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Review Article

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Environmental Hazards of Petroleum Refinery in Bangladesh: A Review

Md. Shajedul Islam and M. G. Mostafa*

Institute of Environmental Science University of Rajshahi, Rajshahi 6205, Bangladesh.

***Corresponding author**
M.G.Mostafa, Institute of Environmental Science University of Rajshahi, Rajshahi 6205, Bangladesh.

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Abstract

The petroleum refining industry plays a significant role in the national economic activities of Bangladesh. Though, potential environmental hazards related to petroleum and petrochemical factories have caused increased concern for peoples near them. This apprises provides a general impression of the processes involved and some possible environmental contamination associated with petroleum industries. Petroleum refineries separate crude oils into different petroleum materials through a sequence of physical and chemical separation methods. The refining industry provided numerous widely used products as well as gasoline, diesel, kerosene, motor oil, asphalt, waxes, and petroleum gel. But refineries are usually considered a key source of contaminants in areas where they are located and contaminate the air, soil, water system. Pollutant releases from the petroleum refineries occur in every stage of the oil-producing procedure from the extraction to the consumption chain. Now a day, due to vast environmental contamination it is crucially needed to find out of alternative cleaner energy sources rather than liquid petroleum. Bangladesh, a highly populated country and have no sufficient ability to tackle any natural and anthropogenic pollution. So, the environmental impact of petroleum refinery emission in Bangladesh is a serious concern to the government and environmentalists.

Keywords: Bangladesh, Petroleum refinery, Petrochemicals, Environmental hazards, Petroleum waste management.

Introduction

Bangladesh is a densely populated (2890/mile2, which ranks 10th in the world), developing, and deltaic country. The most important effluent discharging industries are tannery industries, sugar mills, thermal power plants, oil refineries, paper mills, textiles, distilleries, fertilizer units, electroplating plants, pesticide, and herbicide industries. These industrial effluents containing organic, and inorganic compounds consist of heavy metals and toxic elements pose a serious threat to the ecosystem [1-4]. The Bengal delta has a hydrocarbon-rich sediment basement with vast mineral deposits. The northeastern Sylhet Division has the largest natural gas field and crude oil producer, followed by Chittagong, Dhaka, and Barisal Division; while dozens of offshore blocks lay in the Bay of Bengal. The country has minored reserves of oil and coal, but potentially very big natural gas resources. Bangladesh is the 19th largest producer of natural gas in the Asia Pacific [5]. These gas supplies meet 56% of household energy demand.

Though, the country faces a severe energy crisis in meeting the stresses of its vast and growing population. This country is a net importer of crude petroleum and petrochemicals. The energy sector is dominated by government-owned companies, including Petrobangla and the Bangladesh Petroleum Corporation (BPC). Statoil, ConocoPhillips, Chevron, ONGC, and Gazprom are major international companies involved in Bangladesh's petroleum refineries, with Chevron's gas fields accounting for 50% of natural gas production Mine expert and geologists believe that the country's maritime high-class economic zone holds one of the largest oil and gas reserves in the Asia-Pacific. Lack of technical capability and protectionism have obstructed Bangladesh's potential to emerge as a major global hydrocarbon producer [6]

Figure 1: Eastern refinery an only public petroleum company of Bangladesh.

Eastern Refinery Limited (Fig. 1) is the only Petroleum Refining Company in Bangladesh which was established in 1968. Its loading capacity is 1.5 million metric tons (mMT). But now it can hardly operate 1.3 mMT due to its aged effect. In Bangladesh, the average annual demand for petroleum products is about 4 mMT and it is increasing gradually. Eastern Refinery Limited (ERL) can meet only 30% of our demand. The rest 70% is imported by the BPC [3]. It saw from the demand/supply ratio of petroleum products in Bangladesh that the need for diesel is higher than all other petroleum oil because of transportation and irrigation. It is vital to point out that in the last 5 years kerosene demand has been dropping and in 2006, it has recorded a major fall [7]. The demand for LPG in rural areas as cooking fuel and rural electrification help to decrease the demand for kerosene.

