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ENERGY AND WASTE MANAGEMENT FOR PETROLEUM REFINING EFFLUENTS: A CASE STUDY IN BANGLADESH

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ABSTRACT

Transport fuel is one of the major concerns of the energy market. This fuel mainly comes from the processing of crude petroleum oil. The transport fuel processing industries, such as crude oil distillation plants, gas condensate fractionation plants, natural gas processing plants, etc., are one of the most energy- and emission-intensive sectors in the world. On the other hand, the handling and transportation of petroleum products like gasoline, kerosene, diesel, naphtha, octane and sprite, etc. also produce environmental pollution. This study reviewed energy and waste management by transport fuel processing industries in Bangladesh. Such industries are also known as petrochemical industries. They mainly produce gaseous pollutants such as process gas, waste gas, etc. and liquid pollutants such as produced water, waste oil and grease, etc. The gaseous pollutants are burnt in the flare system to save the environment. The liquid pollutants are more hazardous because of their higher salinity and corrosivity and higher amounts of grease. The literature on waste water management techniques, pollution abatement techniques and oil-water separator techniques is described. The waste water treatment techniques used in the case study industries are briefly discussed. Energy flows for both gaseous and liquid waste management are developed. Energy-saving and time frame measures which can be implemented are also outlined. The study found that the rational use of energy and proper environmental management are essential for achieving the energy and environmental sustainability of transport fuel process industries.

Keywords**:** EQS; waste management; pollution abatement technique; petroleum industries; produced water; rational use of energy.

INTRODUCTION

The energy crisis and environmental pollution are two of the most important global issues. History shows that energy consumption from liquid petroleum oil is likely to grow faster than any other type of energy in the world [1]. This liquid oil is mainly consumed by the transport sector. For this reason, it is also called transport fuel. The world's total energy consumption by this sector rose to 33% in 2013 [2]. Transport fuel processing industries cause more environmental pollution while processing this energy [3]. The word environment comes from the French verb *environner* (to surround) and means surroundings or something that surrounds [4]. It includes all the conditions, circumstances, influences surrounding and affecting an organism or group of organisms. Environment is taken to mean all non-organic components of the atmosphere, lithosphere and hydrosphere [5]. Therefore, environment is a combination of the matter and energies around us. Coordination of the resources (manpower, physical, financial and information) of an organization is called management. Environmental management is a broad area of research which is important for the planet's environment [6]. Environment is the aggregate of external conditions that influence the life of an individual person; environment ultimately determines the quality and survival of life [7, 8]. Environmental pollution may be defined as the unfavorable alteration of our surroundings by human actions, through direct or indirect effects of changes in energy patterns, radiation levels, chemical and physical constitution of organisms, etc. [6, 9]. The environment has two categories, i.e. global environment and local environment [10]. The global environment is the combination of all local environments in the universe and is increasingly important. Bangladesh introduced environmental activities after the Stockholm Conference on the Human Environment in 1973. In subsequent years various events took place as described below [6]. In 1977, an Environment Pollution Control Board was established with 16 members ruled by a member of the planning commission and environment pollution control cell. This was followed in 1985 by the restructured and renamed Department of Environment, the activities of which are overseen by a director general. The department discharges its responsibilities through a head office and six divisional offices located in Dhaka, Chittagong, Khulna, Rajshahi (Bogra) and Sylhet in Bangladesh [4-6]. Environment can be polluted by transport fuel processing industries in many ways because they produce both gaseous and liquid pollutants. Gaseous pollutants can be managed easily by burning in the flare system [11]. Liquid waste management for transport fuels and its techniques are more complicated and hazardous [12-14]. The study reviews waste water management for petrochemical process industries and waste water treatment techniques which can help to minimize environmental impact [15, 16]. To identify polluting industries more easily some key factors are identified in the literature, which are presented below.

(1) Total waste load generated [17].
(2) Negative impact on the environment.
(3) Capital cost of remedial measures needed to reduce the impact [18].
(4) Waste load. The major polluting industries in Bangladesh can be ranked as follows: textiles (dying and printing), tanneries, food and sugar, paper and pulp, cement, fertilizer, pharmaceuticals, basic chemicals and refineries [19, 20].
(5) Both (textile and tannery) industries are major polluters because of the high discharge levels of organic chemicals associated with textile dying and leather tanning processes [21].

Environmental acts, rules and regulations in Bangladesh

The following policy, acts and rules facilitate the activities of the Department of the environment (DoE) of Bangladesh [6].

(1) Environment Policy, 1992

(2) Environment Conservation Act, 1995 and subsequent amendments
(3) Environment Conservation Rules, 1997 with amendments
(4) Environment Court Act, 2000 and subsequent amendments
(5) Ozone Depleting Substances Control Rules, 2004
(6) Noise Control Rule 2006

Environmental clearance required to launch a process industry

There are three types of environmental clearance which are required to set up an industry in Bangladesh.

