A Study on Energy and Environmental Management Techniques Used in Petroleum Process Industries

A.K. Azad, M.G. Rasul, Rubayat Islam, and S.F. Ahmed

1 Introduction

The energy and environment is one of the major concerns in the present world nowadays (DOE). The environment is a combination of matters and energies around us. The coordination among the resources of an organization is called management. So, environmental management is a broad area of research which is important for the global environment. Environmental pollution can be defined as the unfavourable 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. (Hossain 2009; Azad and Alam 2011). These changes may affect directly or indirectly the environment (MEF 2007; Cholakov 2010). The first environmental activities in Bangladesh were taken soon after the Stockholm conference on human environment. As a follow-up action to the Stockholm conference, the Bangladesh Government funded, under the aegis of the department of public health engineering and with a staff level of 27 and after promulgating the water pollution control ordinance in 1973, a project primarily aimed at water pollution control. In the subsequent years, various events took place (Hossain 2009). In 1977, the Environment Pollution Control Board (EPCB) with 16 members ruled by a member of the planning commission and environment pollution control cell was formed and renamed as Department of Environment in

A.K. Azad (✉) • M.G. Rasul • S.F. Ahmed
Central Queensland University, School of Engineering and Technology,
Rockhampton, QLD 4702, Australia
e-mail: azad.cqu@gmail.com; a.k.azad@cqu.edu.au

R. Islam
Department of Mechanical Engineering, Bangladesh University of Engineering
and Technology, Dhaka 1000, Bangladesh

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1985. The department discharges its responsibilities through a head office and six divisional offices located in Dhaka, Chittagong, Khulna, Rajshahi (Bogra) and Sylhet in Bangladesh (DoE 2007, Hossain 2009, DoE 2008). The following policy, acts and rules facilitate the activities of DoE (Department of Environment) in Bangladesh: Environment Policy, 1992; Environment Conservation Act, 1995, and subsequent amendments; Environment Conservation Rules, 1997, with amendments; Environment Court Act, 2000, and subsequent amendments; Ozone Depleting Substances Control Rules, 2004; and Noise Control Rules in 2006 (Hossain 2009).

The environment can be polluted in many ways. One of the major sources of environment pollution is industrial waste water which can be defined as any physical, biological or chemical change in water quality that adversely affects living organisms or makes water unsuitable for desired uses. The polluted water has some signs like bad taste, offensive odour, oil and grease floating on water surface, etc. (Abdel-Gawad and Abdel-Shafy 2002; El-Gohary et al. 1987; Ramalho 1977). The waste water sources can be categorized into, namely, point source and non-point source. The factories, power plant, sewage treatment plants, underground coal mines, gas processing plants and oil well are classified as point sources. Non-point sources include runoff from farm fields, feedlots, lawns and gardens, construction sites, logging areas, roads, streets, parking lots, etc. (Correia et al. 1994). Waste water treatment is very important to save the environment. This pollution can be managed by applying some treatment techniques such as effluent treatment plant (ETP). ETP is the most commonly and widely used technique for industrial waste water treatment. The treatment techniques mainly depend on the quality of untreated waste water.

This study summarizes the energy and environmental management practices in natural gas process industries in Bangladesh. Management and treatment system of the hazardous pollutant like waste water which is more intensive for environmental pollution is developed in this study. The rational use of energy and its management system are also reported, and further recommendation is made for energy-efficient process industries in Bangladesh.

2 Environmental Management

2.1 Pollution Abatement Technique

Waste water treatment system can be categorized as preliminary treatment, primary or physical treatment, secondary or biological treatment and tertiary or advanced treatment (Fakhru'l-Razi et al. 2009; Brindle and Stephenson 1996; Knoblock et al. 1994; Kirk et al. 2002; Cummings 1991; Van Loosdrecht et al. 1998; Glaze et al. 1987; Kuba et al. 1997). The primary treatment involves screening; grit removal and settling give about 30–35% reduction in biological oxygen demand (Fakhru'l-Razi et al. 2009; Brindle and Stephenson 1996; Parinos et al. 2007;

