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Introducing an application method for industries air pollutants emission control planning by preparing environmental flow diagram maps

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A B S T R A C T

In industrial units, EFD maps are used as suitable methods for optimal management and controlling the release of pollutants into the environment. Hence, the main objective of the present research was to obtain the Environmental Flow Diagram-Air Pollutants (EFD-AP) map of the Purified Terephthalic Acid Production Units (PTA) of petrochemical industries. To this end, the flow of materials, feed, and productions of a PTA production unit in the southwest of Iran was analyzed. The pollutants of all 7 process sources and 2 combustion sources were sampled and measured using standard procedures. Finally, according to the results some calculations were done to determine the APs emission factors of the sources, and the EFD-AP maps of the studied unit were prepared. Results showed that the total emission factors of the Acetic acid, Methyl acetate, PTA powder, oil mist, CO, NO, NO_x, C_xH_y, Co, Mg, Cu, Ni, Cd, Ti, Mo, Cr, and Pb were 219.518, 1.912, 44.58, 0.888, 64201.211, 1982.094, 2091.858, 23082, 76.868, 0.0193, 15.102, 36.829, 2.914, 37.623, 15.367, 200.572, and 2.888 mg per tonne of PTA, respectively. Also, results revealed that process sources emit different toxic and criteria pollutants into ambient air, while combustion emission sources (S8: hot oil furnace, S9; incinerator) have the main role in releasing criteria air pollutants, toxic trace elements and GHGs. It should be noted that emission factor of GHGs (CO_2) for selected PTA unit was equal to 54661355 mg per ton of PTA production. Therefore, EFD-AP maps used for prioritization, controlling and management of APs emissions. Moreover, these maps have main role for preparing industrial atmospheric emission control action plan.

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1. Introduction

Process Flow Diagrams (PFDs) show the plant design basis. They can be used for indicating feedstock, product and main streams flow rates and directions, major equipment involved in the process, operating conditions of the process units within an industrial plant, as well (Coker, 2011; Turton et al., 2012). Combining PFDs and EFDs which shows the sources, amounts, and emissions types of the pollutants, may contribute to a reliable instrument in order to plan and control the pollutants emission (Karbassi et al., 2008). EFDs are used to display a wide range of emitted pollutants which the Atmospheric Pollutants (APs) part is illustrated by EFD-AP (Sekhavatjou et al., 2011). Drawing an EFD-AP map for industrial atmospheric pollutants needs a set of tasks including identifying the sources of emissions, sampling and measuring the concentration of emitted pollutants, calculating the emission levels, determining the emission factors, and finally, drawing the maps (Qiasuddin, 2006: Crawford, 1976: Dadashzadeh et al., 2011). Previous studies showed that large amounts of GHGs led to severe climate changes all around the world, especially in arid and semi-arid areas (Karbassi et al., 2008: Jiang et al., 2016; IPCC, 2007: IPCC, 2013: IPCC, 2014a, 2014b). Therefore, different countries have compiled several strategies and programs for carbon emission reduction and improving allocation ratios for carbon emission allowance in different sectors such as industry (Zeng et al., 2016a, 2016b; Jiang et al., 2016).

Iran is located in a semi-arid area and there are a lot of reservoirs of oil fields in the south part. So many petrochemical complexes are working in this area of the country. It is a good idea to prepare some EFD-APs maps in order to set different mechanisms to control carbon and toxic pollutants emission in this important and

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economical industry. The main objective of this study was to draw the EFD-AP for Purified Terephthalic Acid (PTA) production process. The other goals were 1- identifying all the atmospheric pollutants emission sources (i.e. organic, criteria and toxic pollutants, trace elements) in the studied unit; 2- compiling emission factors of the criteria, and toxic pollutants and trace elements for each identified source and the whole studied industry; 3- investigating the share of individual sources of different pollutants; 4- determining the CO_2 emission rate per produced goods; 5- presenting technical approaches for pollution emission reduction in selected industry in order to make more clean production. To this point, some executive field activities applied in the PTA production unit of Tondgooyan Petrochemical Complex (TPC), the only producer of PTA in Iran (MHI, 2003c; Razavi, 2005a, 2005b), which is located at the north of the Persian Gulf, southwest of Iran. PTA is the main raw material for producing Polyethylene Terephthalate (PET) in the downstream units and has several different applications in producing textile fibers, soft drinks bottles (mineral water and drinking water), electrical insulation and polyester film and tape (Meyer, 2005).

