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Performance of a variety of treatment processes to purify wastewater in the food industry

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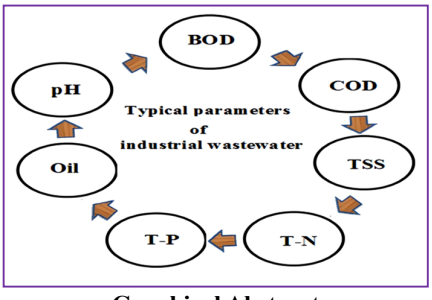
A B S T R A C T

The food industry consumes large amounts of water although there is an increasing demand for water and a rapid decrease in the level of natural water resources. Wastewater resulting from food industries needs to be assessed for their compliance to standards. In this study, wastewater treatment steps from the food industry were investigated for accurate assessment of wastewater loading by analyzing parameters of the concentration of compounds present in the effluents. The results revealed that the parameters of treated wastewater were as follow, electrical conductivity 2931 µs/cm, total suspended solids 100 mg/L, biochemical oxygen demand 90 mg/L, chemical oxygen demand 250 mg/L, total phosphorus 7.9 mg/L, and total nitrogen 70 mg/L. This exerts a huge load on the biological treatment unit. Thus, this study offers an understanding and support in selecting appropriate treatment for industrial wastewater to obtain an effluent suitable in compliance with standards of the environmental quality.



Graphical Abstract

1. Introduction

The availability of freshwater is one of the important issues facing the world today. Fresh water quality is greatly affected by human activities, and industrial activities in particular constituted one of the most important problems of environmental pollution and the degradation of aquatic ecosystems when comparing their resulting effects with other pollution sources.[1]

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Recent studies indicate that nearly a third of the world's population uses groundwater for drinking, but groundwater pollution because of industrial effluents became a main problem.[2] In developing countries, studies indicated that about 80% of all diseases are correlated to polluted drinking water and unhealthy environments.[2,3] The growing concern about the impact of pollutants from increasing industrial activities on the environment has led to the existence of strict environmental rules for industrial applications to reduce the impact of these pollutants.[4] In the developing world, many industries were constructed without assessment study of an environmental impact. These industries were often located near population centers and water basins. Nearly 90% of these industries simply discharge their untreated effluents into the environment, which mainly affects the environment due to the content of industrial wastewater on organic and inorganic materials.[5]

Among industrial actions, the food activity has one of the largest consumptions of water and is one of the major manufacturers of effluent that disrupts the ecological balance and declines the water quality. In order to decrease environmental pollution, industrial wastewater treatment is the most important way to ensure that waste is properly handled before it is finally discharged into ecosystems. A wastewater treatment plant is effective if it meets recommended microbiological and chemical guidelines with low cost, operational and maintenance requirements. it's quality are mainly determined in terms of chemical oxygen demand, biological oxygen demand, total dissolved solids, total suspended solids, ammonia content, and toxic metals.[5]

Industrial Effluents include high levels of several organic matters containing carbohydrates, proteins, oil, organic and inorganic salts as well as the chemicals used for cleaning, which cause an increase in chemical oxygen demand, biological oxygen demand, and suspended solids.[6] The wastewater generated from a series of different sections (production, coating and packing, and cleaning) is one of the major sources in environmental pollution. The discharged wastewater with diverse levels of pollution load are usually collected and treated in a public sewage treatment plant or an on-site.[7] However, it is supposed that more effective treatment is needed to assure the discharged wastewater conforms with the environmental standards.

Physicochemical treatment technique is a usually used method in the field of wastewater treatment as pretreatment. Physicochemical techniques of treatment are employed for the removal of oils and greases, inorganic and organic components, difficult to decompose, high salt concentrations and heavy metals.[8]

In Taiz city-Yemen, industrial wastewater treatment plant of The Yemen Company for Industries and Commerce isa type of wastewater that uses a biological method to treat wastewater. Owing to the variation in the kind of products manufactured, wastewaters are very complex. In addition, the total quantity of industrial wastewater produced from the factory is very large compared with the maximum receiving capacity of the plant. This exerts a huge load on the biological treatment unit. Therefore, this study was conducted to define the compliance of the released water from the treatment plant with the environmental standards.

2. Materials and Methods

2.1 Plant Location and Description

The present study describes the wastewater treatment plant at The Yemen Company for Industries and Commerce. The company located 17 km to the east of Taiz city-Yemen, coordinates: 130 37′29.63′ N and 44006′ 13.64′ E. It is constructed in 1970 and comprises a variety of industries as sweets, chocolate, biscuit's, and cakes. Industrial wastewater includes manufacturing waste (80%) which comes from different sections as production, coating, packing, cleaning, cooling, and heating processes as well as sewage (20%). The treatment plant was designed to treat 100 m^3/day of wastewater as a secondary treatment plant comprising a series of ponds using aerobic -anaerobic techniques as shown in **Fig.1**.