Petroleum is a very essential substance and it has many uses, and the environmental impact of the petroleum refineries are consistently expansive and widespread. Crude petroleum is prime energy and raw material sources that allow several aspects of the world economy and modern daily life. Its supply grew up rapidly over the last century to meet the demands of the fast-increasing human population, consumerism, and creativity [5]. The consumption of petroleum products is increasing day by day in Bangladesh (Fig. 2). The increasing trend line is very positively significant with R2 = 0.845. Substantial amounts of harmful and toxic wastes are produced during the abstraction, refinement, and transportation phases of oil. Among these phases, refining crude petroleum is the crucial stage. This refinery industry has a substantial influence on the total pollution of the environment from industrial waste disposal. In the operation section of this phase, the atmospheric air is polluted with volatile hydrocarbons (HC), carbon monoxide (CO), sulfur dioxide (SO2), hydrogen sulfide (H2S), nitrogen oxides (NOx), and other toxic particulate substances. Globally, the petroleum refinery industries directly contributed about 8% (2.7 BT) of the total emission (32.8 BT) of CO2 in the year 2017 [8-9]. The major pollutants are SO2 and HC. The Eastern Refinery and other related industries are generally situated on the river bank and they used freshwater in the product cooling section and this water returned to the original source of water containing petroleum products, crude oil, and mineral salts as contaminants. The important rivers of Bangladesh such as the Karnafuli, the Meghna, The Buriganga, and the Sitolakhkha massively polluted by the petroleum industries. The water and air pollution depend on the processing technology and control measures employed.

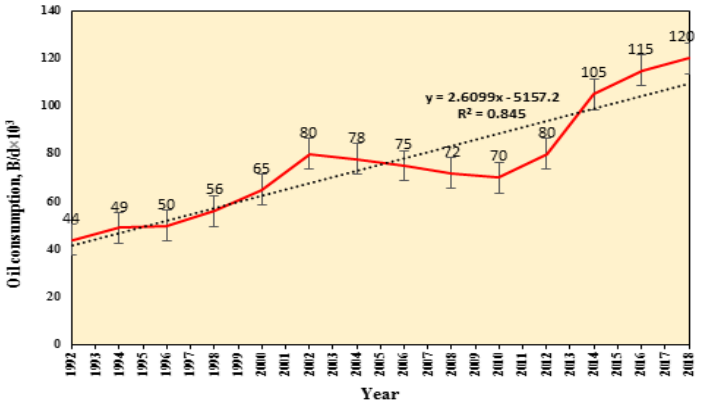

Figure 2: Oil consumption trends in Bangladesh

The expansion rates in petroleum refining capacity are to be kept a minimum in the future to reduce the release of pollutants, if they continue to be at this level, it will be difficult combating the air and water pollution of the country. The action is required in mapping out a set of measures, which will apply with acceptable levels of capital investment to reduce the industrial discharges to the environment to stop further aggravated the hazards. They need to include the introduction of fundamentally new refining processes, improved equipment, and units, and advanced methods for organizing production. In understanding these measures, the first attention of scientific-study institutes and planning and designing organizations must be directed not only towards the way to reduce the polluting and poisoning action of industrial discharges on the environment but primarily towards preventing or diminishing the discharges of the refineries.

Oil consumption and reserve in Bangladesh

Bangladesh has minor reserves of oil and coal, but potentially very large natural gas reserves. Commercial energy feeding is around 71% natural gas, with the remainder almost entirely oil (plus limited amounts of hydropower and coal). Household energy sources, such as wood, agricultural residues, and animal wastes, are estimated to account for over half of the country's energy consumption. Liquid petroleum such as petrol, diesel, octane furnace oil, and kerosene account for about 22% of the commercial energy supply in the country. Locally produced gas condensate contributes only 6% of total liquid fuel uses. Bangladesh imports nearly 1.2 mMT of crude oil along with 5.5 mMT (approx.) of refined petroleum products per year [7].

