Treatment of petroleum refinery effluents and wastewater in Iraq: A mini review

Mahdi Nuhair Rahi*, Ali Jweid Jaeel and Abdulaziz Jafar Abbas
1 Department of Civil Engineering, College of Engineering, Wasit University, Iraq

* Corresponding author: mahdi_rahi@uowasit.edu.iq

Abstract. In the analysis undertaken, we review waste from the crude oil and fuel refining. In addition to petrochemical intermediate products industry in Iraq in petroleum refinery effluents (PRE). The study shows the significant detrimental impacts of the Iraqi refinery effluent pollution. The research illustrated the handling of wastewater in refineries. This study shows that the emissions from Iraqi refineries comes out to the farthest extent. We were often based on environmental toxins such as Couscous Pollutants, Liquid Pollutants and Strong Pollutants in the Southern Refineries. In addition, we follow the forms in which refining waste in Iraq is treated. To date, oil refineries have struggled to meet their commitments effectively while atmospheric regulation in their fields continues to be neglected and environmental protection schemes that contribute to oil pollution mitigations are less regarded. The government, on the other hand, has shown no commitment to enact its minimum environmental legislation. As a consequence, it is clear that the area's oil and refineries, particularly refineries, have important repercussions for livelihoods and agriculture.

1. Introduction
Petroleum refinery effluents (PRE) were wastes produced from the crude oil and fuel processing and petrochemical intermediate products industries. Such effluents are a significant cause of contamination in the natural ecosystem [1]. In addition to several such industrial contaminants, the effluents are made up of oil and grate. Although concerted attempts were made to substitute fossil fuels, crude oil remains a significant raw rial [2]. The need to adapt to growing global energy demand, which over the next two decades is estimated to increase by 44 %, raises significant global issues in the manufacture of crude oil and PRE. The extraction method of crude oil requires huge volumes of water. A large wastewater volumes are therefore produced [3]. The amount of PRE produced during processing is 0.4–1.6 times the quantity of crude oil products processed. Thus, the world production of a total of 33.5 MBpd of effluent on the basis of the existing yield of 85 million barrels per day of crude oil [4]. Over the next 2 decades, global demand for oil is estimated to grow to more than 107mbpd and the world energy output by 2030 would account for 32% of the global demand for oil. The contribution from renewables including wind and solar energy is predicted to be 4-15% and biofuel is predicted to reach 5.9 billion mbpd by 2030. These statistics explicitly show the ongoing development and drainage of effluent from the oil sector into large water sources around the world. The environment is influenced by these pollutants. Based on the oil form, the plant layout, and operating procedures, PRE will be substantially different [5].

They reach waterways and influence the quality of the water supply. The PRE treatment approaches include adsorption, coagulation, chemical oxidation and biological processes [6]. A New
technologies have also been studied such as membranes and catalytic microwave oxidation in the wet conditions [7]. These techniques typically require the transition of chemicals from one medium to another, so a further phase is needed to extract organic compounds. They are distinguished by low performance and sludge generation and can only work in a small pH range [8]. Chemical oxidation is also an enticing method. Even then, its usage is restricted by very low reaction rates and the large number of oxidants used when processing large volumes of waste (typically for industrial waste), which lead to limit these applications [9]. Advanced oxidation processes (AOPs), distinguished by hydroxyl radical production (•OH), can be used [10]. A broad variety of organic molecules may theoretically be destroyed. The •OH is correlated with other oxidants and has a strong oxidation potential (estimated at +2.8 V) [11]. The oxidation capacity is 2.07, 1.78, 1.49 and 1.36 for ozone, H2O2 and chlorine. HOCl and chlorine. Among the various AOPs, a highly successful treatment technique has been described as a heterogenic catalytic degradation [12]. The option of this technique was focused on its strong mineralization ability of organic waste and the catalyst itself is not harmful, cost-effective and readily accessible [13].

This paper will sheds light on several issues, such as explain the status and harmful impacts of oil refinery effluents and illustrate separate procedures for pre- and advanced PRE treatment and review the methods that used to get rid of pollutants in oil refinery in Iraq.

