Global J. Environ. Sci. Manage., 2(3): 299-310, Summer 2016
DOI: 10.7508/gjesm.2016.03.009

Case Study

Decreasing emission factor of pollutants in an oil refinery by renovating the furnace design

A. Zabihi[1,*], *M.R. Raazaitabari*

[1]*Mazandaran Gas Company, Taleghani Street, Sari, Iran*

[2]*Department of Environmental Engineering, Islamic Azad University, Ahvaz Branch, Ahvaz, Iran*

Received 1 March 2016; revised 15 April 2016; accepted 25 April 2016; available online 1 June 2016

ABSTRACT: The significant consumption of gas in the World results in the emission of greenhouse gases into atmosphere. Abadan refinery has always been the biggest and oldest oil refinery in the Middle East and has a variety of refined products. After six months of collecting data about pollutant concentration emitted from a stack of old furnaces of units 75 and new unit 200, the emission factor of the pollutant was calculated. The result showed that the emission factor of some hazardous pollutants emitted from old unit 75 was tremendously higher than that of unit 200. This study suggests the installation of a forced fan to provide the excess air and a feed temperature controlling system to control fuel gas consumption. These would make the fuel combustion complete and decrease its consumption. Meanwhile, further results showed that the renovation of unit 75 could lead to a significant annual reduction of some pollutants such as CO, H_2S, and C_xH_x to 66 ton, 3 ton, and 800 kg, respectively; this would increase the emission rate of pollutant SO_2 up to 150 ton annually. Finally, the new data of pollution coming from unit 75 were compared to pollution standard at American refineries. Results showed that the emission factor of most pollutants were below the American standard limits. However, the emission factor of sulfur dioxide emitted from upgraded furnace of unit 75 surpassed the American standard values. Fuel gas needs to be free of hydrogen sulfide in order to decrease SO_2 emission in unit 75. It is predicted that the renovation of other 11 old furnaces belonging to Abadan refinery will result in significant decrease of pollutants CO, C_xH_x and H_2S up to 320, 94 and 76 ton annually.

KEYWORDS: *Combustion; Emission factor; Furnace; Pollutant*

INTRODUCTION

The increasing growth of the various industries especially petroleum and gas has caused significant emission of pollution and greenhouse gasses into the air. Industrial pollution takes a back seat and vehicular emissions take precedence as the major cause of urban air pollution (Lohe *et al.,* 2015). In particular, gradual exposure to toxic air pollutant may impact adversely on human respiratory health (Ma *et al.,* 2013). Refinery units are energy processes that consumes great amount of energy and consequently help to emission of greenhouse pollutant such as CO_2 (Gadallaa *et al.,* 2006; Al-Salem, 2015). Abadan refinery is the biggest and oldest crude oil refinery in Iran, and it produces diesel, gas, LPG, oil and heavy diesel. There are different active units in this regards at the refinery and each one of them has various furnaces used for heating the feed. More than 420000 B/day of crude oil is refined in Abadan. At this refinery, big furnaces with high consumption of gas are active at the different units. As a result of the combustion of natural gas at these

*Corresponding Author Email: *azabihirami@gmail.com*
Tel.: +98 113 320 7591; Fax: +98 113 320 4076
Note: Discussion period for this manuscript open until September 1, 2016 on GJESM website at the "Show Article".

furnaces, different pollutants have been created and therefore emitted into the atmosphere. Despite the renovation of certain units of the refinery, some old furnaces at old sites are still active because of low thermal efficiency. This has been considered as the main source of pollution. Considering the location of Abadan refinery which is situated in the suburbs of Abadan city, a sort of populated city, the residual areas of this city are under constant bombardment with pollutants coming from the refinery. Therefore, measuring the amount of pollutant and presenting a solution for the reduction is a critical issue.

Ahmadi *et al.* (2016) studied the Asmari gas compressor station where several sources of pollutants such as CO_2 and CH_4 are released. They concluded that equipment which burns natural gas emits more CO_2 in comparison with those operated with fuel oils.Chavoshi *et al.* (2011) studied on the amount of SO_2 emission coming from Tehran's refinery stacks. They measured the emission of sulfur dioxide pollutant in the northern and southern units of the refinery as old and new plants, respectively. They discussed that emission factors of SO_2 in the old units were 2 to 3 times higher than that of new plants and concluded that the use of new technologies cause significant decrease of pollutant's emission. Shtripling and Bazhenov (2013) considered the emission of air pollutants released by refineries.

