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Research Article

EFFECT OF AIR POLLUTANTS AND ITS EMISSION CONTROL STRATEGIES IN PETROLEUM REFINERIES

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ABSTRACT

In this paper, the effect of air pollutants in the refineries such as particulate matter comes from the cracking and reforming sections due to uncontrolled combustion of oil cracking operation. This is due to catalytic or thermal cracking units are a major source of seven different air pollutants (particulates, carbon monoxide, sulfur dioxide, nitrogen oxides, hydrocarbons, aldehydes and ammonia) in an oil refinery. The emission of SO_2 and NO_2 from the Fluid catalytic cracking called as flue gases have much higher emission when compared with other cracking process. The aromatic compounds such as Benzene, Toluene, and Xylene called as BTX compounds causes more health effects to the people and to the environment. It is found that NO_2 has high level of concentration of 450 $\mu g/m^3$ which is very higher as per the AAQs standards. These pollutant levels in the refineries should be minimized while processing the crude oil.

INTRODUCTION

Unrefined petroleum is refined into melted oil gas, lamp fuel/avionics turbine fuel, diesel oil, and remaining fuel oil. Synergist splitting, Catalytic transforming, warm breaking, and other optional procedures are utilized to accomplish the coveted item specifications (Amman, *et al.,* 2008). Certain refineries additionally create feedstocks for the make of greasing up oils and bitumen. A few refineries likewise fabricate coke. Refineries handle raw petroleum into items like gas, diesel fuel, lamp oil, fly fuel, black-top and condensed oil gas and discharge contaminations from various distinctive sources. There are number of units in the refineries, for example, liquid synergist splitting units, sulfuric corrosive plants, warmers, boilers and sulfur recuperation units are generous producers of nitrogen oxides (NO_2) and sulfur dioxide (SO_2) (Asuquo *et al.,* 1995). Flaring outcomes in discharges of SO_2, nursery gasses and poisonous air toxins, including unpredictable natural mixes (VOC's) and perilous air contaminations. Fugitive emissions of VOC's result from leaking valves and pumps and can result in numerous health effects, including eye, nose and throat irritation, headaches, nausea and damage to liver, kidney and the central nervous system, among other effects. Leaks, flares, and excess emissions from refineries emit hazardous air pollutants, or air toxics, that are known or suspected to cause cancer, birth defects, and seriously impact the environment. SO_2 and NO_2 have numerous adverse effects on human health and are significant contributors to acid rain, smog and haze. Refineries also emit greenhouse gases that contribute to climate change, as well as VOCs. Refineries emit many different types of toxic air pollution, including cancer-causing benzene, lead and hydrogen cyanide (Beckett, *et al.,* 1998). In addition to cancer, pollution from refineries can lead to respiratory problems, birth defects, and neurological problem. Petrochemical and oil and gas processing generates exhaust streams laden with potentially harmful chemical and gas residue.

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Chemical scrubbers, thermal flares and thermal oxidizers are used to remove the residue from the exhaust.

Sources of air pollution in petroleum refinery

The various sources of air pollution encountered in the refineries are:

1. The exhaust emission from engines, generators, gas compressors and pump engine
2. Process of evaporation of crude oil vapors from oil pits during production testing.
3. Discharge of natural gas directly to the atmosphere during production testing
4. Burning of oil from the effluent treatment plants
5. Burning of gas and waste water from the flare pit in the air directly from various oil terminals
6. Oxidation of different sources of pollutants
7. Due to flaring, the temperature of the surrounding environment gets increased
8. Discharge of associated low-pressure gas to the atmosphere.

Onshore air pollution

The main sources of continuous and non-continuous air emissions resulting from onshore activities includes

1. Venting of hydrocarbons
2. Flaring of hydrocarbons
3. Use of gas compressors, pumps, diesel engines, gas turbine etc.

The major sources of air pollutants that is generated from these emissions are as follows:

1. Nitrogen dioxide
2. Sulfur dioxide
3. Particulate matter (PM10, PM2.5)
4. Volatile organic compounds
5. BTX compounds
6. Moderate percentage of carbon monoxide

Air quality impacts have been determined by comparing with standard air quality standards to ensure that there will not be any harmful and adverse effects to the human health and the workers in the refineries (Broadmeadow, *et al.,* 1998). The most significant sources of exhaust gas emissions from the onshore facilities is due to combustion of gas or liquid fuels in gas turbines, boilers, compressors and pumps for heat generation. However, oil refineries have used flares or vapor combustors for emission and tail gas treatment. These applications are applied range from API (American Petroleum Industry) separators, sulfur recovery systems, wet wells, tank venting or barge loading and unloading (Bradely, 1974).