2. Refinery configuration
Numerous potential configurations exist in refining systems and each is constructed in order to accomplish a particular goal, such as kerosene, gas-line and petrochemical feedstuffs, which turn crude oil into usable goods [14]. Al Zarooni and Elshorbagy (2006) categorized refineries as either a hydro-skimming device consisting of 3 sub-unit device (a rough distillation unit that separates crude oil into many components) or a complicated unit with additive sulphurizing components, which reduces the content of sulphur in several fractions such as kerosene and naphtha and a re-for-shake device [15]. In addition to a complex system integrating in the hydro-skimming refinery a more catalytically cracking unit.

A wider categorisation was proposed in, which grouped refineries into four groups. In the refining complex, petrochemical plants are also included [16]. Each PRE therefore depends on the number of units and refinery setup, which result in a lack of standardization in the composition of the effluent discharged [3]. Irrespective of the configuration, the contribution from the crude units involved is the final waste stream produced [17].

| Table 1: Minimum standard discharge Limit for refinery effluents [18]. |
|----------------------|--------------|--------------|--------------|--------------|----------------|----------------|---------------|--------------|
| PH | COD mg/l | BOD mg/l | DOC mg/l | O&G mg/l | SS mg/l | Ammonia mg/l | Phenols mg/l | Sulphides mg/l |
|-----|----------|----------|----------|----------|---------|--------------|--------------|----------------|
| 6.9 | 100      | 10-15    | -        | 10       | 70      | 15           | -            | -              |
|     | -        | 100      | 40       | -        | -       | -            | -            | -              |
| 6.7 | 200      | -        | 20       | 23       | -       | 70           | 3.7          | -              |
| 6.9 | 150      | 30       | -        | 10       | 30      | -            | -            | 1              |

Oil refining, e.g. burning, hydro-skimming, hydro-cracking, sniffing, condensate flare and desalter [19]. Oil refining: Similarly, the overall amount of wastewater is greatly influenced by other systems which are not specifically engaged in production such as sanitary, crude as well as laboratory water [5].

3. Harmful consequences of effluent
Due to their strong polycyclic aromatological material, PRE are priority toxins which are poisonous and appear to be more prevalent in the atmosphere [6]. They contain a large variety of chemicals of different amounts which are usually hazardous. Reduced algae abundance, which is a very significant
link in the food chain, was due to such consequences for PRE-accepting water bodies. About 2 mg / L, the minimum dissolved oxygen required for regular aquatic lives, and the unnecessary bacterial intake of oxygen is due to the drainage of high organic material including wastewater into bodies of water [5]. In an attempt to oxidize the effluent, oxygen is depleted from the water more quickly than it is emitted into the environment from the air. This dilemma allows higher life types to be preserved inadequately [13]. Oxygen supply is also critical as the end products of a chemical as well as biochemical reaction in aerobic systems also generate aesthetically displeasing colours, tastes and odors that are aesthetically displeasing to water [11].

Oil and fats are sticky in nature; they appear to aggression and clog drainage pipes and sewage pipes which lead to undesirable odors and corroding sewers [6]. The activities of the urban wastewater treatment facilities are often dealt with when they sit on the river as a layer. They therefore block strainers as well as filters on pipes and walls [7]. Owing to their intense toxicity, persistence, bioaccumulation and tendency to persist in the atmosphere for a long period of time, phenolic compounds pose a serious danger to the ecosystem [9]. They are normally carcinogenic, do substantial harm to the environment and to human health in water sources. The effluent is extremely hazardous in nitrogen and sulphide and is expressed respectively in ammonia and hydrogen sulfides (H2S). H2S occurs in the watery phase in combination with bisulphide (HS-) and sulfide (S2-), the latter being the least sulfidized shape [20].