They concluded that the use of continuous emission measurement systems helped refining companies to solve air pollution problem. They emphasized that this system can be used due to its accuracy in controlling and significantly decreasing the risk of accidental pollutant emission as well as obtaining pollutant emission factors at a given time. In their study, Dios *et al.* (2013) measured emission factors for CO_2, SO_2, and NO_x released from coal combustion for a period of 8 years. Results from their studies showed that CO_2 and SO_2 emission for coal mixtures indicated a very good consistency with the experimental data. On the other hand, for NO_x, the use of experimental method resulted in serious incompatibility with measurements. Increase of excess air effects on the thermal NO_x production. Then, at the same temperature, higher excess air increases the emissions of NO_x (Lio *et al.,* 2010; Tang *et al.,* 2012). Khodabandeh *et al.* (2016) studied on the effect of excess air on thermal efficiency of fired heater in a petroleum refinery. They concluded that excess air over 18% decreases the furnace efficiency and as a result increases pollutant emission into environment. Jafarigol *et al.,* 2015 considered the measurement of CO, SO_2, NO_2, and NO_x emission factor for refineries phase 6, 7 and 8 in the south of Iran. They concluded that CO and NO_x pollutants had the highest rate emission of gas refinery, while the lowest emissions were belonged to SO_2 and NO_2. Abdul-Wahab *et al.,* 2006 assessed the health risk of SO_2 emission from a refinery in Oman. The result of their study revealed that the level of SO_2 were lower than the standard limit. Therefore, the resident of areas close to refinery were under no risk of health. A study was done on the progress of air-monitoring techniques including on-line gas chromatography in industries (Nguyen *et al.,* 2009). Ruei-Hao and Chana, (2013) considered tracking hazardous pollutant coming from refinery fire accident. They concluded that back trajectory and dispersion modelling can monitor emission sources of pollutants relating to refinery fire. A study on possibility of decreasing pollutants in refinery fired heater revealed that the NO_x emission decreased significantly when the heater fuel is switched to hydrogen (Ditaranto *et al.,* 2013). Another research on the emission rate of pollutants coming from stack of steam boiler having a nominal capacity of 280 Mw showed that only NO_x and PM exceeded emission limits (Nakomcic-Smargdgkis *et al.,* (2014). Jaramillo and Muller, (2016) examined the cost of social damages made by air pollutants emitting from energy sector in US. They concluded that the greatest social damages have been made by SO_2 emission from power plants. Similar studies showed that exposure of high NO_2 and PM_{10} pollutants is related to mortality of people (Heinrich *et al.,* 2013; Willers *et al.,* 2016; Carugnoa *et al.,* 2016). Yassen *et al.,* (2014) considered the variation of pollutant concentration adjacent to a power plant. They found that the emission rate of both gases SO_2 and NO_2 was consistently higher during the day time.

The present study analyzed the effect of renovating the burner and chimney of the furnace at the vacuum distillation unit that caused a significant reduction in the emission of pollutants. The emission factor and degree of each pollutant were measured sequentially for the chimney and the result was used to calculate the amount of pollutant degrees. The study was held in Abadan refinery during 2015.

MATERIALS AND METHODS

The process operation of units 200 and 75

Units 200 and 75 are both vacuum distillation plant that are in Abadan oil refinery. They operate with the nominal capacity of 70000 and 50000 B/day, respectively. The bottom product of the atmospheric distillation tower is sent to vacuum distillation towers as the unit's feed. The feed is first passed through exchangers where it is preheated. Then, it is sent to the furnace for secondary heating. After that, it is transferred to the bottom part of the vacuum tower where it is flashed suddenly. As a result, heavy hydrocarbons are separated from light hydrocarbons. The main products of vacuum distillation units are light gas, gas oil, light lube oil, heavy lube oil, waxy distillate, and vacuum bottom. Finally, tower products are transferred to exchangers and coolers for cooling. Unit 200 was built about ten years ago that had the latest technology of digital controlling system (DCS). All the operating parameters including temperature and flow of streams are controlled automatically. Fig. 1 shows a temperature controller was installed on the line of feed leaving the furnace to regulate the fuel gas consumption. Moreover, there were some new type of technology in designing of the new unit 200 furnace. It was equipped with a forced fan to provide the needed excess air of fuel gas for combustion. Also, an economizer was installed in the path of the flue gas to preheat the excess air entering the furnace. But, unit 75 was constructed hundreds years ago and most of the device controller have been regulated manually. As Fig. 2 indicates there is no automatic controlling system as well as forced fan and economizer were designed in the construction of old unit 75 furnace.