Table 1: Petroleum budget of Bangladesh

Category	Barrels	Global Rank
Oil Reserve	28,000,000	82nd in the world
Oil production	4,105 B/d	99th in the world
Oil consumption	113,000 B/d	77th in the world
Daily Deficit	-108,895	-
Oil Imports	23,554	-
Oil Exports	0	-

Bangladesh holds 28.0 million barrels of confirmed oil reserves as of the 2016 survey, ranking 82nd in the world and accounting for 0.0% of the world's total oil reserves of 1,650,585.140 million barrels (Table 1) [7]. The total proven oil reserves in the country (Fig. 3) are less than even a year (41.245 million barrels as of 2016), making Bangladesh highly oil import dependency. Bangladesh consumes 0.03 gallons of oil per capita every day, or 11 gallons per capita per year. Bangladesh consumes 1.13 million barrels/day (mB/d) of oil as of the year 2016. This country ranks 77th in the world for oil consumption, accounting for about 0.1% of the world's total consumption of 97.104 mB/d. Nationally produces 4,105 barrels per day of oil (as of 2016) ranking 99th in the world. Bangladesh produces every year an amount equivalent to 5.4% of its total proven reserves (as of 2016). Bangladesh imports 21% of its oil consumption (23,554 barrels per day in 2016).

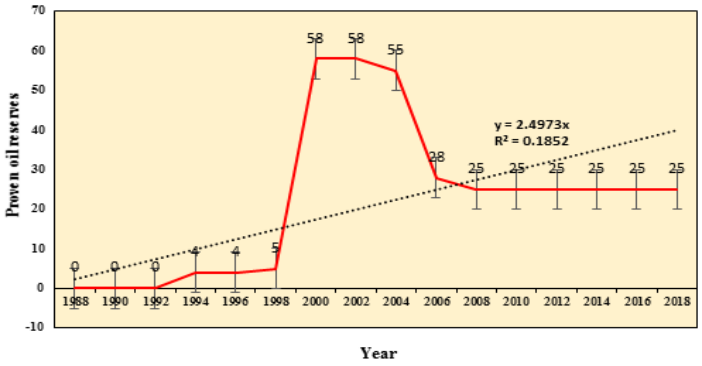

Figure 3: Proven oil reserve in Bangladesh

Toxic substances released from refinery industry

Petroleum is a complex mixture of numerous organic compounds. These compounds contain straight-chained, branched, cyclic aliphatic; and monocyclic and polycyclic aromatic hydrocarbons. The toxicity of oils can understand using the toxic potential of each distinct compound of oil at the water solubility of that compound [10]. Different oils and petroleum-related products have different degrees of toxicity. Levels of toxicity are influenced by many factors such as dissolution, weathering, and persistence capacity. Enhanced weathering led to reducing the degree of toxicity as more soluble and lower molecular weight components are removed. Highly soluble materials tend to have higher levels of toxicity than materials that are not weakly soluble in water [11]. There are several methods used to measure the toxicity of crude oil and other petrochemicals. Certain studies assess the degree of toxicity using the target lipid model or colorimetric analysis, which use the colored-dyes to measure toxicity and biodegradability.

Usually, oils that have more benzene rings and with longer carbon chains hydrocarbon have higher levels of toxicity. Besides, Sulphur and Lead mixt oil also have serious toxicity. Benzene is a petroleum product with the highest level of toxicity and carcinogenic risk. Like benzene, other highly toxic substances are toluene (methylbenzene) and ortho- and para-xylenes. Despite variable levels of toxicity among different variants of oil, all petroleum-derived products harm the human body and the ecosystem. Examples of opposing effects are oil- emulsions in peptic systems in certain animals might result in a controlled capability to digest foods that might lead to the death of certain animals. Also, symptoms include capillary ruptures and internal bleeding. Ecological food waves can affect owing to a decrease in algal species production, therefore, threatening certain types of species [11, 12]. Crude oil is intensely lethal to fish, that is, it kills the fish rapidly, at a concentration of 4 gm/L [13].

The toxicity of several petrochemicals threatens human health. Many chemical compounds found in the oil are highly poisonous and can cause cancer as well as other deadly diseases [14]. Benzene and benzene like compounds are present in both gasoline and crude oil and is the cause of Leukemia in humans' body. Those compounds are also known to lower the white blood cell count in humans, which would leave people exposed to it more vulnerable to infections on the other hand, fossil oil and gas naturally contain minor amounts of radioactive substances which are released during mining[15]. High levels of these components in brine are an environmental and technological concern. Also, fine particulates of soot blacken humans' and other animals' lungs and cause heart problems or death. Soot is cancer-causing (carcinogenic). A study exploring the effects of oil refineries in Taiwan showed an increased percentage of mothers who gave premature births lived near oil refineries than mothers who lived away from oil refineries. There were also differences observed in sex ratios and the birth weight of the children [16].