2. Materials and methods

2.1. Characterization of studied variables

Atmospheric pollutants emission sources in PTA units were identified based on the information given in PFD and the data gathered in field studies. Tables 1 and 2 provide some key specifications of the process.

2.2. Sampling and measurement methods

According to the chemical and physical (gas/particle) properties of APs emitted from sources (Tables 1 and 2), several types of sampling and measurement equipment were needed which are presented in Table 3. Sampling and measuring of the process and combustion pollutants were conducted in accordance with the standard methods described in Table 4.

To calculate the emission level of process sources, first the surroundings of the sources was completely confined and sealed to prevent any inlet and outlet diffusion air. Next, pollutants in the confined space were sampled and measured at two different times for each sources in order to obtain the differences between the related primary and secondary concentrations. Finally, in order to measure the concentration of pollutants in the combustion sources from the incinerator funnels, direct-reading (online) devices were used. Fig. 1 shows steps of sampling procedure from different sources.

To determine emission factors of different pollutants, the following equations were used:

$$dm/dt = \left[(C_2 - C_1)/\Delta T\left(mg/m^3/min\right)\right] \times V\left(m^3\right) \quad (1)$$

where:

C_1= Primary concentration at time t_1
C2= Secondary concentration at time t_2
$\Delta T = t_2\text{-}t_1$ (min.)
V= Volume of confined space surrounding of emissions sources (m^3)
dm/dt = Mass flow rate of APs emissions (mg/min)

$$EF_{Poll} = ER_{Poll}(dm/dt\ \ mg/min) \times PR(tonne/min) \quad (2)$$

where:

PR= Production mass flow rate (tonne/min)
EF_{Poll} = Emission Factor of APs (mg/tonne production)

The rate of PTA production by the PTA-2 unit of TPC when operating at full capacity is 1060 ton/day (which equals to 45 tonne of powder per hour and 0.75 tonne per minute). However, when sampling was done at the unit by 80% of its capacity, it is 0.6 tonne/min which has been used in calculations of this study. Moreover, pollutants emitted from combustion sources resulted from the incinerator and hot oil furnaces were measured using a TESTO 350 instrument. The analysis of natural gas consumed by these two furnaces are given in Table 5. It should be noted that TESTO can be utilized in order to measure the natural gas compounds (methane

Table 1
Process emission sources and APs emitted from them in PTA unit [MHI, 2003a, 2003b].

Emission source	Source physical specifications	Source technical specifications	Source function	Air pollutants
2 PV-1821D (S1)	L: 3490 mm W: 1350 mm H: 800 mm	Manufacture: ROTEX EUROPE 5 mesh 4.0 mm aperture 1.0 mm wire diameter Screen Area: 2.1 m^3 Capacity: 56 ton/h	Sieves coarse particles of CTA powder entering the unit	Acetic Acid Methyl Acetate
2DR-1845 (S2)	L: 26.7 m D: 3100 mm Slope: 2%	Leakage of powder from the early mobilization packing with the following specifications: Number of packing: 126 42 packing in three sizes with 139, 3.114, and 1.89 mm diameters	A dryer for drying the powder	PTA Powder
2G-1874A (S3) 2G-1874S (S4)	Centrifugal pump Centrifugal pump	Manufacture: EBARA Capacity: 8 m^3/h Motor power: 5.5 kw	Transferring paratoluic acid particles to the CTA unit using acetic acid fluid	Acetic Acid
2FT-2201 (S5)	Horizontal Belt Filter L: 4.2 m W: 1.0 m Filter Area: 4.2 m^2	Cloth speed: 0.5–3 m/min	a residue filter for separating the liquid catalyst from solid residues	Acetic Acid Methyl Acetate Cobalt Manganese
2 TK-2202 (S6)	L: 1.5 m W: 1.0 m H: 1.8 m VOL: 2.8 m	–	Service Washing Water Tank	Acetic Acid
2G-1802 (S7)	Centrifugal pump	Pressure Outlet: 9 bar Pump Temp: 290 °C	Hot Oil Circulation Pump	Oil Mist (Hot Oil)

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