Furnace operation

The furnaces of units 200 and 75 are both used to heat the unit's feed. However, there is significant difference between the system of controlling burner fuel consumption and providing excess air for fuel combustion. As mentioned, burner fuel consumption is controlled by a control valve which is regulated by the temperature of feed leaving the heater. This leads to prevention of any extra heating of feed and as a result decrease the fuel gas consumption. In this case, the emission rate of pollutants reduces significantly if feed is not heated to a temperature over the needed temperature. On the other hand, the fuel consumption of furnace 75 is manually controlled by operators. This can increase the fuel gas consumption because the operator monitoring is not continuous. Therefore, the emission rate of pollutants coming from old furnace of unit 75 are more than that of unit 200 based on the same fuel gas consumption. Moreover, the needed excess air of furnace 200 for combustion process is provided by a forced drafting system that is sent by a large fan. Also, an economizer is installed which preheats the excess air entering to furnace of unit 200.

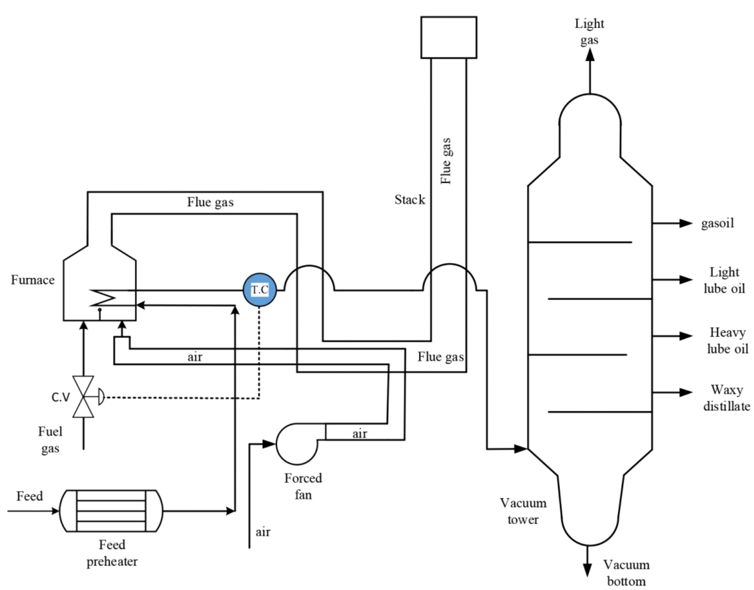

Fig. 1: Process flow diagram of furnace 200

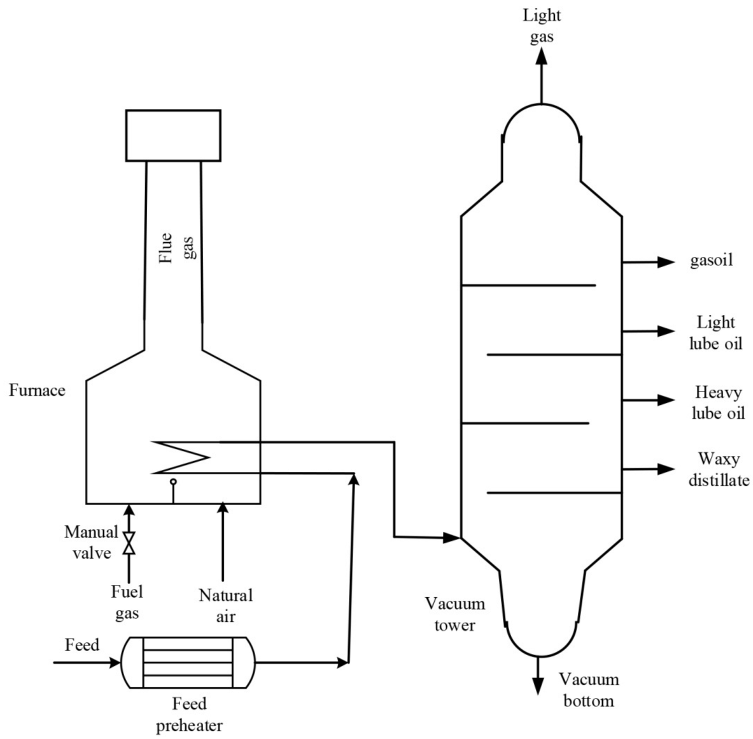

Fig. 2: Process flow diagram of furnace 75.