(1) Initial environmental examination (IEE) for site clearance certificate
(2) Environmental impact assessment (EIA) for environmental clearance certificate
(3) Environmental management plan (EMP) for environmental clearance certificate

The study overviewed the energy and waste management practices in transport fuel processing industries in Bangladesh. Waste water management, pollution abatement techniques, oil-water separator techniques, etc. are briefly discussed and presented. The liquid pollutants which are more harmful in terms of environmental pollution and their treatment are discussed. Three industries are selected as a case study and their effluent treatment process and quality are outlined. The timescale for rational use of energy and its management system are also discussed in this article.

WASTE WATER MANAGEMENT

The management of industrial waste water from the transport fuel process is a hazardous process but essential for successful operation of the industry. The water is polluted when any physical, biological or chemical change in water quality adversely affects living organisms or makes the water unsuitable for the desired use. Waste water and polluted water have a bad taste and offensive odor, oil and grease floating on the surface, change in color and unchecked growth of aquatic weeds, etc. [22-24]. The sources of water pollution can be categorized as point source and non-point source. Factories, process industries, power plant, sewage treatment plants, underground coal mines and oil wells are classified as point sources [25]. Industrial waste water treatments are very important for the environment. Waste water can be well managed by efficient techniques such as an effluent treatment plant (ETP). The ETP is the most commonly and widely used technique for industrial waste water treatment. The main stages in the implementation of ETP, i.e. procurement and supply of equipment and materials, commissioning and performance guarantee, test runs, etc., are shown in the following work schedule.

(1) Planning and design: objectives, preliminary project development proforma, financial source, documentation for tender schedule.
(2) Installation and commissioning: effective date of contract, piping foundation, structure, installation of equipment, installation of piping, mechanical completion, pre-commissioning and commissioning start, final acceptance certificate.
(3) Operation and maintenance according to the type of plant.

The design and construction of an ETP depends on the specific industry and its effluent quality. In the literature different techniques have been developed to manage industrial waste water. Many more technologies are available and some of them are presented in Table 1.

Table 1. Available waste water treatment technologies.

No.	Treatment technology	No.	Treatment technology
1.	Activated sludge systems	15.	Membrane bioreactor
2.	Advanced oxidation process	16.	Parallel plate oil-water separator
3.	API oil-water separator	17.	Reverse osmosis
4.	Bioreactor	18.	Rotating biological contactor
5.	Carbon filtering	19.	Sand filter
6.	Chemical addition wastewater treatment	20.	Sedimentation
7.	Dissolved gas flotation	21.	Sedimentation (water treatment)
8.	Distillation	22.	Septic tank
9.	Electrocoagulation	23.	Sequencing batch reactor
10.	Expanded granular sludge bed digestion	24.	Sewage treatment
11.	Microbial fuel cell	25.	Soil bio-technology
12.	Stabilization pond	26.	Treatment pond
13.	Ultrafiltration	27.	Ultraviolet disinfection
14.	Vacuum evaporation	28.	Upflow anaerobic sludge blanket digestion

The use of treatment technology depends on the characteristics of the waste water, quantity, metals contained and end use like irrigation, reuse, potable water, etc. This article briefly discusses different technologies used for waste water treatment in petroleum industries. Different research groups have used the pollution abatement techniques listed in this study. Their findings are briefly discussed in Table 2.

INDUSTRIAL POLLUTION ABATEMENT TECHNIQUES

As discussed above, transport fuel processing industries produce both liquid and gaseous pollutants. Gaseous pollutants are easier to manage as liquid pollutants are complicated. ETP can efficiently treated liquid pollutants (i.e. waste water) to save the environmental pollution. The treatment system can be divided into four categories as below [26-33].

(1) Preparatory or preliminary treatment: to remove coarse suspended and floating matters, oil or grease.
(2) Primary or physical treatment: to remove settleable and suspended solids.
(3) Secondary or biological treatment: to remove organic solids through a biological process.

(4) Tertiary or advanced treatment: to achieve additional removal of suspended solids, colloidal particles, nutrients, and refractory organics and further reduction of fecal coli.

Table 2. Literature on petroleum waste water treatment, parameters investigated and findings by different research groups.