Environmental hazards of petroleum refineries

Bangladesh's petroleum refineries are situated in the populated city area, and it is hardly possible for a massive impact of petroleum hazard to nearby inhabitants. The pollutant releases from the petroleum refineries during the oil-producing procedure from the extraction to the consumption chain. In the extraction stage, several noxious gases, aerosols, and by-products were discharged. In the petroleum distillation process, typically the combustion is not complete, and the chemical reaction generates various types of by-products that all are not safe for the environment. Though, despite large amounts of pollutants, there is a variation in the number of certain pollutants [17]. In the refinery stages of petroleum also contributes to large amounts of pollutants in the city areas. After all, petroleum refineries may pollute the air, water, marine, and soil systems.

Air pollution hazard

Petroleum refineries are a major source of hazardous and

toxic air pollutants such as benzene, toluene, xylene, and ethylbenzene. They are also vital sources of air pollutants, such as carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO2), hydrogen sulfide (H2S), volatile aliphatic hydrocarbons (VAH), and particulate matter (PM). The possible sources of air pollutants at petroleum refineries are brief in Table 2. Some of the chemicals released are known or assumed cancer-causing agents, accountable for developmental and reproductive problems. Along with the possible health effects from exposure to these chemicals, these chemicals may cause concern and fear among residents of neighboring people. Air pollutants can come from several sources within a petroleum refinery, such as high-temperature combustion processes in the real burning of fuels for power generation; equipment leaks from valves; the heating of process fluids; and the transportation of products. Many thousands of pounds of these pollutants are naturally released into the air environment throughout a year through usual discharges, fugitive and accidental emission, or plant upsets. The mixture of volatile hydrocarbons and oxides of nitrogen also contribute to ozone formation. Then the ozone form PNA, which cause one of the most important air pollution problems in the USA

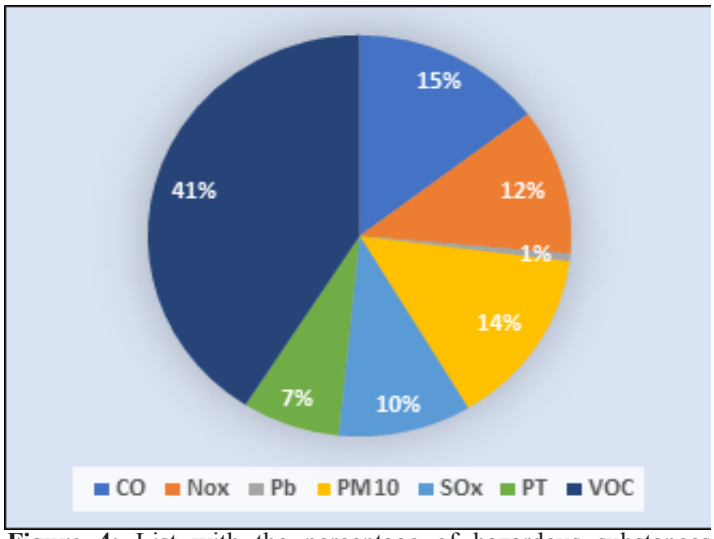

Figure 4: List with the percentage of hazardous substances released from the refinery section in petroleum industries

The study of St. Cholakov showed that the hazardous materials, which emission from the refinery stage in petroleum industries are stated in Fig. 4. Figure shows that the pollutants CO (15%); NOx (12%); SOx (10%); Lead, Pb (1%); Particulate matters below 10 µm, (14%); Particulate matter total, PT (7%); and Volatile organic compounds, VOC (41%)[18].