This caused higher thermal efficiency of the furnace burner and as a result led to lower consumption of fuel gas. Otherwise, in the furnace of unit 75, the needed excess air is sent through dampers naturally to combust fuel gas in burner. This lead to incomplete combustion of fuel gas and increase emission factor of pollutants significantly specially CO and C_xH_x. Moreover, lack of initial preheating of the excess air entering to unit 75 furnace is a cause of lower burner thermal efficiency. This lead to higher fuel gas consumption and pollution emission rate (AORED, 2015).

Calculation of pollutant emission factor

As it was already mentioned, the furnace of unit 75 has an old design with more pollution than the new furnace. In order to determine the level of pollution of each of these units, the method of continuous factor determination was used; by calculating the emission factor of pollutants, the rate of emission of pollutant was determined based on time. The emission factor is usually expressed on the basis of the polluting mass produced, divided by the product or raw material (volume or the mass). For example, in an industry that used coal as a source of energy, the level of emission of particles based on kilogram per mega gram of the burned coal, determines the emission factor of the output of that particular industry (Zhao *et al.,* 2010). There are different methods of determining the emission factor; one of such methods is continuous measurement, the equating of simulating materials and several other methods have been used.

In the furnaces used to refine raw petroleum, the emission factor based on amount of produced emission or the gases produced by combustion divided by the mass of burned fuel is calculated using Eq. 1. In general, the rate of emission is calculated using Eq. 2 (EEA, 2009).

$$EF = \frac{m_p}{m_f} \quad (1)$$

m_f : mass flow rate of fuel gas (g/h)
m_p : mass flow of pollutant at the point of pollutant concentration measurement (mg/h)

$$E = A \times EF \times \left(1 - \frac{ER}{100}\right) \quad (2)$$

A: mass flow of fuel gas (g/h)
EF: pollutant emission factor (mg/g)
ER: the percentage of total decrease of emission, if the system of decreasing pollutant is not used, would be equal to zero

E: pollutant emission rate (mg/h)

In order to calculate the emission factor of pollutants, the amount of discharged mass flow of the pollutant coming out of the stack of units 200 and 75, must be determined. This was done together with the assays and environmental projects. The instrument used for analysis of the pollutants was Testo 350 MXL, made in Germany. This instrument was equipped by two probes: one was used for measuring the concentration of gases produced by combustion and other related parameters. The other probe pipe was used to measure flow and speed. The gas flow of stack was computed using Eq. 3.

$$Q = v \times a \tag{3}$$

v: velocity of stack gas at the point of pollutant concentration measurement (m/s)
a: stack sectional area (m^2)

Q: stack gas volume flow at the point of pollutant concentration measurement (m^3/h)

Table 1 shows the average of measured parameters for 6 months, including stack gas velocity, pressure and temperature, stack sectional area and furnace fuel consumption as well as calculated values of stack gas flow for units 200 and 75. Trend of measured values of gas coming from stack of units 200 and 75 revealed that there was a direct relationship between fuel gas consumption and variation of flue gas velocity and temperature. The mass flow of each pollutant must be calculated in order to estimate the emission factor. This was computed using Eq. 4. Since the unit of concentration value of Eq. 3 is in milligram per cubic meters, Eq. 5 was used to convert the unit of ppm to mg/m^3 (CCOHS, 2016).

$$m_p = C \times Q \tag{4}$$

C: pollutant concentration (mg/m^3)
Q : stack gas volume flow at the point of pollutant concentration measurement (m^3/h)
m_p : mass flow of pollutant at the point of pollutant concentration measurement (mg/h)

$$C\left(\frac{mg}{m^3}\right) = \frac{C(ppm) \times M \times P}{RT} \tag{5}$$

$C\left(\frac{mg}{m^3}\right)$: pollutant concentration (mg/m^3)

$C(ppm)$: pollutant concentration (ppm)

M: molecular weight (g/mol)
P: pressure of stack gas at the point of pollutant concentration measurement (atm)
R: molar gas constant (atm.L/mol.k)
T: temperature of stack gas at the point of pollutant concentration measurement (k)

The emission factor of each pollutant was calculated by dividing pollutant mass flow by furnace fuel mass flow. The average measured value of units 200 and 75