Research groups	Pollutant type	Parameters investigated	Findings, results and comments, etc.
Diya'uddeen et al. [34]	Petroleum refinery effluent	COD, BOD, Oil & grease, TPH, S, P.	Reviewed different techniques and identified photo-catalytic degradation as a more efficient technique.
Yavuz et al. [35]	Refinery waste water	BOD, COD	Identified method for waste water is electrofenton process followed by electrochemical oxidation using boron doped diamond anode.
El-Naas et al. [36]	Petroleum refinery waste water	pH, COD, sulfate	Electrocoagulation was found most effective for pH but there was no significant removal of the other two parameters.
Adams et al. [37]	Oily and greasy effluent	COD	Significant amount of COD (about 85%) reduction within 10 minutes.
Jain and Shrivastava [38]	Oily and greasy effluent	COD	82.5% reduction of COD within 40 min. Irradiation for high initial concentration of 1345 mg/L catalyst.
Ji et al. [39]	Heavy oil-produced water	BOD, COD, oil, TKN	Surface flow constructed wetland can removed by 80%, 93%, 88% and 86% of the parameters.
Lefebvre et al. [18]	Highly saline waste water	NaCl, turbidity	The use of reverse osmosis is particularly efficient for removing salt concentration, suspended solids and organic matter.
Li et al. [40]	Oil field waste water	COD, $(NH_4)_2SO_4$	Polyvinyl alcohol can efficiently remove COD from waste water.
Ji et al. [41]	Heavy oil waste water	BOD, COD, mineral oil, TKN	Subsurface flow constructed wetland treatment can efficiently remove more than 80% of the parameters.
Grzechulska et al. [42]	Oily waste water	COD and oil content	Photocatalytic decomposition of oily waste water in 2h by modification of catalyst activity.
Stepnowski et al. [43]	Petroleum refinery waste water	H_2O_2	UV radiation accelerates the photo-degradation process for lower concentrations of H_2O_2.
Alhakimi et al. [44]	Oily & greasy waste water	COD	Oily waste water completely degraded in 5 h.
Li et al. [45]	Oil field waste water	COD	Significant reduction of COD level by 80%, 88.9% & 93% in 30, 60 & 120 min

Some of the pollution abatement techniques.

The treatment systems are briefly discussed below. In every step, effluent should be tested to meet the standards. If it fails at any stage, it needs more advanced treatment or recycling for further treatment before discharge into the environment. A typical flow diagram for industrial waste water treatment is presented in Figure 1.

Primary or Physical Treatment

Primary treatment involves screening; grit removal and settling. The settleable floating solids are removed, giving a 30% to 35% reduction in biological oxygen demand [26, 27, 46, 47]. It is the first stage of industrial waste treatment. Primary treatment can be performed by a sedimentation tank, a septic tank, an Imholf tank or dissolved air floatation

Secondary or Biological Treatment

Secondary treatment is one of the more effective steps of the waste water treatment. It generally consists of a biological aeration step in which the dissolved organic matter is converted into a settleable form and removed as sludge. This sludge can be settled into a secondary settling tank. It must have been previously aerated and is referred to as activated sludge. Part of it is recycled back to the aeration tank and the remaining part is withdrawn from the system as excess sludge [27, 48, 49]. The excess sludge and primary settled sludge are mixed and thickened. This mixture is sent to a sludge digester for further stabilization followed by dewatering. The treated effluent from the second settling tank generally removes 90% of BOD, which is sufficient. Sometimes primary and secondary treatment can be accomplished together. Lagoons and ponds are the best example of this. They consist of an earthen basin; wastewater is retained long enough for natural purification. Oxygen is presented at all depths in shallow ponds (aerobic ponds). Oxygen from air cannot penetrate to the bottom of deep ponds (anaerobic ponds). In lagoons oxygen is provided by artificial aeration [50-57].