4. Wastewater treatment in refineries
Quantities of water, in particular for cooling, distillation, hydrotreating and desalination, are used in the refining processes. Also generated are tank drains, flushing equipment’s, rivers and sanitary wastewater. Consequently, it is clear that refinery wastewater could be widely classified as process or non-process wastewater treatment [21]. These different wastewater systems are channeled into sewage systems in most modern refineries. In most petroleum refineries, at least two independent sewers exist: one for storm water and exterior run-off and one for all processing water and water produced by power stations. Nevertheless, process water drains are generally split into more than one wastewater sewage in most efficient refineries and therefore the charge in wastewater treatment plants is reduced, the efficiency of each treatment unit increased and wastewater reusability opportunities expanded in various refining systems increased [22]. Of course, the treatment of refinery wastewater streams is not universal. The amount and characteristics of wastewater generated depend on the configuration of the procedure. As a broad guideline, about 3.5 to 5 cubic meters (m3) per ton of crude water is produced during the recycling phase of cooling water [23]. Refineries create wastewaters with biochemical (BOD) and chemical demand (COD) of about 150–250 mg/l, and 300–600 mg/l, contained in biochemical demands; oil levels of between 20–200 mg / l in desalted water, and up to 5,000 mg / l in tank bottoms; benzene concentrations from 1–100 mg / l; benzo(a)pyrene values of less than 1-100 mg / l in desalted water and up to 5,000 mg / l in bottom of the tank Refineries are also generating solid waste and lots, of which 80% can be considered dangerous because of the presence of toxic organic products and of heavy metals (from 3 to 5 kg per ton crude processed). Because refinery pollutants are complex and diverse, combining treatment methods often becomes the norm before discharge. Separation of the water streams, such as stormwater, , process water, hygiene systems, wastewater, etc is essential for minimizing treatment requirements [24]. Awareness of the distribution of oil droplets in waste refining is critical for knowing the conduct of wastewater in a water and oil separator. This volume distribution is important for deciding and reliability of the right oil-water separation method. Various proven or modern methods can be used to extract oil and grain in wastewater produced in the oil processing industry.

Many scientists have attempted to separate the continuum of oil droplets and then prescribe the best form of treatment for any portion. In general, a refinery wastewater treatment plant should include the units at least represented in Figure 1 in order to achieve an effluent that complies with the existing EPA effluent disposal regulations. The setup in Figure 1 is very easy and definite or total in no way [25].
Many research aims to treat the industry effluents by perfect methods that employing adsorption and electrochemical techniques [26]. Turbidity and chemical oxygen demand (COD) were selected as pollutant models due to their wide occurrence in this type of effluent. According to reference [27] the utilizing of 200 mg of activated carbon (AC) and four aluminum electrodes within the adsorption and electrochemical units, respectively, can decrease COD and turbidity by about 72% and 85% in some particular conditions. There are many effective methods for treating wastewater and dyes such as electrocoagulation that can be used for this purpose [28]. The Ultrasonic-assisted electrocoagulation (U-ELE), can be utilized for the removal of nitrates from wastewater under a particular situation. It was found that the nitrate eliminating using only the ELE method was about 77% but the results showed that employing ultrasonic for about 10 min. (the U-ELE method) has increased the removal rate to 87.8% [29].

It should be mentioned. If a whole wastewater treatment system is in service, consisting of three phases of treatment – main, secondary and tertiary – so an effluent can be collected and reverse osmosis can be applied in recycling units to recovered processed wastewater. Removals may be made up of 90% to 99% of all parameters; 'COD, BOD, O&G, BTEX, SS, NH3', Heavy Metals [30].

Fig 1. Typical phases of treating oily wastewater refinery.

5. Oil Refineries in Iraq
Iraq was a major contributor to the rise of OPEC liquids, with the 2010-17 era of IOCs reaching about 1.9–1.8 mb/d (millions barrels daily). After this upstream expansion, Iraq's downstream midstream has struggled to keep speed – a dynamic that enables Iraq to take a peculiar role within its oil complex: it is the only big producer in an area that is diminishing future production potential for onshore pipelines (including storage and pumping capability). Iraq is likewise the only big producer that relies heavily on refined product imports, as opposed by its upstream provincial pairs, indicating an underdeveloped refinery infrastructure as well as a misalignment between Iraq's refining product yield and domestic demand. With Iraq growing in significance on global oil markets, especially the medium hard physical sour. The interaction between upstream, mid-stream and downstream demand would have a big effect on Iraq's short-term outlook on output. In the context of this interaction is:

- Iraq's potential development portfolio is rising with the significance of the Mishrif Reservoir (24-30 degrees API) expanding over time;
- delays in improving shore storage and pumping power, affecting rugged content dynamics and growth in export;
- The growed significance of water supply for oil supply, especially in view of complex mega-projects like the Typical Seawater Supply Project (CSSP);
Specifications for improving current refineries to both satisfy the need for refined oil, while growing output expansion, and handling improvements in the quality of crude feedstocks gets heavier.

A fresh democratic transition phase after the May elections in Iraq, with repercussions for the potential course of investment in the oil sector and fiscal reform.