Table 1: Average value of 6 months measurement of stack gas velocity, pressure and temperature, stack sectional area, calculated stack volume flow, and furnace fuel consumption

Month	Stack gas velocity (m/s)		Stack cross sectional area (m^2)		Stack gas pressure (psi)		Stack gas temperature (°C)		Stack gas volume flow at temperature and pressure in stack (m^3/h)		Furnace fuel consumption (kg/h)	
	Unit 200	Unit 75	Unit 200	Unit 75	Unit 200	Unit 75	Unit 200	Unit 75	Unit 200	Unit 75	Unit 200	Unit 75
March	8.1	4.9	7.6	4.8	9	9	158	340	221616	72324	2964	764
April	7.9	4.6			10	11	152	337	216144	67896	2919	757
May	8.3	5			9	9	160	342	227088	73800	3039	769
June	7.9	4.5			10	8	153	333	216144	66420	2920	756
July	8.3	4.9			8	9	161	339	227088	72324	3074	815
August	8.5	5.1			8	8	164	343	232560	75276	3086	821
Average value	8.2	4.8			9	9	158	339	224352	70848	3000	781

stack pollutant concentration during 6 months and the computed value of mass concentration and emission factor of each pollutant are shown in Table 2, respectively.

Suggestion of renovation of furnace of unit 75

The calculated emission factor of pollutants of units 75 and 200 furnace was compared. The result showed that the emission factor of CO, C_xH_x, and H_2S coming from unit 75 was more than that of unit 200. Carbon monoxide and hydrogen sulfide are considered as dangerous air pollutants, because they can cause respiratory problems for humans when emitted into the atmosphere at a high rate. Moreover, C_xH_x which are hydrocarbons that are not burnt in the combustion process of fuel gas, are indicated as greenhouse with ample global warming. Therefore, it was suggested that the furnace of unit 75 be upgraded based on the design of unit 200. The first change was the installation of a new forced draft fan in old furnace of unit 75. This is designed generally based on the needed excess air of the fuel gas entering to the furnace. Moreover, an economizer was needed to be installed on the stack of the old furnace of unit 75 in order to preheat inlet excess air of furnace. These changes make the fuel combustion of furnace more complete than the old one and as a result, decreases the emission of CO, C_xH_x and H_2S significantly. The final change was installing temperature controller on the feed line leaving the old furnace of unit 75 to regulate the fuel consumption. This prevents extra heating of feed and as a result decreases the consumption of fuel gas. Emission rate of pollutant decreases once the furnace consumes lower fuel gas.

The emission factor of pollutants leaving the furnace of unit 200 was equated with that of unit 75, in order to calculate the new emission rate of pollutants after furnace renovation. The annual emission rate of each pollutant leaving the stack of renovated unit 75 furnace was computed using Eq. 1. Moreover, the new emission factor of pollutants leaving the stack of unit 75 furnace were compared to standard of American refineries; accredited by United States Environmental Protection Agency, in order to investigate the statue of pollution rate in the upgraded unit of Abadan refinery (US Environmental Agency, 2015).

RESULTS AND DISCUSSION

Some emission factors of pollutions coming from the stack of unit 75 furnace were more than that of unit 200. Fig. 3 shows the emission factor of CO_2, NO_x, SO_2, and H_2S leaving units 75 and 200. The emission factor of CO coming from unit 75 was more than 14 times that of unit 200. Moreover, the emission value of hydrogen sulfide and unburnt hydrocarbons was higher than that of unit 200. This was due to the old design of unit 75 in which the needed excess air of fuel combustion is provided naturally and manually. This leads to incomplete combustion of fuels in the furnace burner. On the other hand, the emission factor of SO_2 and NO_x leaving the stack of unit 200 was more than that of 75. Furnace of unit 200 has a forced fan that provides the needed excess air system that culminates to complete combustion of fuel at burners. Therefore, the nitrogen and sulfur elements of fuel are converted to nitrogen and sulfur oxides.