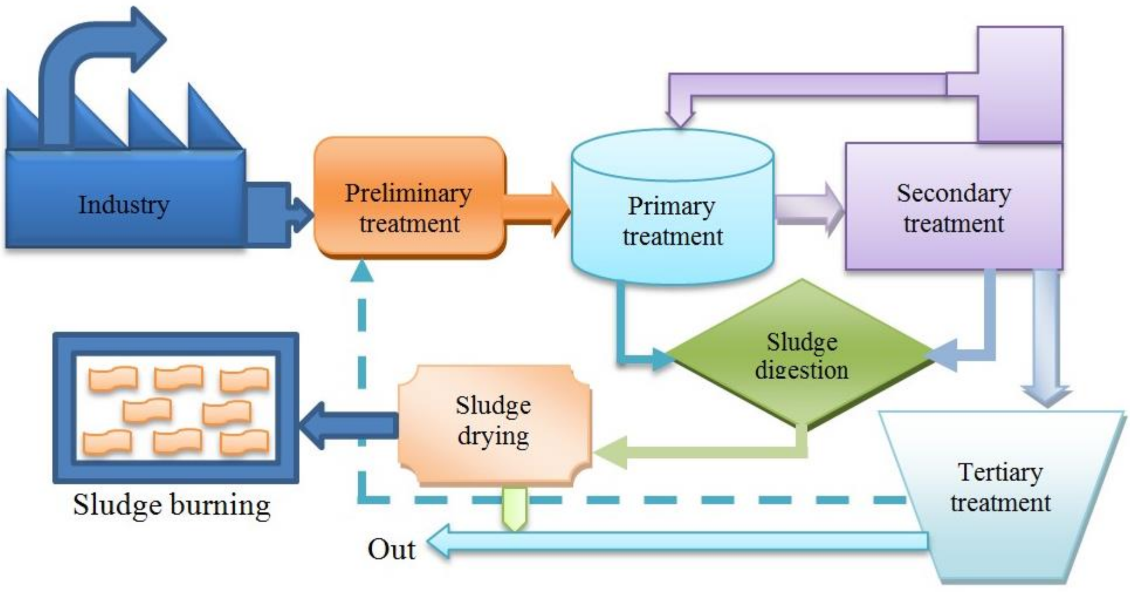

Figure 1. Typical flow diagram for waste water treatment plan.

Tertiary or Advanced Treatment

Tertiary treatment is preformed when more treatment is needed. The actual steps which are needed depend on the purpose for which the effluent is to be used. Tertiary treatment consists of many integrated process as below [28, 48, 50, 58, 59].

(1) Air stripping for removing ammonia, nitrogen or other gases.
(2) Nitrification process for converting ammonia to nitrate [60].
(3) Denitrification process for converting nitrate to nitrogen [60].
(4) Chlorination process to destroy pathogens and other disease-causing organisms [61].
(5) Dechlorination process for removing free and combined chlorine [60].
(6) Chemical precipitation to remove heavy metals [62].
(7) Reverse osmosis for removing dissolved inorganic materials [63].
(8) Ion exchange process to remove dissolved inorganic materials [64].

The above-mentioned abatement techniques are used in both chemical and petroleum industries for waste water treatment. Including this techniques petroleum industries are needed to use more technique to separate oil or grease from the waste water. The widely used technique for oil-water separation is briefly discussed below.

API OIL-WATER SEPARATOR

An oil-water separator is one of the efficient ways to remove water particles from petroleum products. The petroleum industries tend to use the American Petroleum Institute (API) separator for this purpose [65]. In general, raw oil and natural gas contain about 0.5 to 2.0% of water which must be removed from the finished products. In the gas process a knockout separator is used to remove water and higher hydro-carbons from the raw gas. The water which emerges with the raw gas is also called produced water or underground water or waste water [66, 67]. At the initial stage 2 or 3 phase a knockout separator can separate the produced water from the gas but it still has some oil components mixed with it. An API oil-water separator is a device designed to separate gross amounts of oil and suspended solids from the waste water effluents of oil refineries, petrochemical plants, chemical plants, natural gas processing plants, etc. [26]. Such separators are designed according to standards published by the American Petroleum Institute [68]. A typical API oil-water separator is presented in Figure 2. It comprises mainly a two-chambered vessel containing a trash trap (including rods), oil retention baffles, flow distributors (vertical rods), oil layer, slotted pipe skimmer, adjustable overflow wire and sludge sump, chain and flight scraper.

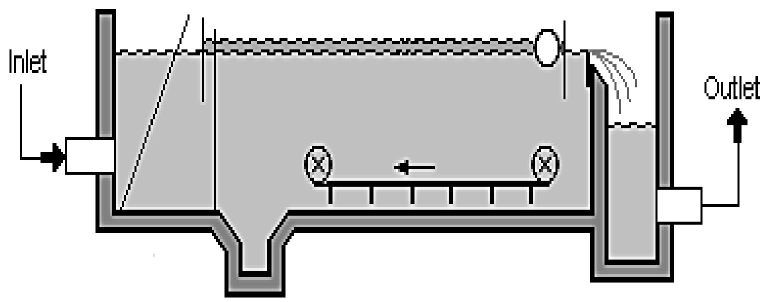

Figure 2. Typical API oil-water separator for petroleum industries (side view).

STANDARDS FOR INDUSTRIAL EFFLUENT IN BANGLADESH

The following standard parameters apply to industrial effluent in Bangladesh. Some of the most important parameters are presented in Table 3.

Table 3. Standard parameters for industrial effluent in Bangladesh.