Table 2: The sources of air pollutants from the petroleum refinery industry and relative impact on the human body

Type of emission	Potential source	Effects
Carbon monoxide	Incinerators, Combustion, Catalyst coking operations, regenerators, flares.	Silent killer, Headache, dizziness, and nausea.
Sulfur oxides, SOx	Catalyst regenerators, gases from Sulfur recovery, decoking operations, acid sludge disposal, flares, Boilers, heaters, furnaces.	respiratory system irritation, lung damage, coughing, asthma, and chronic bronchitis.
Volatile organic compounds (VOCs) and odors	Effluent-handling pumps, equipment, air blowing, catalyst regeneration, barometric condensers, decoking operations, blowdown systems, boilers, compressors, cooling towers, processing vessels, flares, heaters, furnaces, vacuum jets, loading facilities, sampling operations, tanks.	Eye and respiratory irritation, form photochemical smog, breathing and neurologic problem, stress.
Nitrogen oxides, NOx	Boilers, catalyst regenerators, flares, furnaces	Asthma, respiratory infections, chronic lung disease
Fine Particulate matter, FPM	Tanks, catalyst regenerators, coking operations, boilers, flashes	Eye, throat, nose, and lung irritation; coughing, sneezing, runny nose, lung function disease, asthma, and heart disease.

Water pollution hazards

In Bangladesh, all the petroleum and petrochemical industries built nearby freshwater sources, and that waterbody becomes highly polluted through these industries. Petroleum refineries are also potentially the most important contributors to natural water contamination. Several refineries' plants use deep-injection tanks to dispose of wastewater produced inside the plants, but a portion of these wastes end up in sub-surface groundwater. Wastewater in refineries may be highly polluted given the number of sources it can meet during the refinery process (such as equipment leaks, spills, and desalinating of crude oil). This contaminated water may be process wastewaters from desalting, distillation, water

from cooling towers, cracking, or stormwater. It may hold residual oil and many other dangerous wastes. This water recycled over many phases during the refining process and goes through some treatment processes, including an effluent treatment plant (ETP) before released into the surface water body. The effluents released into surface waters are subject to state discharge regulations and regulated under the National Water Act (NWA). These discharge guidelines boundary the levels of ammonia, sulfides, suspended solids (SS), and other hazardous compounds that may exist in the effluent. Although these guidelines are in place, occasionally significant pollution from past emissions may remain in surface water bodies. This regulation cannot obey all times and misused acts in this country.

Soil pollution hazards

Because of the low density, higher viscosity, and minor emulsifying capacity of petroleum, it is easy to absorbed in topsoil, affecting the porosity and hydraulic permeability of soil [19,20]. Petroleum is carbon-rich and barring a small number of nitrogenous compounds. It can change the structure and composition of soil organic matter (SOM) and affect the pH, Eh, Carbon-Phosphorus ratio, Carbon-Nitrogen ratio, Electrical conductivity (EC), and salinity of soil [19- 21]. The trace and heavy metals like vanadium (V) and nickel (Ni) in oil mixes and high levels of salt in oilfield output water can also damage the soil system [22,23]. On the other hand, residual oil can obstruct the regular growth of harvests such as decrease the germination rate and fertility and deterioration of the resistance to pests and diseases [24]. Furthermore, the oil components could react with inorganic Phosphorus and Nitrogen, preventive the nitrification and elimination of Phosphoric acid, so the active Phosphorus and Nitrogen in the soil body would decline and the absorption of crops will affect [25, 26]. Another impact of petroleum product on the soil surface is the essential microorganisms in soil are damaged by that pollution. In normal conditions, the microbes can resist oil pollution, while in polluted soil, they adapt to this kind of environment and produce specific enzymes and steadily form dominant contamination with cooperation or symbiotic effect [27].

Petroleum waste management

The refinery industries produce four (4) wide categories of waste, i.e., process waste; operative and maintenance wastes; commercial waste, and gaseous waste. These broad categories can be divided more individually as shown in Table 3.