Fig. 4 shows the emission factor of CO_2 emitting from units 200 and 75. More carbon dioxide was emitted from the stack of unit 200 furnace in comparison to unit 75. The presence of an induced fan provided excess air to the furnace, which made the combustion of fuel gas complete; as a result, most of the fuel hydrocarbons were converted to CO_2. Moreover, there was an economizer installed in the path of the excess

Table 2: The average value of 6 months measurement of pollutant concentration and calculated mass flow of pollutants leaving the stack of units 200 and 75

Pollutant Name	Pollutant Molecular weight (g)	Pollutant concentration (ppm)		Pollutant concentration (mg/m^3)		Pollutant mass flow (g/h)	
		Unit 200	Unit 75	Unit 200	Unit 75	Unit 200	Unit 75
CO	28	9	150	11.4	139	978	9730
CO_2	44	56000	50300	111493	73284	22744572	5129880
NO_x	30	35	31	45.7	30.8	9322	2156
SO_2	64	106	20	306	42.4	62424	2968
C_xH_x	16	9	15	12.2	14.9	2488	1043
H_2S	34	0	3.9	0	4.4	0	308

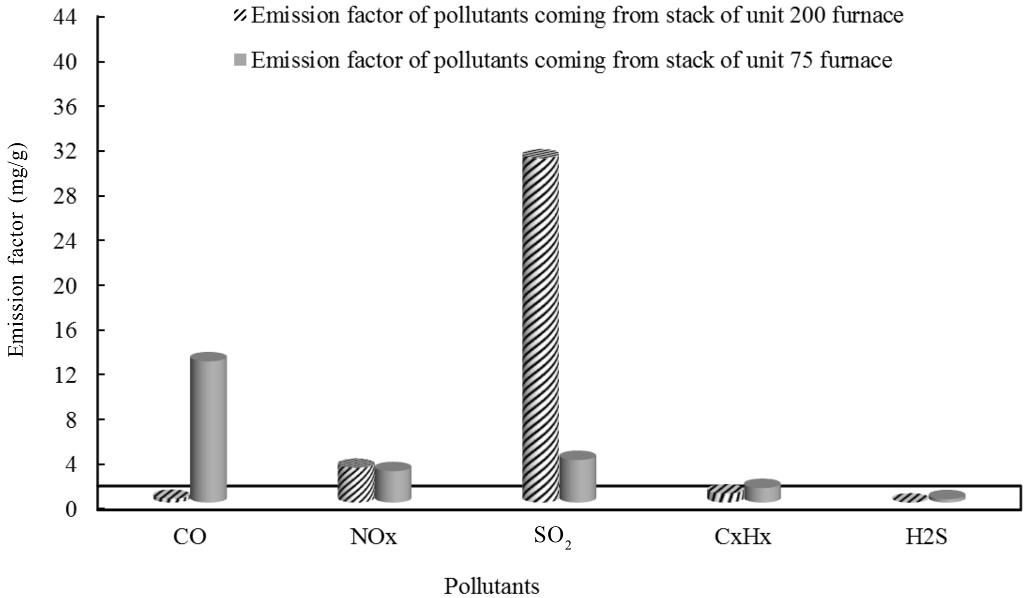

Fig. 3: Emission factor of pollutants CO, NO_x, SO_2, C_xH_x and H_2S coming from furnace of units 200 and 75

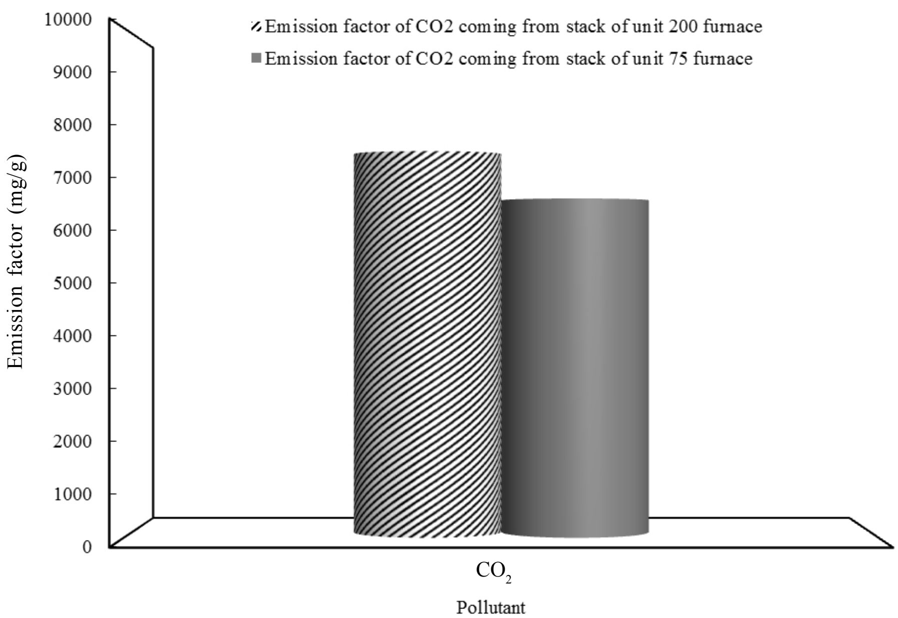

Fig. 4: Emission factor of pollutant CO_2 coming from furnace of units 200 and 75