Parameters	Unit	Discharge to		
		Inland surface water	Secondary treatment plant	Irrigable land
BOD at 20°C	mg/L	50	250	100
COD	mg/L	200	400	400
Dissolved oxygen, DO	mg/L	4.5 - 8	4.5 - 8	4.5 – 8
Electric conductivity, EC	μohm/cm	1200	1200	1200
Total dissolved solid	mg/L	2100	2100	2100
Oil and grease	mg/L	10	20	10
pH	mg/L	6-9	6-9	6-9
Suspended solid	mg/L	150	500	200

The following parameters were tested on waste water samples: dissolved oxygen (DO), biochemical oxygen demand (BOD at 20^{O}C), chemical oxygen demand (COD) [$K_2Cr_2O_7$ method], chloride (C_l), ammonia (NH_3-N), ammonium (NH_4-N), nitrate (NO_3-N), chromium (Cr -Total), cadmium (C_d), lead (P_b), total suspended solid, total dissolved solid, phosphate (PO_4-P), sulfate (SO_4-S) and oil and grease content, etc. [17, 48, 51].

INDUSTRIAL EFFLUENT – A CASE STUDY

Petroleum industries in Bangladesh are natural gas processing plants, condensate fractionation plants, oil refining plants, LPG plants and coal processing plants, etc. Bangladesh is blessed with natural gas and black coal. Natural gas is used for many purposes like power generation, household cooking, transport sector, etc. Raw natural gas contains about 94-98% methane, 1.21-3.97% ethane, 0.14-1.10% propane, 0.08-0.29% iso-butane, 0.01-1.23% N-butane, 0.04-0.41% higher composition, 0.02-0.99% nitrogen, 0.07-0.90% CO_2 and 0.5 to 2.0% water [69]. Produced water is the largest waste stream generated in the oil and gas processing industries. It is a mixture of different organic and inorganic compounds, minerals and hydrocarbons, etc. The study examined waste water management and treatment of petroleum industries in Bangladesh. The name of the industries is not revealed for confidential reasons, and they are indicated as Industry 1, 2 and 3 respectively. Effluent compositions were tested. The test results are presented in Table 4. As seen from the Table, oil and grease are present in significant amounts in petrochemical industries. The combined process flow diagram for the waste water treatment is presented in Figure 3, excluding oil-water separator parts, which are shown in the energy flow diagram in subsequent section. After treatment, waste water can be used for irrigation if the required treatment has been performed properly.

Table 4. Waste water composition for case study industries [70].

No.	Items	Unit	Name of the industry		
			Industry 1	Industry 2	Industry 3
1.	*pH*	--	6.5 – 8.0	9.5 – 11.0	8.73 – 13.5
2.	BOD	mg/L	37	26	19
3.	COD	mg/L	400	424	378
4.	Electric conductivity	µohm/cm	--	3.74	2.98
5.	Oil and grease	mg/L	201	263	428
6.	Suspended solid (SS)	mg/L	180	215	231
7.	NH_3 (as N)	mg/L	150	--	130
8.	Total Kjeldahl nitrogen	mg/L	200	--	--
9.	Nitrate (NO_3-N)	mg/L	50	38	46
10.	Phosphate (PO_4-P)	mg/L	30	45	63
11.	Cyanide, CN	mg/L	--	0.1	0.3
12.	Color	Pt-Co unit	298	303	305
13.	Turbidity	NTU	5.6	6.3	8.6
14.	Salt concentration	g/L	90-110	102-130	120-150

As seen from the Table, *pH* and COD are higher than the standard values for all industries. It can be noted that oil and grease content is significantly higher than the standard industrial effluent. The petroleum industrial waste water contains more dissolved salt and has more corrosive characteristics. For these reasons, the effluent treatment is a very difficult and time-consuming process. A typical process flow diagram for petroleum waste water is presented in Figure 3.