Table 3: Waste category with minimization processes of petroleum wastes

Waste category	Description	Ways of Minimizing
Refinery process	b) Oil dealing wastes: unsaleable and waste treatment by-products, spent chemicals and catalysts, off-specification substance. a) Oil handling wastes: greasy and non-greasy sludge from process equipment and boilers and sludge from wastewater treatments.	Reduce
Maintenance and operative related waste	a) Plant construction waste b) Residues from equipment scrubbing and cleaning c) Pass away product samples d) Used electrical goods. e) Spent paint and solvents and related clothing, rags, etc. f) Spill cleaning substances and polluted soils	Reuse/disposal
Commercial	a) Office waste b) Packaging materials— pollutants and non-pollutants c) Other hazardous substances (e.g., batteries, mercury and fluorescent bulbs, asbestos-containing materials, etc.)	Recycling/disposal
Oil impacted wastes	a) Volatile and semi-volatile organic compounds (e.g., benzene, toluene, xylene, phenol, ethyl benzene) b) Liquid hydrocarbons, petroleum gel, tars. c) Trace heavy metals include Nickel, Vanadium, Chromium, Lead, Arsenic.	Treatment
Catalyst Wastes	Metals related to the catalyst itself dependent on specific catalysts and services, but may comprise Nickel, Cobalt, and Molybdenum. Metal Sulphide	Treatment
Waste gases	Carbon monoxide (CO), Nitrogen oxides (NOx), Sulfur dioxide (SO2), Hydrogen sulfide (H2S), Volatile aliphatic hydrocarbons (VAH)	Treatment

The waste management process should be combined with the waste management scheme to classify the ways of waste generated to reduce the waste amount. The waste must need to be treated to decrease its potential impact upon dumping and thus reduce its basic hazards. Waste minimization activities that can lead to the drop in wastes disposal are showing in Table 3.
The overall performs that apply to all category of waste generation and management include:

- systematic upkeep of equipment to reduce waste generation;
- disposal raw material vessels and process equipment fully;
- minimalizing the use of cleaning materials, taking care after transferring and deliberation of
- chemicals substances to reduce spills, and choosing the least hazardous chemicals that are suitable to the application;
- using dry sweep approaches rather than wash with water;
- minimizing the amounts of solid incoming refinery process sewers, to decrease the waste generation and preservation costs along with cleaning and disposal of solids sludge from the effluent treatment system;
- applying coordination activities and relative law or acts to prevent waste deposition; and
- The strategy of major maintenance to minimize trouble at the refinery wastewater treatment plant, and making suitable use of the treatment provided by the wastewater treatment plant for aqueous wastes.

Conclusion

Petroleum is an important energy source use as an essential part of modern society and will be a prime source of energy and power for the next few decades. Hence, it is essential to take measures to control pollution management from the use of petroleum and petrochemicals. Besides, the capability of the environment to absorb the discharged waste materials and the natural resources are also limited. The study observed that there are potential tools that should consider being safe to mitigate the safety and health risks of petroleum refineries. These include measures to reduce oil spills, false floors to prevent gasoline drips in the water table, and double-hulled tanker ships. The review found a relatively new technology that can mitigate air pollution is called biofiltration. Biofiltration is where off-gasses that have biodegradable volatile organic substances or inorganic air toxins are vented out through a biologically active material. It also found that the technology is successfully used in various countries, and it is crucially indeed in Bangladesh. The pollutions of the petroleum refinery industries are the burning issues in the environmental activist of Bangladesh. The finding of the study will help to understand the impacts of petroleum refinery on the environment and thus need to take measures to reduce environmental degradation.