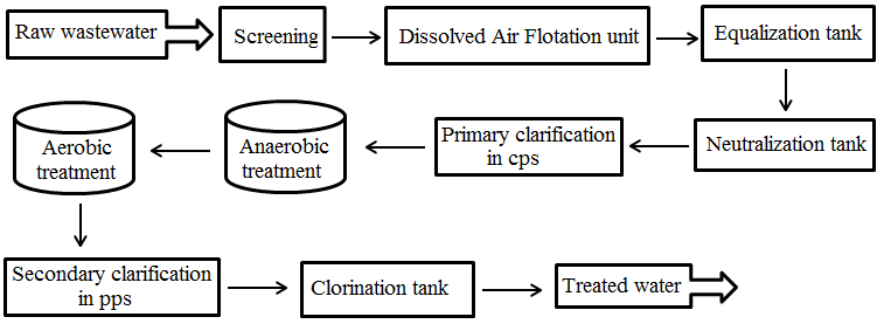

Fig. 1. Diagram of treatment plant

2.2 Physico-chemical Analysis

All physical and chemical analyses of effluents were evaluated according to APHA.[9] Samples were taken from two points, namely the main collection tank (Raw wastewater) of all industrial units and the final effluent tank (Treated wastewater). The samples were kept in sterile plastic bottles and the experiments were carried out in the laboratory of the company and in the Water and Environmental Center in the Faculty of Engineering Sana'a University, Yemen. Triplicate analysis of every parameter was done regularly to get acceptable results.

3. Results and Discussion

To estimate the pollution load in the industrial wastewater, composite samples from diverse food industries wastewater were analyzed for several physico-chemical features and the results were compared with values of the quality criteria of industrial effluents. The studied parameters show significant diversity with values of the quality standards because of the diverse additives used for diverse food products and the chemical used during cleaning processes as displayed in (**Table 1-2**).

Table 1. Characteristics of industrial effluent with the quality standards.

Parameter	Unit	Standard	Raw wastewater	Treated wastewater (final tank)
Temperature	°C	40	38	32
pH value	-	5.5-9	6.68	8.12
Electrical Conductivity	µs/cm	2000	3737	2931
Oil and Grease	mg/L	10	52.8	16
BOD_5 at 20 °C	mg/L	50	1010	90
COD	mg/L	200	2820	250
Total Suspended Solid	mg/L	50	1050	100
Total Nitrogen	mg/L	10	154	70
Total Phosphorus	mg/L	2	18	7.9

Table 2. Concentrations of selected heavy metals with the quality standards.

Metal	Unit	Standard	Raw wastewater (collection tank)	Treated wastewater (final tank)
Fe	mg/L	2	0.681	0.001
Mn	mg/L	1	0.112	o.001
Cu	mg/L	0.2	0.061	0.003
Zn	mg/L	2	0.265	0.011
Ni	mg/L	0.2	0.139	0.007
Pb	mg/L	0.5	0.078	0.029
Cd	mg/L	0.01	0.784	0.001
Co	mg/L	0.05	0.077	0.029

3.1 Temperature

Temperature is a main factor of water quality, which can affect the biological treatment process. It depends on the seasons, the process of production, and time sampling, etc.[10] The value of temperature of effluents (**Table 1**) was conformity with the quality standards.

3.2 pH

pH is a basic biotic indicator that works as an index for pollution. The pH has directly influenced the performance of the biological treatment process due to the survival of most biological life depending on a critical and narrow range of pH.[11,12] The pH of the effluent was found to be 8.12 which is alkaline. pH value was within the allowable levels compared with the quality standards.

3.3 Electrical conductivity

EC employs as a function for total dissolved solids (TDS) known as ions concentration and assesses the quality of water. EC of effluent was outside the allowable levels as a result of the salt load of water supply and the chemical used during cleaning and treatment processes. Basically, higher electrical conductivity is due to increase in concentration of solids (solubility), which is directly correlated with an increase in temperature and that can produce salinity problem if released to irrigation water.[11-12]

3.4 Oil and grease

Oil and grease values were above the allowable values of the quality standards. High quantities of oil and grease can prevent the biodegradation process. The intermediate products (Long chain fatty acids) in biodegradation process of oil and grease have toxicity on cells and also lead to sludge floatation effect that can lead to operational disadvantages.[13,14]

3.5 Biochemical Oxygen Demand

BOD is a factor, which is used to determine the quantity of oxygen consumed by microorganisms while stabilizing biodegradable organic matters in aerobic conditions. During the biological oxidation processes, microorganisms consume a lot of dissolved oxygen to convert organic matter to CO_2 and H_2O. Hence decreasing in dissolved oxygen value is the scale of BOD relation. Results revealed that BOD in the effluents was above the quality standards i.e. 90 mg/L indicating if such discharges combined with groundwater, it will have unsafe threats on aquatic life because consumed oxygen level in water.[12]