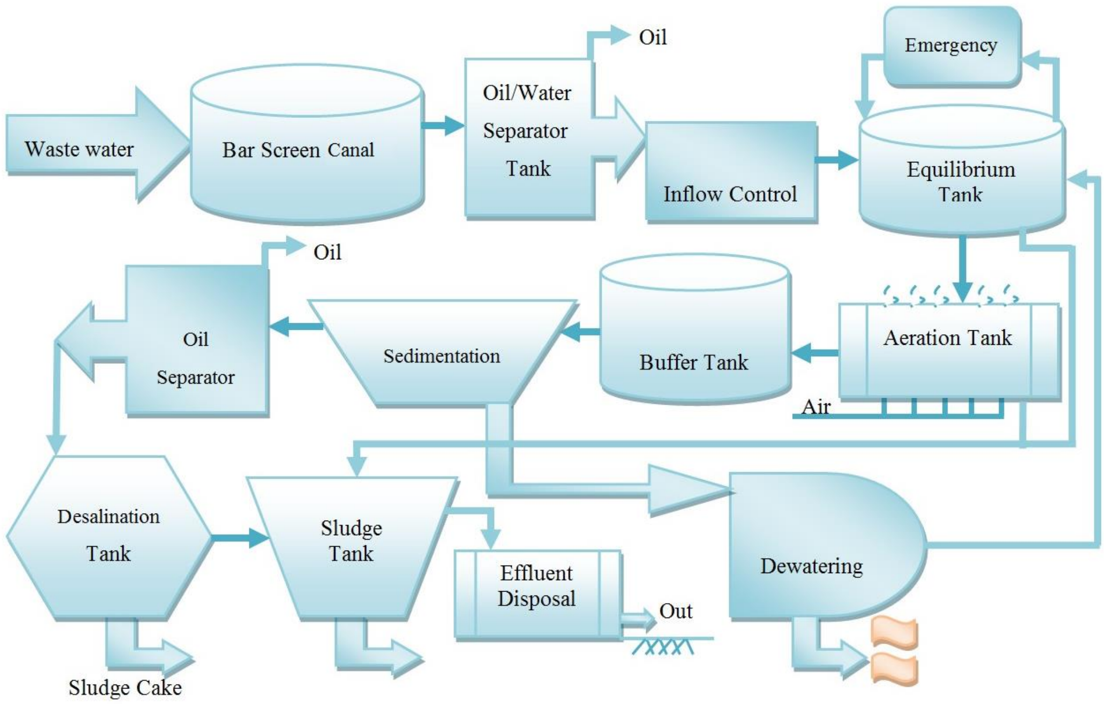

Figure 3. Designated process flow diagram for petro-chemical effluent treatment.

Figure 3 shows the designated process flow diagram for effluent treatment in petroleum industries. Produced water is conventionally treated by different physical, chemical and biological methods. In current practice it is very hard to remove small suspended oil particles and dissolved elements. Also, many chemical treatments have high initial running costs and produce hazardous sludge. In onshore facilities, biological pretreatment of oily waste water can be a cost-effective and environmentally friendly method. The quality of the industrial effluent after treatment is presented in Table 5.

Table 5. Effluent quality after treatment.

No.	Items	Unit	Name of the industry		
			Industry – 1	Industry – 2	Industry–3
1.	*pH*	--	6.5 – 8.0	7.5	9.2
2.	DO	mg/L	--	5.2	2.5
3.	BOD	mg/L	30	14	11
4.	COD	mg/L	192	101	137
5.	Electric conductivity	μohm/cm	--	1.32	1.75
6.	Oil and grease	mg/L	8.9	9.3	10.2
7.	Suspended solid (SS)	mg/L	97.3	82.1	98.7
8.	NH_3 (as N)	mg/L	48.2	--	52
9.	Total Kjeldahl nitrogen	mg/L	93.8	--	--
10.	Color	Pt-Co unit	--	219	136
11.	Turbidity	NTU	3.4	1.8	0.79

The following steps were taken for treatment of the effluent. The *pH* in the neutralization tank was maintained at 6 to 7.5. MLSS of 1500 to 1800 mg/L was maintained in the aeration tank. The oil separation was done in two stages and the desalination process maintained carefully.

INDUSTRIAL ENERGY MANAGEMENT

Energy management can prove better at energy conservation, making savings of about 10% to 30% without capital investments or reduced production [71, 72]. Worrell et al. [73] investigated the energy consumption by industrial processes in the European Union. Their study suggested that best practice technology could make a potential improvement in energy efficiency of 15±4% on average for petroleum industries [73]. The process industries are the most energy- and pollution-intensive sector in the world. The rational use of energy by the most suitable and economically viable methods can save energy and environment alike. Rasul et al. reviewed the rational use of energy in process industries like textile, steel and alumina refining respectively [71, 74, 75]. They noted that waste recovery methods have an additional impact on boiler or heater efficiency by 19.04% per unit of fabric production [76]. Therefore, energy conservation is important for long-term economic well-being and security. The International Energy Agency (IEA) provides valuable insights regarding the importance of industrial energy use by sector and region, as presented in Table 6. Utlu and Hepbasli [77] reviewed energy efficiency in the Turkish industrial sector and reported 90% efficiency in energy use in petroleum refining thanks to the energy recovery system. Together chemical and petroleum industries use about 30% of industrial energy in the world [78]. The energy distribution of the petrochemical industries is presented in Figure 4.

Table 6. Industrial energy uses (including coke ovens and blast furnaces) [78].