Iraq currently has 15 oil refineries, with the exception of the Salah al-Din complex, which has a production capacity of 310 thousand barrels per day (and the Basra refinery has a production capacity of 150 thousand barrels per day), and the Dora refinery has a production capacity of 110 thousand barrels per day. At a time when Iraq has 15 refineries with a low production capacity, The UAE has 5 oil refineries with a production capacity of 778 thousand barrels per day (and Saudi Arabia has 8 refineries with a production capacity of 2120 thousand barrels per day, therefore Iraq is losing the profits that can be made by economies of scale, and the capacity of existing refineries in Iraq can be reduced.

Table 2. The Iraqi refineries capacities

| Years | Refining capacity | Total production | Total consumption |
|-------|-------------------|------------------|------------------|
| 2001  | 570               | 457.0            | 338.0            |
| 2002  | 570               | 457.0            | 342.3            |
| 2003  | 587.0             | 444.0            | 347.2            |
| 2004  | 597.0             | 513.0            | 420.5            |
| 2005  | 597.0             | 476.9            | 405.2            |
| 2006  | 597.0             | 484.1            | 328.5            |
| 2007  | 597.0             | 319.0            | 277.6            |
| 2008  | 597.0             | 447.0            | 360.4            |
| 2009  | 789.0             | 436.0            | 411.5            |
| 2010  | 858               | 510.7            | 458.0            |
| 2011  | 860               | 551.6            | 509.0            |

We note from the above table that the capacities of the Iraqi refineries are almost constant, with minor changes during separate periods. In 2005 there was an agreement with the Hydrocarbon Supply Limited Company and the Ircop Company from the Czech Republic to make improvements to the refineries at a cost of $ 110 million.

In order to increase the production capacity of this refinery to 170 thousand barrels per day, and there were plans in 2005 to build a new oil refinery in Basra with a production capacity of between 250 thousand and 300 thousand barrels per day, the National Oil and Gas Authority. The Ministry of Oil is working to establish two refineries Two investors with a capacity of 550 thousand barrels per day, one in the Dhi Qar governorate, with a production capacity of 300 thousand barrels per day, and the other in the Dohuk governorate, with a capacity of 250 thousand barrels per day, in addition to the Najaf refineries Samawah, Karbala and Diwaniyah, with a production capacity of 250 thouk per day. The refinery is to be established in the Kurdistan Region of Kosing-J-Bazian-Érbil, with a capacity of 110 thousand barrels per day, but despite these attempts, the capacity of the Iraqi refineries did not increase in proportion to these plans.

Total production of refineries is not commensurate with the existing refining capacity in Iraq, and some experts believe that the existing refineries operate at a rate of between 75% and 50% of their capacity, and the figures in Table 1 confirm this fact. As the energy consumption rate is estimated at
2007, 2011, 2009 at 53%, 55% and 46% respectively. The low use of filtering capacity in Iraq and the increasing consumption of petroleum products forced the government to import some 200 thousand barrels per day of petroleum products, gasoline, white oil, liquid gas, gas, oil, in order to compensate for the shortage of oil products, costing the state 250 million dollars per month.

6. Elements of environmental pollution in the Southern Refineries Company
The oil refining industry depends on a series of manufacturing processes by which petroleum products can be extracted from undesirable organic and inorganic materials. A collection of chemical treatments for crude oil should also be carried out for the purpose of extracting and purifying petroleum products from the elements and impurities that impair the potency of those products as used [35]. No matter how much purification is used to avoid harmful pollution into the environment, fugitive pollution is emitted from the pipes, motors, compressors, containers, flanges, and others. This pollutants and by-products cause harm to the internal atmosphere of the refinery, as well as to the external environment, and these chemicals constitute a form of environmental contamination (contamination of the environment) [36]. Environmental contamination components in the oil processing sector may be classified as following:

6.1. Couscous Pollutants
They are the gases and vapours resulting from the manufacturing rings that are emitted into the atmosphere through the chimneys and flares spread in the units, which are 21 chimneys in the Basra Filter Complex. The quantity and quality of the pollutants released depends on the nature of the fuel used, its sulphur and nitrogen content, and on the designs and the feet of the combustion systems. Flame gas emissions are waste hydrocarbons from active and complementary processes that are not used as fuel in furnaces and boilers. In addition to carbon dioxide emissions, which are estimated at 13,593,713 tons/month, sulphur dioxide, which is estimated at 3,545 tons/month, and nitrogen oxides, which is estimated at 404,1 tons/month for Southern Refineries in 2011 [37].