3.6 Chemical Oxygen Demand

COD is used to determine the quantity of oxygen required for the chemical oxidation process of organic substances without the assistance of forceful chemical oxidant agents. The COD value was 250 mg/L in the effluents and was above the allowable values of the quality standards. The waste is determined in indication of quality of oxygen needed for oxidation of organic substance to CO_2 and H_2O. It is a fact all organic substances with limited exceptions can be oxidized via the action of forceful oxidizing factors in acidic media. The conjugation of BOD parameter with COD parameter is more useful in indication of poisonous conditions and the existence of biological resistance matters. The proportion of the BOD and COD can give additional information on the tested samples. Commonly, in industrial wastewater, COD value is higher than BOD value due to numerous organic materials having a higher susceptibility to chemical oxidation compared to biological oxidation. The ratio of COD/BOD is 2.8 in the effluents which must be less than 2.5, this means that the organic matter has a poor biodegradability.[14,15]

3.7 Total Suspended Solids

The SS indicates the quantity (mg/L) of organic and inorganic substances held in the watercourse. The SS are fine particles with a diameter below 62 μm. All water courses contain some SS in normal states. The SS value in effluent was outside the safe levels. However, increase in concentration of SS, will lead to change of the chemical, physical, biological characters of the water, and hence become such wastewater inappropriate for agricultural purposes.[16]

3.8 Phosphorus and Nitrogen

Phosphorus element is one of the parameters that is required to be checked in the wastewater. Phosphorus concentration in effluent was outside the safe levels. An extra amount of phosphorus can motivate eutrophication of water. If a high quantity of phosphorus is discharged into the watercourse, it will stimulate primary production particularly for cyanobacteria, whose phosphorus element is their limiting nutrient.[17] Also, high concentrations of nitrogen cause quick growth of aquatic organisms. As these organisms die, they become organic matters. The vast degeneration of this organic matter cause reduction of the oxygen level.[17]

3.9 Heavy Metals

Removal of heavy metals, namely Fe, Mn, Zn, Cu, Ni, Pb, Cd, and Co were within the safe levels (**Table 2**). Basically, the low concentrations of heavy metals are due to the kinds of food industries found in the factory. Many studies suggested that the decrease in many concentrations is due to the different mechanisms that work inside the used filters, as chelation and physicochemical adsorption.[11,18] Also, it is essential to indicate that the pH of effluent (8.12) was higher than that of the influent (6.68). It is well-known that the solubility yield of metals is controlled by the pH value. Consequently, little increasing of metal precipitation may occur.[19] However, the major amount was centered in the sludge. As a result, sludge should not be employed for the agricultural uses without sufficient treatment to minimize the level of metals to the safe levels.[20-22] This work is considered evidence on the importance of applied sciences in agriculture and other fields as reported before.[23-70]

4. Conclusion

Industries discharge effluents with high quantities of pollutants and need a specified treatment system. In the developing world, many industries were constructed without assessment of an environmental impact. Consequently, no appropriate treatment plants are available for industrial wastes treatment. Most wastewater is released into the water bodies and open space nearby to the factories without any treatment, and thus eventually pose a dangerous effect on human health and the aquatic ecosystems. The study aims to assess suitably the wastewater loading, an analysis pathway was applied. It was examined the degradation of the pollutants by analyzing the parameters content of the contained organic matters in effluents: COD, BOD, TSS, TN, and TP.The results indicated that the values of parameters in the effluents were above the allowable limits of the quality standards, which means the wastewaters have a poor biodegradability. Based on the results, practical possibilities should be applied to get an effluent appropriate of Industrial wastewaters before its disposal into the ecosystem through carried out improvements of a pretreatment stage (physicochemical treatment technique), using more efficient coagulant agents to minimize the organic load on biological treatment unit as well as using advanced technique to reduce

the electrical conductivity, followed by a strong biological treatment process through separating the influents into more than aerated pond equally and supplying the sufficient oxygen demand via the aerators and/or a long retention period.

Author Contributions

Adel Q. S. Shamsan, Waleed A. R. M. Yacoob, and Mokhtar A. Abd ul-Malik: designed the study, performed the searches, screened investigations for eligibility, and extracted the data.

Mohamed R. Fouad and Shaban A. A. Abdel-Raheem: study guide, paper preparation, writing original draft, writing review and editing.

Conflicts of Interest

There are no conflicts of interest to be declared.

Abbreviations used

EC, Electrical Conductivity; BOD, Biochemical Oxygen Demand; TSS, Total Suspended Solids; COD, Chemical Oxygen Demand; TDS, Total Dissolved Solids.

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