Carballa et al. 2005). It can be performed by (a) sedimentation tank, (b) septic tank, (c) Imhoff tank and (d) dissolved air floatation (DAF). Secondary treatment generally consists of biological aeration steps in which the dissolved organic matter is converted into an able settled form and removed as sludge by settling in a secondary settling tank. This sludge having been previously aerated is referred to as activated sludge, a part of it is recycled back to the aeration tank and the remaining part is withdrawn from the system as excess sludge (Brindle and Stephenson 1996; Kornaros and Lyberatos 2006; Lin et al. 2001). The excess sludge and primary settled sludge are mixed, thickened and sent to a sludge digester for further stabilization followed by de-watering. Sometimes primary and secondary treatment can be accomplished together. Treatment in lagoons and ponds is the best example of this type of treatment (Svenson et al. 1992; Gurbuz et al. 2009; Legrini et al. 1993; Henze 2002; Scott and Ollis 1995; Fuhs and Chen 1975). The tertiary treatment is also called as advanced treatment. If more treatment is needed to achieve the standard of the effluent water, then advanced treatment is required. The actual steps needed for this treatment depend on the purpose for which the effluent is to be used for. Tertiary treatment consists of air stripping, the step which removes ammonia, nitrogen or other gases (Kornaros and Lyberatos 2006; Knoblock et al. 1994; Owen et al. 1995; Oliveros et al. 1997), nitrification process (Focrrr and Chang 1975), denitrification process (Focrrr and Chang 1975), chlorination process (Takht Ravanchi et al. 2009), dechlorination process (Focrrr and Chang 1975), chemical precipitation (Dean et al. 1972), reverse osmosis (Wang et al. 2005) and ion exchange process (Namasivayam and Ranganathan 1995). A typical flow diagram for waste water treatment plant is shown in Fig. 1. This abatement technique can be used in petroleum process industries for their waste water treatment.

2.2 *Oil and Water Separation Technique Used in Petroleum Industries*

Bangladesh is blessed with natural gas and black coal. Raw natural gas contains about 0.5–2.0% water (Mondal et al. 2013b). This raw gas is processed in gas processing plant. In this plant, one of the main challenges is to remove water and higher hydrocarbons from the raw gas. The water which comes out with the raw gas is called produced or underground waste water (Barbosa et al. 2007; Lettinga 1995). At the initial stage, a two- or three-phase knockout separator can separate the produced water from the gas but has some oil component mixed with it (Mondal et al. 2013a). API separator is one of the most important devices to remove oil from the waste water (Dobson and Burgess 2007). It is mainly a couple chambered vessel containing trash trap (including rods), oil retention baffles, flow distributers (vertical rods), oil layer, slotted pipe skimmer, adjustable overflow wire and sludge sump, chain and flight scraper. The waste water samples were tested for the

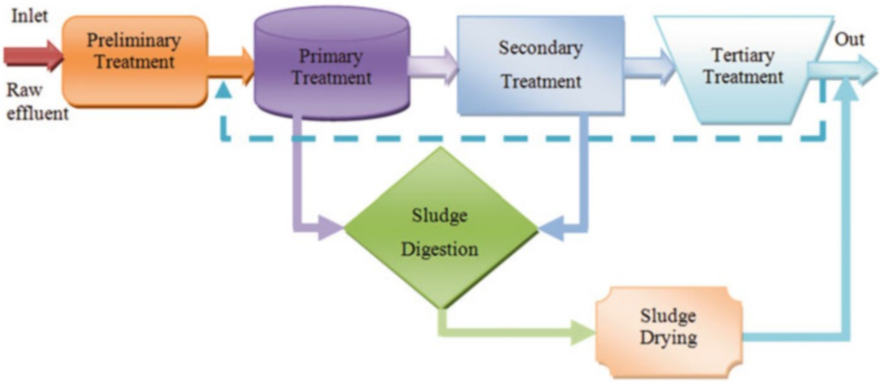

Fig. 1 Typical flow diagram for waste water treatment plant

following 14 parameters: dissolved oxygen, biochemical oxygen demand (at 20 °C), chemical oxygen demand, chloride, ammonia, ammonium, nitrate, chromium, cadmium, lead, total suspended solid, total dissolved solid, phosphate and sulphate (Fuhs and Chen 1975; Kornaros and Lyberatos 2006; Lund and Lund 1971). Table 1 shows some standard parameters for industrial effluent and their discharge limit in three discharge points.