In other words, total emissions, burners and gaseous fuels are measured at 65,686,929 tons per month in the Southern Refineries General Company, the Shuaiba site alone, and there are gaseous contaminants resulting from the combustion of fuel gas and natural gas, which make up 12.5 per cent of the total fuel consumed.

One research stated that the main gaseous contaminants, namely carbon monoxide, sulphur oxides, hydrocarbon compounds, suspended matter and nitrogen oxides, account for 98% of the overall gaseous pollutants. These gaseous pollutants, if a person is exposed to them in certain concentrations and for a limited period, will be exposed to infection. It can directly threaten life and such diseases affect the immune system, nervous system, reproductive system, respiratory system, etc., In addition to the possibility of these pollutants entering the body directly through the air. Part of the air pollutants may be deposited in the soil and infect tree branches and leaves of plants and transfer to the bodies of animals that live on these plants and finally settle in the human body as a result of eating plants or animal meat [38].

6.2. Liquid Pollutants
They are liquid products that are formed through the use of water in production units and liquid spills as well as rain and cooling water. Often, these pollutants account for (39% of the total relative cost of spending in the refining industry). The refining process consumes large quantities of water as every ton of crude oil needs to be refined by 10 M3 of water and the volume of polluted water resulting from the refining of one ton of crude oil is approximately 3.5-5 M3, and the data in the table below show that the amount of polluted water from the oil refining complex in Basra reached 1100 m/3 hours, equivalent to 87 m/3 hours [39].
6.3. Solid pollutants
These pollutants are either the result of production processes such as iron and carbon oxides, solid materials and clays, or are the result of damaged pipes, waste, damaged spare parts and plastic waste resulting from construction work. The presence of pollutants in their forms, plastic boxes and various materials have caused great damage to the surrounding environment. And the quantity of these pollutants is directly proportional to the amount of production. In other words, increasing production means increasing the revenues generated by the liquidation projects, but it leads to greater environmental damage. That is, there is one party that makes profits that another party bears the burden because the first party bears the burden of the lost cost only, while the other party bears the social cost of the commodity, which is increasing with the increase in the volume of production of the project, which leads to an increase in the rate of environmental pollution.

There are other pollutants that are not in themselves toxic or hazardous to humans, but can affect the environment through their influence on the physical balance of our earth system, which leads to a number of cosmic phenomena, including climate change, the phenomenon of ozone layer erosion, global warming, acid rain and others [40].

6.4. Ways to deal with waste from refineries in Iraq
The processes of production in oil refineries result in a large quantity of liquid waste, which is characterized by its high content of oil pollutants, and these discharges pose a serious threat to the environment if they are discharged without treatment or inefficient treatment, as they cause pollution of the water resources if they are discharged, resulting in damage to all kinds of aquatic resources. Furthermore, the discharge of polluted waste into the soil causes damage and loss of its usability, along with the risk that the pollutants will reach the groundwater. Liquid waste from 5 refineries is discharged to the water sources and a treatment unit for these discharges. The refineries are monitored and evaluated in various governorates by means of periodic visits and sampling of these discharges and by conducting laboratory tests, and the results of the tests are compared with the determinants in force, with a focus on the value of oils and fats that should not exceed 10 mg/liter, according to the applicable parameters, while monitoring the other parameters [41]. The results of laboratory tests carried out on models of liquid discharges of refineries through periodic follow-ups during the preceding period show that these results fluctuate between conformity and deviation. In comparison with the restrictions in force under the Environmental Protection and Improvement Act No. 27 of 2009, punitive legal measures were taken in the event of a diagnosis of deviations in the liquid materials of the refineries. This is done by providing a warning for the purpose of dealing with the deviation and by imposing financial penalties in the event that the violation remains after the end of the warning period. In this regard, six warnings were sent to refineries which have diagnosed problems with the efficiency of treatment procedures for the discharging of liquid materials that are poured into water sources. Financial fines were imposed in 5 cases of diversion related to liquid waste, 3 warnings were issued and financial penalties were imposed in 3 cases relating to the disposal of liquid waste to neighbouring lands. In table 3 the way that refineries in Iraq get rid of Effluents is shown [42].
Table 3. The methods that used to dispose of waste during the operation of Iraqi refineries.