air in which it preheated the air by the heat of flue gas. This helped the fuel combustion to be more efficient and as a result lowered consumption of fuel; and lead to a lower pollutant emission in unit 200. Finally, an oxygen sensor was installed on the stack of unit 200 furnace which monitored the concentration of O_2. This could help the unit operators regulate the needed excess air of fuel gas to be combusted. Figs. 5 and 6

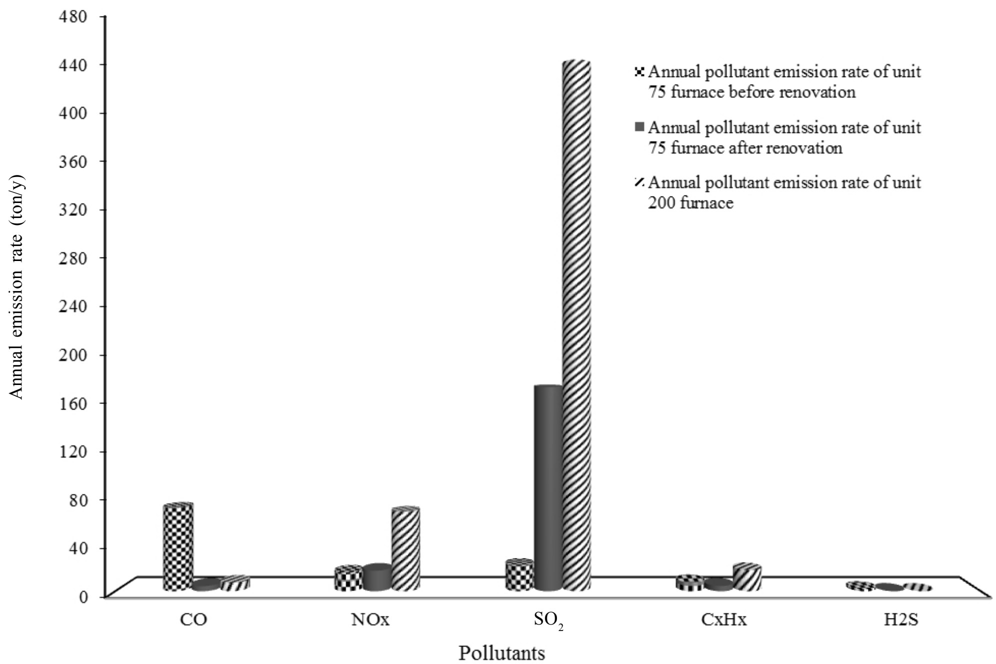

Fig. 5: Annual emission rate of pollutants CO, NO_x, SO_2, C_xH_x and H_2S coming from furnace of unit 75 Before and after renovation, and unit 200 furnace