Sources and health effects of particulate matter

The various waste characteristics from boilers, heaters and other auxiliary Equipments are the major sources of particulate emission in the refineries (Croxford *et al.,* 1996). Exchange of catalyst from one unit to the other unit and coke production will emit a huge amount of particulate matter emission in the refineries (Compilation of Air Pollutant Emission Factors, 1994). The emission may be PM10, or PM2.5, due to the increased production rate or supply of catalyst involved during the production. For each ton of crude processed in CPCL, the emissions from this refinery are as follows:

- Particulate matter: 0.7 kg, ranging from less than 0.1 kg to 2 kg.
- Sulfur oxides: 1.5 kg, ranging 0.3 kg to 0.6 kg; 0.1 kg with the Claus sulfur recovery process.
- Nitrogen oxides: 0.4 kg, ranging 0.04 kg to 0.6 kg
- Benzene, toluene, and xylene (BTX): 3.5 grams (g), ranging 0.55 g to 5 g; 1 g with the Claus sulfur recovery process. Of this, about 0.16 g benzene, 0.35 g toluene, and 1.4 g xylene has been released per ton of crude processed.
- VOC emissions depends on the production techniques, emissions control techniques, equipment maintenance and observed as 0.8 kg per ton of crude processed (ranging from 0.5 kg/ ton to 4 kg/ton of crude).

Petroleum refineries use high volumes of water, especially for cooling systems. Surface water runoff and sanitary wastewaters can also be generated. The quantity of wastewaters generated and their characteristics depends on the process configuration. As per the data found in CPCL Refinery, approximately 4.5 Cu.m to 6 Cu.m of wastewater per ton of crude are generated when cooling water is recycled (Coburn, 2007). In this refinery, polluted wastewaters containing biochemical oxygen demand (BOD) and chemical oxygen demand (COD) levels of approximately 250 mg/l to 350 mg/l and 400 mg/l to 600 mg/l, respectively. The level of phenol ranges from 20 mg/l to 300 mg/l, whereas oil levels ranges from 150 mg/l to 300 mg/l in desalter water and up to 5,000 mg/l in tank bottom. Benzene levels of

1 mg/l to 80 mg/l. This refinery has also generated the solid wastes and sludge (ranging from 4 kg to 5 kg per ton of crude processed), 70% of which may be considered hazardous because of the presence of toxic organics and heavy metals (CONCAWE, 1998).

Effect of gas scrubbers in the refinery

Liquid was injected into the scrubber and then mixed with the exhaust vapor. The required time that is needed in between the vapor and cleaning fluids is estimated based on the pollutant in the vapor that needs to be removed, its concentration in the exhaust and the desired removal efficiency. The reduced rates are over 98.99% and these scrubbers can produce clean exhaust for release into the atmosphere (Department of the Environment, 1995).

Effect of catalytic oxidizers

Catalytic oxidizers are recycled with little, stable VOC applications, and also used to give petrochemical process expend tributaries that do not comprise high levels of particulate nor toxins (Department of Petroleum Resources, 1995). Catalytic Oxidizers are a worthy regulator choice in tenders that have consistent unstable organic mixtures (VOC's). By exhausting a substance bed in the air management apparatus, oxidation is consummating at much lower heats related to thermal oxidation (Energy Information Administration, 2006). A catalytic oxidizer activates at 370°C to 480°C ranges can accomplish the same productivity as a thermal oxidizer functioning between 600°C and 840°C which outcomes in fuel savings of 90%. Even for extra operating costs, a recuperative Catalytic Oxidizer sideways with a heat exchanger that improves the method heat for extra use within the structure (Hatch and Matar, 1981).

Effect of particulate matter in the refineries

Particulate matter in the air usually refers to small solid particles of material found in the atmosphere in addition to gases (Hoffman, 1991). Particles of organic or inorganic composition that is suspended can be individual elements. Chemical particle size diameter may be used to classify the types of sources. Suspended particulate matter (SPM) in the air refers to particles, which are very fine to have falling velocity and therefore tend to stay suspended in atmosphere for a considerable time. Metallic fumes, fibrous materials, heavy metals, all micro-organisms, various allergens and many organic carcinogens are present in air in the form of SPM having the PSD up to 100 μm (Hawkins, 1995). Air dust contaminant sizing from 0.25 μm to 10 μm is called as RSPM.