2.3 *Study on Industrial Effluents*

Produced water or waste water is the largest waste stream generated in oil and gas industries. It is a mixture of different organic and inorganic compounds, minerals and hydrocarbons. Due to the increasing volume of waste water all over the world in the current decade, the outcome and effect of discharging produced water on the environment has lately become a significant issue of environmental concern. The study was made on waste water management and treatment for three natural gas processing industries in Bangladesh. Due to confidentiality, the names of the industries have been removed and indicated as Industry A, B and C, respectively. For the study, the effluent compositions were tested which are presented in Table 2. From the Table, it seems that the waste water contains a significant amount of oil and grease in petroleum industries. Figure 2 shows the designated process flow diagram for effluent treatment in petrochemical industries. Produced water is conventionally treated through different physical, chemical and biological methods. However, current technologies cannot remove small suspended oil particles and dissolved elements. Besides, many chemical treatments require high initial running cost. In onshore facilities, biological pretreatment of oily waste water can be a cost-effective and environment-friendly method. Table 3 shows the quality of effluent after treatment.

Table 1 Standard parameters for industrial effluent

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	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

Table 2 Waste water composition in studied industries

Items	Unit	Name of the industry		
		A	B	C
pH	–	6.5–8.0	8.5–10.0	8.73–11.5
BOD	mg/L	37	26	19
COD	mg/L	400	424	378
Electric conductivity	μohm/cm	–	3.74	2.98
Oil and grease	mg/L	20	263	428
Suspended solid (SS)	mg/L	180	215	231
NH_3 (as N)	mg/L	150	–	130
Total Kjeldahl nitrogen	mg/L	200	–	–
Nitrate (NO_3-N)	mg/L	50	38	46
Phosphate (PO_4-P)	mg/L	30	45	63
Cyanide, CN	mg/L	–	0.1	0.3
Colour	Pt-Co unit	298	303	305
Turbidity	NTU	5.6	6.3	8.6

3 Energy Management

Rationalization of an industrial operation is quite complex for an existing industrial system. However, in order to save energy, the following time frame measures can be implemented depending on the size of the investment and their cost-effectiveness as short-term measure, medium-term measure and long-term measure. In the case study, processing plants used short-term and medium-term measures to efficiently run process using existing process facilities. These three terms are briefly discussed below.

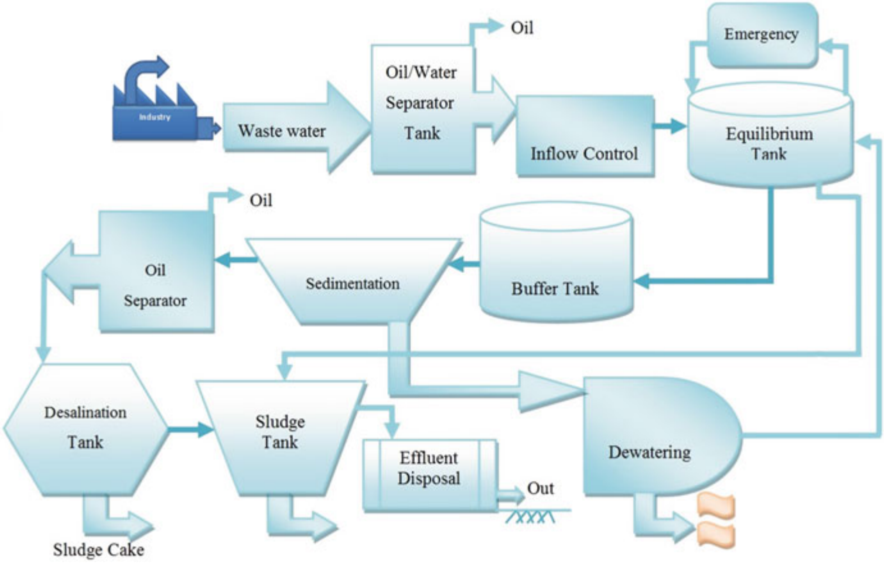

Fig. 2 Designated process flow diagram for effluent treatment plant in petroleum industries