Reference

1. M A Rahim, M G Mostafa (2021) Impact of Sugar Mills Effluent on Environment around Mills Area, AIMS Environmental Science 8: 86-99.
2. M Rafiqul Islam, M G Mostafa (2020) Characterization of textile dyeing effluent and its treatment using polyaluminum chloride. Appl. Wat. Sci. (Springer) 10:119.
3. M K Saha, S J Ahmed, M A H Sheikh, M G Mostafa (2020) Occupational and environmental health hazards in brick kilns. Journal of Air Pollution and Health 5: 135-146.
4. Helal Uddin SM, Mostafa MG, Haque A (2011) Evaluation of groundwater quality and its suitability for drinking purpose in Rajshahi City, Bangladesh. Wat Sci and Tech: Wat Supply 11: 545–559.
5. EIA (2020) U.S. Energy Information Administration (EIA).
6. BFS (2015) Bangladesh Fact Sheet, May 2015.
7. BPC (2017) Bangladesh Petroleum Corporation year book.
8. IEA (2009) Data and Statistics: CO2 emissions by energy source, World 1990-2017. International Energy Agency (Paris).
9. IEA (2009) racking Fuel Supply - Methane emissions from oil and gas. International Energy Agency (Paris).
10. Toro D, Dominic M, McGrath, Joy A, Stubblefield WA, et al. (2007) Predicting the toxicity of neat and weathered crude oil: Toxic potential and the toxicity of saturated mixtures. Environmental Toxicology and Chemistry 26:24-36.
11. Renato Nallin Montagnolli, Paulo Renato Matos Lopes, Ederio Dino Bidoia (2015) Screening the Toxicity and Biodegradability of Petroleum Hydrocarbons by a Rapid Colorimetric Method. Archives of Environmental Contamination and Toxicology 68:342-353.
12. WB Group (2016) Environmental, heath, and safety guidelines petroleum refining.
13. Prasad MS, Kumari K (1987) Toxicity of Crude Oil to the Survival of the Fresh Water Fish Puntius Sephora (HAM.). Acta Hydrochimica et Hydrobiologica 1529-1536.
14. Speight JG (2013) Petroleum Refining and Environmental Control and Environmental Effects.In: Malhotra R. (eds) Fossil Energy. Springer, New York, NY.
15. Kirkeleit J, Riise T, Bråtveit M, Moen BE (2005) Benzene exposure on a crude oil production vessel-animal occupational hygiene. The Annals of Occupational Hygiene 50:123-129.
16. Lin M C, Chiu H F, Yu H S, Tsai S S, Cheng B H, et al. (2001) Increased Risk of Preterm Deliveries in Areas with Air Pollution From a Petroleum Refinery Plant in Taiwan". Journal of Toxicology and Environmental Health Part A. 64:637-644.
17. Tuccella P, Thomas JL, Law KS, Raut JC, Marelle L, et al. (2007). Air pollution impacts due to petroleum extraction in the Norwegian sea during ACCESS aircraft campaign. Elem Sci Anth 5:25.
18. Cholakov G (2009) Control of pollution in the petroleum industry. Pollution Control Technologies 3:86-107.
19. Shuguang W, Yan X, Zhaofeng L, Jishi Z, Namkha N, et al. (2017)The Harm of Petroleum-Polluted Soil and its Remediation Research. Green Energy and Sustainable Development I AIP Conf. Proc. 1864, 020222-1–020222-8; Published by AIP Publishing.
20. He LJ, Wei DZ, Zhang WQ (1999) Research of microbial treatment of petroleum contaminated soil. Advances in Environmental Science, 7:110-111.
21. Li L, Liu M, Zhao JL (2011) Current status and prospects of microbial remediation of soil pollution in oil fields in northern Shaanxi. Chinese Journal of Soil Science 42:1011-1013.
22. Saadat S, Mirkhani R, Mohebi A (2014) Study on phytoremediation of soils polluted with heavy metals and oil

pollutants in agricultural lands affected by Persian Gulf War (Khouzestan, fars, kohgiluyeh & boyrahmad and boushehr provinces).
23. Efsun DF, Olcay Hüseyin S (2015) Variations of soil enzyme activities in petroleum-hydrocarbon contaminated soil International. Biodeterioration & Biodegradation. 268-275
24. Shan BQ, Zhang YT, Cao QL, (2014) Growth responses of six leguminous plants adaptable in Northern Shaanxi to petroleum contaminated soil. Environmental Science 1125-1130.
25. Pinchin HE, Williams JB, May E (2013) Insitu and microcosm investigations into the phytoremediation of hydrocarbon-contaminated lagoon sediments using phragmite saustralis. Journal of Environmental Engineering 139:488-495.
26. Shen YY (2011) Study on behavior characteristics of petroleum contaminates in soils and rhizoremediation. Shaanxi: Chang'an University.
27. Chiara A, Rosario M, Flavia T (2009) Bioremediation of diesel oil in a co-contaminated soil by bioaugmentation with a microbial formula tailored with native strains elected for heavy metals resistance. Science of the Total Environment. 407:3024-3032.