Sector	Countries		World
	OECD (EJ)	Non-OECD (EJ)	(EJ)
Chemical and petroleum industries	17.76	13.82	31.58
Iron and steel industries	7.97	11.93	19.90
Non-metallic minerals	3.66	4.95	8.61
Paper, pulp and printing industries	5.01	1.07	6.08
Food and tobacco industries	3.03	2.57	5.60
Non-ferrous metal industries	1.96	2.11	4.07
Machinery	2.19	1.76	3.95
Textile and leather industries	0.96	1.07	2.03
Mining and quarrying	0.90	0.82	1.72
Construction industries	0.70	0.61	1.31
Wood and wood products	0.82	0.47	1.29
Transport equipment	0.98	0.27	1.25
Non-specified	5.31	12.88	18.19
Total	51.2	54.37	105.57

As seen from the Table, non-OECD countries use more industrial energy than OECD countries. The chemical and petroleum industrial sectors consume more energy than any other sector listed above. The energy distribution for the petrochemical industries is presented in Figure 4. Rationalization of an industrial operation by using the above-mentioned objectives may be quite complex for an existing industrial system. In order to obtain more economic energy the following timeframe measures can be implemented depending on the size of the investment and their cost-effectiveness as short-term measures, medium-term measures and long-term measures. These three terms are briefly discussed below. The energy flow diagram for petroleum industries is presented in Figure 5.

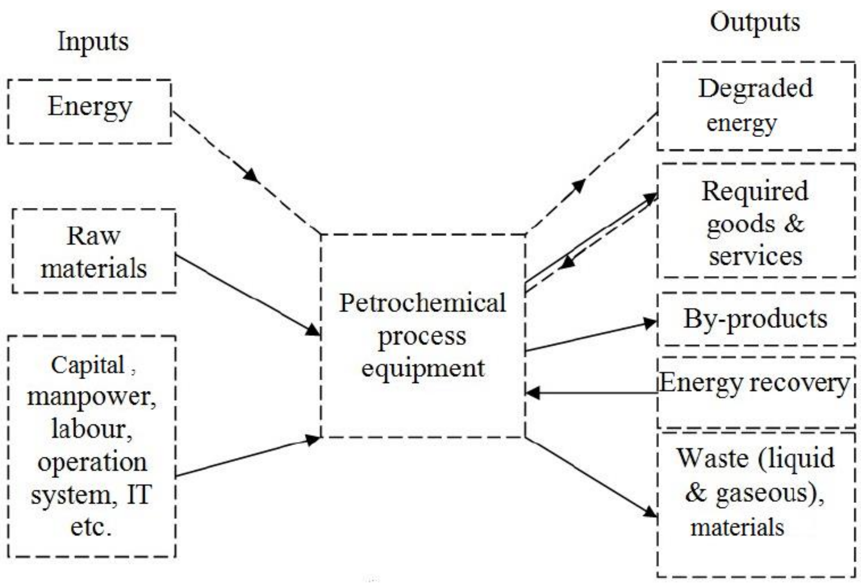

Figure 4. Energy distribution for petrochemical process industries.

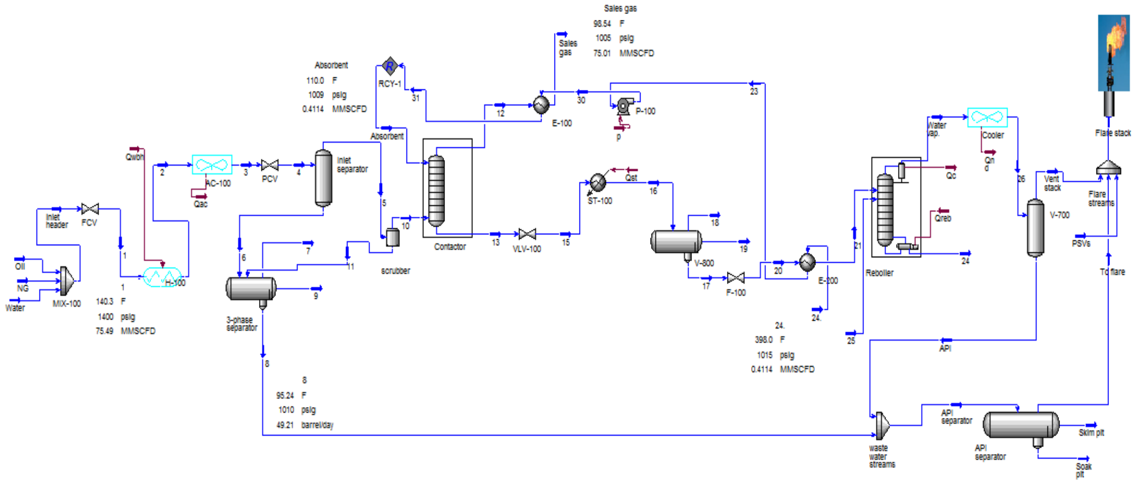

Figure 5. Energy flow diagram for the petroleum industries showing liquid and gaseous effluent handling units.