Heath effects of respirable suspended particulate matter

The dangerous dust from the worker's point of view falls under the category of RSPM chemicals (Jensen-Holm *et al.,* 2010). Invisible fine dust enters the air passages and produces physiological changes. Particles size analysis shows that the PSD of the dust particles varies between 1 to 30 microns and even higher (Lucas, 2008). Particle size varying from 5 to 50 microns result in respiratory troubles, as human nose cannot effectively filter the particles and lead to allergic symptoms like asthma. Some diseases called as disabling lung disease caused due to inhalation of carcinogen chemical dust over long periods of time.

Effect of sulfur dioxide in the refinery

Sulfur dioxide is a fume. It is unseen and has a offensive, strident smell. It responds easily with supplementary elements to procedure dangerous amalgams, such as sulfuric acid, sulfurous acid and sulfate particles [Manning and Feder, 1980]. Almost 99% of the sulfur dioxide in mid-air originates from human sources. The core foundation of sulfur dioxide in the mid-air is manufacturing activity that methods constituents that encompass sulfur. Certain mineral ores also contain sulfur, and sulfur dioxide is released when they are managed. In addition, industrial actions that burn fossil fuels having sulfur can be key sources of sulfur dioxide. Sulfur dioxide is besides present in motor vehicle secretions, as the consequence of fuel combustion (Monn, 1995).

Predicted values of the pollutants in CPCL

The above table shows standard emission values from boilers, furnaces and power plants from CPCL refinery. From this it is clear that the concentration of nitrogen dioxide is higher when compared with sulfur dioxide (Rudd, 2001). The particulate matter concentration is within the environmental standards.

Pollution prevention and control

Petroleum refineries are complex plants and the combination and sequence of processes is usually very specific to the characteristics of the raw materials (crude oil) and the products. Specific pollution prevention or source reduction measures can often be determined only by the technical staff

Table 1. Concentration of air pollutants in CPCL

S. No	Parameter	Concentration μg/m^3
1	Sulphur Dioxide	40
2	Nitrogen dioxide	450
3	Carbon monoxide	180
4	Particulate matter	20

(ORECO, 2011). However, there are a number of broad areas where improvements are often possible, and site-specific waste reduction measures in these areas should be designed into the plant and targeted by management of operating plants.

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REFERENCES

Amman, M., Jiang, K.J., Hao, J.M., Wang, S.X., Zhuang, X., and Wei, W. 2008. GAINS Asia: Scenarios for cost-effective control of air pollution and greenhouse gases in China.

Asuquo, F.E., Morah, F.N.I., Nya, A.E., and Ehrhard, M.E. 1995. Trace metals in crude oils and beach tar balls from Nigerian coastline. *Indian J. Marine Sci.* 74 : 16-18.

Beckett, K.P., Freer-Smith, P.H. and Taylor, G. 1998. Urban woodlands: Their role in reducing the effects of particulate pollution. *Environ. Pollu.* 99 : 347–360.

Bradely, P.G. 1974. Marine oil spills. A problem of environmental management. *Nat. Resour. J.* 14 : 338-359.

Broadmeadow, M., Beckett, K.P, Jackson, S., Freer-Smith, P. and Taylor, G. 1998. Trees and pollution Abatement, pp 39-43. In Forest Research Annual Report and Accounts. HMSO, London, England.

Broekoven, V. 2008. Alkylation with solid catalyst. *Petroleum Technology Quarterly.* pp. 87-93.

Croxford, B., Penn, A. and Hillier, B. 1996. Spatial distribution of urban pollution: Civilizing urban traffic. *Sci. Total Environ.* 190 : 3–9.

Compilation of air pollutant emission factors. Vol. 1: Stationary point and area sources. AP-42, Fifth edition, office of air quality planning and standards, office of air and radiation, US Environmental Protection Agency, Research Triangle Park, NC. January 1994.

Coburn, J. 2007. Greenhouse gas industry profile for the petroleum refining industry. Prepared for U.S. Environmental Protection Agency, Washington, DC. Contract No. GS-10F-0283K. June 11.