Table 3 Effluent quality after treatment

Items	Unit	Name of the industry		
		A	B	C
pH	–	6.5–8.0	7.5	9.2
DO	mg/L	–	5.2	2.5
BOD	mg/L	30	14	11
COD	mg/L	192	101	137
Electric conductivity	μohm/cm	–	1.32	1.75
Oil and grease	mg/L	8.9	9.3	10.2
Suspended solid	mg/L	97.3	82.1	98.7
NH_3 (as N)	mg/L	48.2	–	52
Colour	Pt-Co	–	219	136
Turbidity	NTU	3.4	1.8	0.79

3.1 Short-Term Measures

In the short-term measure, schedule maintenance for energy conservation is needed. Under this term, no new investment is required except for increased maintenance task. It only leads to increase labour cost for maintenance. The main objective is to improve the energy efficiency of the equipment by enforcing better schedule for the maintenance programme. Using exhaust gas analyser for improving combustion efficiency in the furnace and power generator can save more than 5% fuel consumption. The associated work is the better adjustment of the inlet air quality to improve combustion efficiency. Regular cleaning and reduction of pressure drop can improve the heat transfer efficiency of the heat exchangers. Proper cooling system can help to increase the lifetime of the equipment and enable it for proper functioning (Azad et al. 2015b).

3.2 Medium-Term Measures

Small investment is required in medium-term measures on the energy consumption network. It's neither change principal of operation nor general engineering aspect. The objective is to reduce the consumption of high-quality energy and use low-quality energy; some changes are done on the existing network with additional investment. For example, installation of heat recovery unit is done to reheat or preheat the feedstock. It will reduce heat loss and save fuel consumption of the main heating source. Inefficient equipment can be replaced by more efficient one with the small investment. Repair of leakages and proper insulation or re-insulation could save energy as well as money. Waste reduction and waste recovery for reuse can increase productivity and save energy.

3.3 Long-Term Measures

Long-term measures require large investments on the interconnections of the processes. This can be a combination of various measures. Petroleum process industry requires both heat and power for continuing the process run. By-products reprocessing unit installation with the large investment will increase multi-products and will make healthy gross profit as well. Installation of power line to supply excess power to grid or other associated organization will save excess produced power for process run. Very large investments on the principle of the process are also included in this term. Though the finished product is not changed, process itself is modified or redesigned. Older technologies can be replaced by new and advanced technologies which are the major contributing factor for lower specific energy consumption, especially in the case of energy-intensive sector. The case study plants are not using long-term measure for energy management due to very big investment and sophisticated process equipment required. This term of measure is not suitable for the present condition. Energy-efficient and upgrading process principals will get property for any new installation in the future.

3.4 Rational Use of Energy

The process industries are the more energy- and pollution-intensive sector throughout the world. To understand the energy scenario of petrochemical process

Table 4 Types of energy used in case studied petroleum process industries

Process	Type of fuel
Raw materials pumping and storing	Electricity
Feedstock preheating	Heat energy
Heating/furnace running	Natural gas
Gas generator used for power generation for process run	Natural gas
Product pumping	Electricity
Product cooling	Electricity
Product testing in laboratory	Natural gas and electricity
Others (AC for equipment, fan, lighting, etc.)	Electricity
Office, administration and security light	Electricity

industries, energy auditing is needed. The main energy consumption is in the form of heat and power (electricity). The types of energy used by the industry are presented in Table 4. For petroleum process industries, about 80–85% energy is consumed by furnace for heating and 15–19% energy consumed by power generator for process run. The rest of the 1% energy is used in laboratory for property testing of the finished products. So, energy conservation measures should be implemented for more energy-intensive processes such as heating furnace and power generation (Azad et al. 2015a).