| No | Name of the refinery                      | Place of Effluents discharge | River’s name |
|----|------------------------------------------|------------------------------|--------------|
| 1  | Southern Refineries Company / Basra Refinery | Adjacent lands              | ----         |
| 2  | North Refineries Company / Qayyarah Refinery | River                       | Tigris       |
| 3  | North Refineries Company / Kasak Refinery  | Water trocar                 | ----         |
| 4  | Northern Refineries Company / Baiji Refinery | River                       | Tigris       |
| 5  | North Refineries Company / Haditha Refinery | Adjacent lands              | ----         |
| 6  | Mid Land Refineries Company / Dora Refinery | River                       | Tigris       |
| 7  | Mid Land Refineries Company / Samawah Refinery | Adjacent lands              | ----         |
| 8  | North Oil Company / Kirkuk refinery        | River                       | Tigris       |
| 9  | Diwaniyah Refinery                        | Septic tanks                | ----         |
| 10 | Alsinsinah Refinery / Baiji               | Adjacent lands              | ----         |
| 11 | Najaf Refinery                            | Septic tanks                | ----         |
| 12 | Dhi Qar Refinery                          | Adjacent lands              | ----         |
| 13 | Maysan Refinery                           | Adjacent lands              | ----         |

6.4.1. **Gas wastes in Iraqi refineries**

In Iraq, oil refineries differ in the quantity of gas discarded from the production and service units of these refineries, as well as in the proportion and nature of the gasses emitted. These differences arise from the source of the waste, the nature of the fuel used in the incineration process, in addition to the technical means used to control the disposal of the waste, and in general, the waste gas refineries are divided into two main types according to the source of their emissions [43]:

- **The first source:**
  Light gasses from atmospheric distillation processes, hydrogen sulphide gas produced from hydrogenation processes, and improved gasoline in refineries. These gasses are discharged into the atmosphere through the flare system, the height of which varies from one refinery to another.

- **The second source:**
  Fuel burning operations in furnaces for the heating of crude oil and steam boilers in refineries. The proportions and quantities of gasses put into the air vary depending on the nature of the fuel used in the combustion process in boilers and furnaces. These wastes are discharged through regular stacks of varying sizes between one refinery and another and represent sulphur and nitrogen oxides. Carbon is the most important waste gas generated by fuel burning operations.

6.4.2. **Solid waste**

Solid waste is considered to be one of the least waste oil refineries put into the surrounding environment and is usually asphalt and wax waste in refineries with asphalt production and wax extraction units, such as Baiji and Al-Dora refineries. And this waste is usually disposed of through the production units. It can be dealt with by landfilling in oil waste disposal sites, but there is another type of solid waste, which is what treatment plants in refineries leave from sludge and fat residues.
7. Conclusion
The study explores the problems confronting oil refineries in Iraq, where in recent decades there have been unregulated oil refineries and exploration. The paper establishes the detrimental impact on the field, fishermen and village livelihoods of the oil and gas refining sector, both legal and illegal refineries. The relationship between land and heavy petroleum waste has triggered land degradation, resulting in damages and risks to the region's food protection. The paper reveals also that the entire country of Iraq, now the crude oil wastewater, was once the bread basket of tainted crops. Farms and results in a major negative decrease. The wastewater produced by the refineries contained high contaminants and the content at a point of mixing with the people's health, and they were already impactful because of the minor pollution by the surrounding groundwater sources. Technical productivity findings in crude oil-polluting farms have shown that over 22 percent of farming crops are declining, suggesting that the contamination generated by crude oil and refineries has a direct negative effect on agriculture. Finally, although they are also very serious regarding oil refineries, they have not successfully fulfilled their duties to date, as the laws on the atmosphere in their fields appear to be ignored and environmental conservation schemes that will lead to mitigating oil emissions have been less taken into account. On its part, the Government has demonstrated little effort to enforce the minimum environmental regulations it has produced. As a result, it is clear that oil and refineries in the area, particularly refineries located, are having significant implications on livelihood and agriculture.