CONCAWE, 1998. Sulphur dioxide emissions from oil refineries and combustion of oil products in Western Europe and Hungary (1995), 1998.

Department of the Environment (DoE). 1995. Expert panel on air quality standards: Particles. HMSO, London, England. 30 pp.

DPR: Department of petroleum resources. 1995. *The Regulatory Arm of the Oil Industry*. Lagos: Ministry of Petroleum Resources.

EIA: Energy Information Administration. 2006. Refinery capacity report 2006. Prepared by the energy information administration, Washington, DC. June 15.

Hatch, L.F. and Matar, S. 1981. *From Hydrocarbons to Petrochemicals.* Houston: Gulf Publishing Co. 481 pp.

Hoffman, I.J. 1991. Solving the environmental impact, of petroleum production and processing. *OPEC Bulletin*, Oct. 8.14.

Hawkins, W. B., Dunn, A., Rodgers, J.H. Jr. 1995. Evaluation of pilot scale constructed wetlands for tertiary treatment of refinery effluent; Presented at Second SETAC World Congress (16th Annual Meeting), November 5-9, 1995, Vancouver, B.C.

Jensen-Holm, H. and Lindenhoff, P. Combating NOx from refinery sources using SCR-Air pollution control, catalyst and technology, Haldor Topsoe-2nd Annual world refining technology summit and Exhibition 2010, Abu Dhabi, 2010.

Lucas, B. 2008. Memorandum to petroleum refinery new source performance standards (NSPS) Docket No. EPA-HQ-OAR-2007-0011 from Bob Lucas, USEPA regarding Documentation of Flare Recovery Impact Estimates. April 26.

Manning, W.J. and Feder, W.A. 1980. Biomonitoring air pollutants with plants. *Applied Science* Publishers, London, England. 142 pp.

Monn, C.H., Braendli, O., Schaeppi, G., Schindler, C.H., Ackermann-Liebrich, U., Leuenberger, P.H. and SAPALDIA Team. 1995.

Rudd, H.J. and Hill, N.A. 2001. Measures to Reduce Emissions of VOCs during Loading and Unloading of Ships in the EU, Personal Communication, 2001.

ORECO. 2011. Contribution of Oreco A/S to the Mineral Oil & Gas Refineries BREF, 2011.

Pekkanen, J., Timonen, K.L., Ruuskanen, J., Reponen, A. and Mirme, A. 1997. Effects of ultrafine and fine particles in urban air on peak expiratory flow among children with asthmatic symptoms. *Environ. Res.* 74 : 24-33.

Sabo et al., Assessment of control technology options for petroleum refineries in the Mid-Atlantic Region, Mid-Atlantic regional air management association (MIRAMA), 2007.

Quality of urban air review group (QUARG). 1996. Airborne particulate matter in the United Kingdom: Third report of the quality of urban air review Group. QUARG, Birmingham, England. 176 pp.

R. E. Constructors, Validation of inventories of NOX measures in the refinery sector (Validatie van de inventarisatie van NOX maatregelen in de raffinage sector) Environmental processes '98-Hydrocarbon processing, 1998.

Javed, M.T., Irfan, N. and Gibbs, B.M. 2006. Control of combustion-generated nitrogen oxides by selective noncatalytic reduction. *J. Environ. Manage.* 83 : 251-289.

U.S. EPA (Environmental Protection Agency). 1998. Petroleum Refineries-Background Information for Proposed Standards, Catalytic Cracking (Fluid and Other) Units, Catalytic Reforming Units, and Sulfur Recovery Units. EPA-453/R-98-003. Washington, DC: Government Printing Office.

U.S. EPA (Environmental Protection Agency). 1999. U.S. Methane Emissions 1990–2020: Inventories, Projections, and Opportunities for Reductions. EPA 430-R-99-013. Section 3. Natural Gas Systems and Appendix III. Washington, DC. September 1999.

VIyer, V.G. and Mastorakis, N. 2006. Assessment of pollution load from unsafe leather tanneries in India. *WSEAS Transac. Environ. Dev.* 2 : 207-215.

Watkins, L.H. 1991. State of the art review 1: Air pollution from road vehicles. HMSO, London, England. 151 pp.

Worldwide Refinery. 1990. Survey. *Oil gas J.* 88 : 13.