The rational use of energy in petroleum industries can be measured in three ways as shown in Figure 6. One of the more effective ways is schedule maintenance for energy conservation as a short-term measure. No new investment is required but only increased labor cost for maintenance. The use of energy-efficient equipment by enforcing a better schedule and maintenance work is the main target. Proper utilization of measurement equipment can save more than 5% fuel consumption. Under the medium-term measure, small investments are required for energy consumption networks. The objective is to reduce high-quality energy consumption and use low-quality energy without any change in the principal operation technique. Small investment is needed by replacing less efficient equipment and repairing leaks. Proper insulation or re-insulation could save energy.

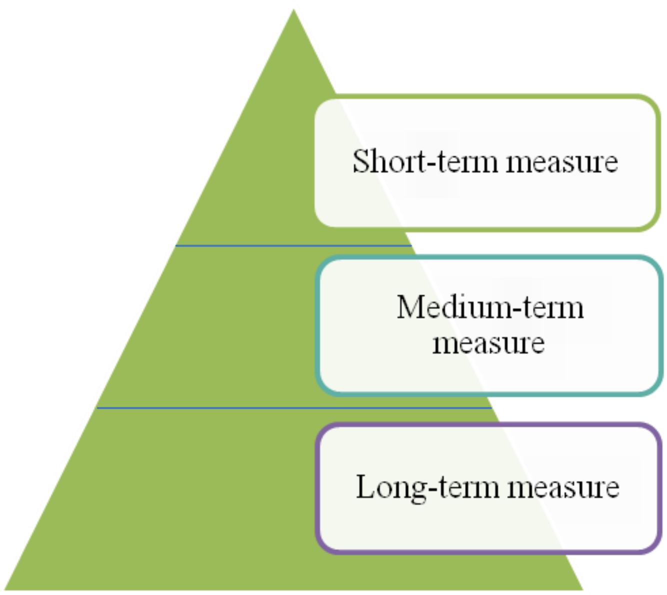

Figure 6. Rational use of energy measures in petroleum industries.

Large investment is needed for long-term measures for interconnecting an existing process. Energy in the form of heat and power is one of the main drivers for successful running of petroleum process industries. More investment is required for installation of co-generation units, by-products reprocessing units and waste recovery units under the long-term measure. Very large investments in the principle of the process are also included in this term. On the other hand, older production processes can be redesigned or modified without any change in the finished product. A more energy-efficient process can be obtained by applying advanced technologies and proper management. Energy use by fuel type in petroleum industries is presented as follows.

ENERGY USED IN PETROLEUM INDUSTRIES

For better understanding of the energy scenario in petroleum process industries, schedule energy auditing is an efficient technique. More energy is needed to obtain finished products by raw or crude petroleum oil processes. The main principle is partial fraction, which requires heat energy to change the liquid phase of the raw materials to the vapor phase. The types of energy used for the process are presented in Table 7. As seen from the Table, more heat and electricity energy is needed to run the process. For petroleum process industries 80% to 85% of energy is consumed by the furnace for heating and 15% to 19% is consumed by the power generator for the process run. The remaining 1% is used in the laboratory for testing of the finished product properties. Therefore energy efficiency improvement and its proper management can yield better results for process industries.

Table 7. Types of energy used in petroleum industries in Bangladesh.

Process	Type of fuel
Raw materials - pumping & storing	Electricity
Feedstock preheating	Heat energy
Heating/ furnace running	Natural gas
Power generation for processing running	Natural gas
Product pumping	Electricity
Product cooling	Electricity
Product testing in laboratory	Natural gas & electricity
Other (AC for equipment, fan, lighting, etc.)	Electricity

CONCLUSIONS

Transport fuel demand is increasing day by day and requires greater exploration and more production of crude petroleum oil. More processing of crude oil leads to an increase in petroleum effluents, which are hazardous compounds containing pollutants. The ecosystem can be adversely affected by these pollutants. Consequently, the treatment of oil and grease from waste water is one of the most important environmental issues for petroleum industries. Another problem is higher salinity and high corrosivity. As high salt concentrations and influent characteristics have a direct influence on the turbidity of the effluent, it is appropriate to incorporate a physical treatment, e.g. membranes, to refine the final effluent. The study reviewed different technologies used for petroleum waste water treatment. The gravimetric method and activated carbon filters can be used to remove the oil, grease and salinity from waste water by secondary treatment. The literature also reports that a reverse osmosis process can significantly reduce salinity in waste water. It is also important to eliminate the heavy metals dissolved as divalent metal oxides from waste water. By considering these parameters, the case study industries in Bangladesh designed an ETP to maintain EQS standards for waste water treatment which can produce environmentally friendly effluent. The study also briefly discussed energy management techniques in the case study petroleum industries. It developed an energy flow diagram, energy distribution diagram and timeframe measures of rational use of energy in petroleum industries. It found that more than 15% of energy can be saved by implementing proper waste treatment process and energy management systems.

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