8. References
[1] Sultan A, Karakaya I and Erdoğan M 2012 Influence of water vapour on high temperature oxidation of steels used in petroleum refinery heaters Mater. Corros. 63 119–26
[2] Livingston T and Abbassi B 2018 A comparative review and multi-criteria analysis of petroleum refinery wastewater treatment technologies Environ. Res. Eng. Manag. 74 66–78
[3] Diya’Uddcen B H, Daud W M A W and Abdul Aziz A R 2011 Treatment technologies for petroleum refinery effluents: A review Process Saf. Environ. Prot. 89 95–105
[4] Yan L, Wang Y, Li J, Ma H, Liu H, Li T and Zhang Y 2014 Comparative study of different electrochemical methods for petroleum refinery wastewater treatment Desalination 341 87–93
[5] Pourehie O and Saien J 2019 Treatment of real petroleum refinery wastewater with alternative ferrous-assisted UV/persulfate homogeneous processes Desalin. Water Treat. 142 140–7
[6] Rahmanisa R A and Widiasa I N 2020 Application of the Fenton Process in the Petroleum Refinery Spent Caustic Wastewater Treatment Reactor 20 96–102
[7] Rasheed Q J 2011 Effect of Additive Agents on Sono-Degradation Petroleum Refinery Wastewater Hydrology: Current Research 2 2–5
[8] Fındık S 2018 Treatment of petroleum refinery effluent using ultrasonic irradiation Polish J. Chem. Technol. 20 20–5
[9] Yavuz Y, Koparal A S and Öğütveren Ü B 2010 Treatment of petroleum refinery wastewater by electrochemical methods Desalination 258 201–5
[10] El-Naas M H, Surkatti R and Al-Zuhair S 2016 Petroleum refinery wastewater treatment: A pilot scale study J. Water Process Eng. 14 71–6
[11] Ibrahim D S, Lathalakshmi M, Muthukrishnaraj A and Balasubramanian N 2013 An alternative treatment process for upgrade of petroleum refinery wastewater using electrocoagulation Pet. Sci. 10 421–30
[12] Al-Malack M H and Siddiqui M 2013 Treatment of synthetic petroleum refinery wastewater in a continuous electro-oxidation process Desalin. Water Treat. 51 6580–91
[13] Pourehie O and Saien J 2020 Homogeneous solar Fenton and alternative processes in a pilot-scale rotatable reactor for the treatment of petroleum refinery wastewater Process Saf. Environ. Prot. 135 236–243
[14] Nie F, Li Y, Tong K, Wu B, Zhang M, Ren W, Xie S and Li X 2020 Volatile evolution during thermal treatment of oily sludge from a petroleum refinery wastewater treatment Plant: TGA-MS, Py-GC(EGA)/MS and kinetics study Fuel 278
[15] Laffly G 1989 Developments in Legislation Related to Treatment of Petroleum Refinery Effluents: A U.S. Overview Water Quality Research Journal 24 355–362
[16] Shoucheng W 2014 Petroleum refinery effluents treatment by Advanced Oxidation Process with Methanol J. Korean Chem. Soc. 58 76–9
[17] Agarry S E 2017 Enhanced ex-situ bioremediation of soil contaminated with petroleum refinery waste effluents by biostimulation through electrokinetics and inorganic fertilizer Niger. J. Technol. 36 534–542
[18] Hoshina M M and Marin-Morales M A 2010 Evaluation of the genotoxicity of petroleum refinery effluents using the comet assay in ooc chromis niloticus (Nile tilapia) Ecotoxicology and Environmental Contamination 5
[19] Quaresma M C B, Cassella R J, Carvalho M D F B and Santelli R E 2004 Focussed microwave-assisted sample preparation: Total phenol determination in petroleum refinery effluents by flow injection spectrophotometry Microchem. J. 78 35–40
[20] Shu H Y, Chang M C and Tsai M K 2017 Degradation and mineralization of bisphenol a in wastewater by the UV/H2O2 and UV/persulfate processes Desalin. Water Treat. 61 68–81
[21] Shut’ko A P and Sorochenko V F 1988 Reagent treatment of wastewater in petroleum refineries Environ. Prot. 38–9
[22] Seng W C 1980 Wastewater Treatment for edible oil refineries J. Am. Oil Chem. Soc. 57 275A-279A
[23] Ngasan C, Areeprasert C, Lionnet G R E, Busayapongchai P, Pattamasuwan A and Withayagiat U 2019 Characterisation and utilisation of fly ash for treatment of brin wastewater in sugar refineries Desalin. Water Treat. 167 133–44
