new algae, to increase bacterial colonies and algal productivity with declining organic compounds. Multiple researches record elimination of polycyclic aromatic hydrocarbons such polycyclic biphenyls by oxidation ponds with the percentage limit from 64.77 to 97.75% [58]. The BOD removal performance depends on many factors and has efficiency about 81% [59,60]. It also depends on the ecological factors not only on the oxidation pond structure itself [56].

## Declarations

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