The rational use of energy considering energy utilization through the most suitable and economically viable methods can save energy and environment concurrently. The better energy management proved to be a better form of energy conservation, saving as much as 10–30% without capital investments (Rasul 1994; Mondal et al. 2014). Worrell et al. (Worrell et al. 1994) investigated the energy consumption by industrial processes and suggested that by applying best practice technology, potential improvement in energy efficiency on an average 15 ± 4% for oil petrochemical industries, 21 ± 2% for ammonia, 25 ± 5% for paper, 13 ± 1% for cement and 27 ± 3% for steel can be achieved (Worrell et al. 1994). Rasul et al. reviewed the rational use of energy in process industries like textile, steel and alumina refining, respectively (Rasul 1994; Rasul et al. 2004; Rasheed et al. 2003). So, energy conservation is important for long-term economic well-being and security. Utlu and Hepbasli (Utlu and Hepbasli 2007) reviewed the energy efficiency in Turkish industrial sector and reported 90% efficiency increase in energy use in petroleum refining due to its energy recovery system. The chemical and petrochemical industries account for 30% of industrial energy use globally (Gielen and Taylor 2007). A generalized energy distribution of the petroleum process industries is presented in Fig. 3, and the energy flow diagram of petrochemical industries is presented in Fig. 4.

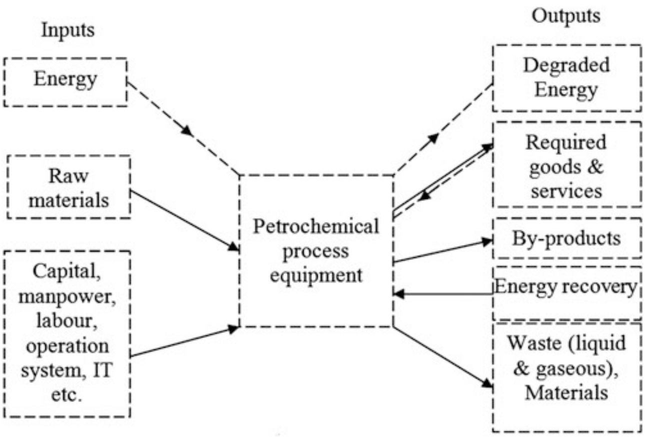

Fig. 3 Energy distribution of petroleum industries

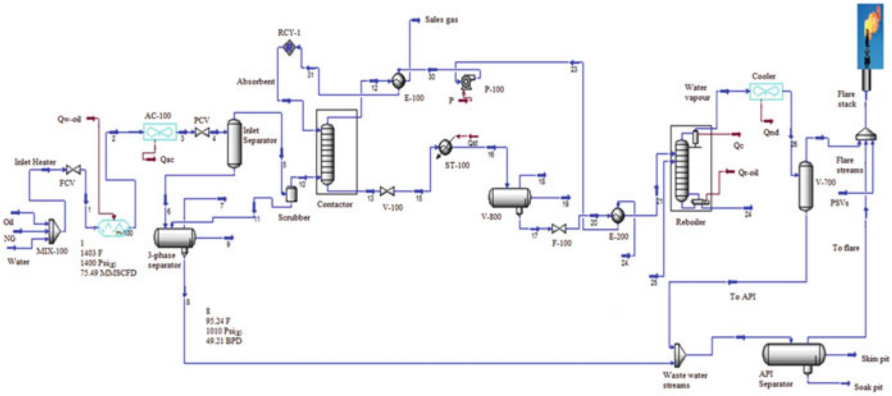

Fig. 4 Energy flow diagram for the petroleum industries with liquid and gaseous effluent handling unit

4 Conclusions and Recommendations

The study reviewed the energy and environmental management for petroleum process industries in Bangladesh. Pollution abatement techniques, main pollutants and the problems associated with waste water treatment are identified in this study. Oil-water separator used in petroleum process industries and the standard of industrial effluents are also outlined. It has been found that high salinity and oil and grease contents of the influent characteristics have direct influence on the turbidity of the effluent of petroleum waste water. The effluent characteristics before and after treatment and the process flow diagram have been analysed. The rational use of energy with energy flow diagram has been developed and briefly discussed. The time frame energy management process is also presented in this study for petroleum industries in order to save energy. The study found from the literature that it is possible to save about 15% of energy uses in petroleum process industries by implementing the proper energy management system. The study recommended the proper selection of treatment technique which can be used to remove the oil, grease and salinity from the waste water by secondary treatment. It is also important to eliminate the heavy metals dissolved as divalent metal oxide as Fe, Mn, Zn, Ni or Cr in produced water. By considering the above-mentioned parameters, an effluent treatment plant can be designed to maintain environmental quality standards (EQS) in waste water treatment for environment-friendly effluent.

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