[24] Jemli M, Sabbahi S and Ayed L Ben 2015 Performance of urban wastewater treatment of four activate sludge treatment plants in Tunisia Int. J. Water Wastewater Treat. 1 1–4
[25] Sabzali A and Gheidari N A 2016 A Full-Scale Chemical/Biological treatment system application for the wastewater treatment of a pharmaceutical-capsule Int. J. Water Wastewater Treat. 2 1–5
[26] Abdulhadi B A, Kot P, Hashim K S, Shaw A and Khadder R Al 2019 Influence of current density and electrodes spacing on reactive red 120 dye removal from dyed water using electrocoagulation/electrofloation (EC/EF) process IOP Conf. Ser. Mater. Sci. Eng. 584
[27] Alyafei A, Alkizwini R S, Hashim K S, Yeooha D, Gkontou M, Al Khaddar R, Al-Faluji D and Zubaidi S L 2020 Treatment of effluents of construction industry using a combined filtration-electrocoagulation method IOP Conf. Ser. Mater. Sci. Eng. 888
[28] Hashim K S, Hussein A H, Zubaidi S L, Kot P, Kraidi L, Alkhaddar R, Shaw A and Alwash R 2019 Effect of initial pH value on the removal of reactive black dye from water by electrocoagulation (EC) method J. Phys. Conf. Ser. 1294
[29] Al-Marri S, Alquzweeni S S, Hashim K S, Alkhaddar R, Kot P, Alkizwini R S, Zubaidi S L and Al-Khaifajia Z S 2020 Ultrasonics-Electrocoagulation method for nitrate removal from water IOP Conf. Ser. Mater. Sci. Eng. 888
[30] Pavlostathis S, Misiti T, Tezel U and Tandukar M 2012 Fate and effect of naphthenic acids on the biological wastewater processes in oil refineries Georgia Institute of Technology E20
[31] Araz Q A 2019 Iraqi Kurdistan Oil and Gas Sector: Iraqi and International Dimensions J. Hist. Polit. Sci. 39 58–67
[32] Jacqueline and Ismael T 2007 Iraqi oil, the international system, and chimera of democracy Int. J. Contemp. Iraqi Stud. 1 287–291
[33] Hussain R F 2017 Insurance on the risks of the oil industry a comparative study between the Iraqi and Norwegian laws J. Univ. Hum. Dev. 3 81–122
[34] Ali B A, Gorgees H M and Kathum R I 2019 Modeling human capital impact on the development of the iraqi oil industry Baghdad Sci. J. 16 1080–1086
[35] Taher F and Mohammed Q 2018 Performance Appraisal of Human Resource Management and Its Effect on Achieving the Organizational Success -A Field Search at the Ministry of Oil J. Econ. Adm. Sci. 24 45–72
[36] Mahdi I D 2017 The impact of the characteristics of human resources information systems in the implementation of the strategic decision of the state Applied research in the Iraqi Ministry of Oil J. Kufa Leg. Polit. Sci. 1 233–252
[37] Al-Shammari A and Ahmad K 2003 Trends in Iraqi oil revenues after 2003 under the effect of world oil prices fluctuation J. Econ. Adm. Sci. 18 254–73
[38] Gayadh E and Jehad M 2019 Effect of particle size of the raw materials used in floor tiles ceramic industry on some properties which extracted from western desert of Anbar Iraqi J. Desert Stud. 9 64–71
[39] Fendi A, Taher F and Salman F 2012 The effect of performance appraisal dimensions On organization confidence J. Econ. Adm. Sci. 18 58–83
[40] Ismayilova R A, Alosmanov M S and Mamedova G M 2020 Conversion of household solid waste organic ingredients into fertilizers containing organic and mineral constituents Chem. Saf. Sci. 4 105–113
[41] Burakov A E, Galunin E V, Burakova I V, Kucherova A E, Agarwal S, Tkachev A G and Gupta V K 2018 Adsorption of heavy metals on conventional and nanostructured materials for wastewater treatment purposes: A review Ecotoxicol. Environ. Saf. 148 702–712
[42] Axelsson L, Franzén M, Ostwald M, Berndes G, Lakshmi G and Ravindranath N H 2012 Perspective: Jatropha cultivation in southern India: Assessing farmers’ experiences Biofuels, Bioprod. Biorefining 6 246–56
[43] Cărburseanu M and Oprea M 2013 Applying computational intelligence to wastewater treatment performance evaluation in the case of refineries IFAC Proc. 46 95–100