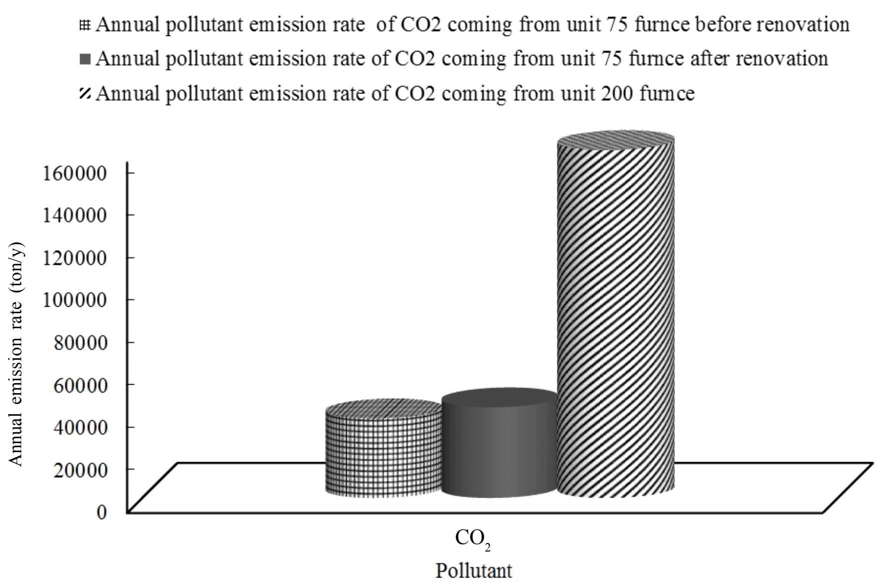

Fig. 6: Annual emission rate of pollutant CO_2 coming from furnace of unit 75 Before and after renovation, and unit 200 furnace

show the annual mass flow rate of pollutants leaving the furnaces of units 75 before and after renovation. According to Figure 5, the CO and C_xH_x pollution coming from unit 75 furnace experienced significant annual decrease of 66.2 and 3 tons, respectively after renovation of unit 75 furnace. Moreover, the emission rate of hydrogen sulfide emitting from the stack of unit 75 furnace reached to zero after furnace renovation.

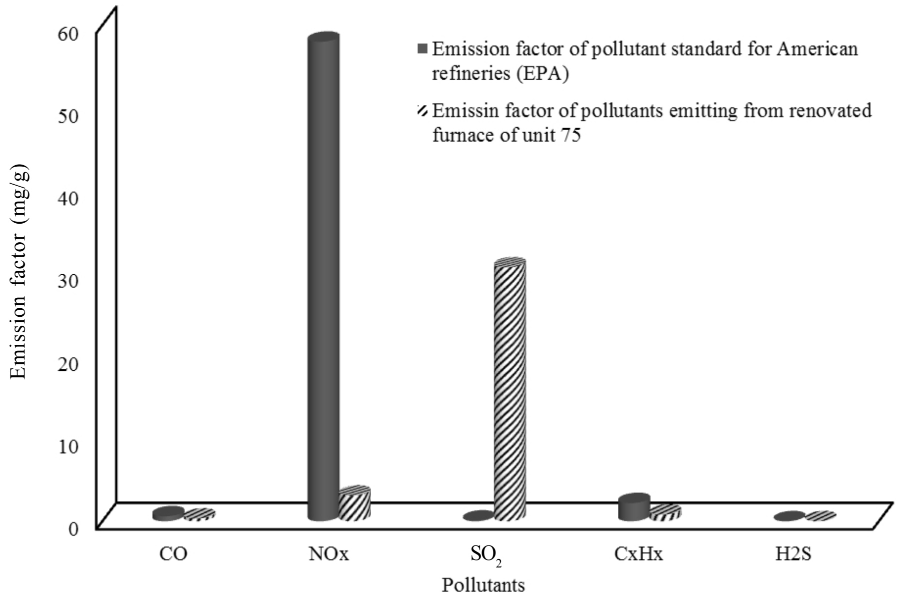

Fig. 7. The comparison of pollutant emission rate coming from furnace of renovated unit 75 and American refinery standards

Carbon monoxide and hydrogen sulfide are the most dangerous air pollutants and are lethal even at a low level of concentration in the atmosphere. Poisonous gases such as CO and H_2S can kill someone at a threshold concentration of 1200 and 700 PPM in air (Hall *et al.,* 2014). On the other hand, the renovation of unit 75 furnace increased the emission rate of NO_x from 15.8 to 17.4 ton per year. Also, the emission rate of SO_2 experienced dramatic increase of over 150 ton annually. Sulfur dioxide can contribute to production of acid rain and damage plants dramatically (Hansard *et al.,* 2011).The main reason for both changes was the complete combustion of fuels in the innovated burner of unit 75 furnace. As a result, all hydrogen sulfide and nitrogen that were present in fuel gas were converted to sulfur dioxide and nitrogen oxide compositions. Even though the fuel gas consumption of unit 200 furnace was nearly 4 times as much as it was in old furnace of unit 75, the annual emission rate of CO coming from unit 200 furnace was significantly lower than that of unit 75 before renovation. Moreover, the annual rate of H_2S emitting from furnace of unit 200 equaled zero while this was 1.7 ton in unit 75 furnace before its renovation. Considering other pollutants, it showed that the annual flow rate of NO_x and C_xH_x coming from stack of unit 200 furnace was higher than that of unit 75 furnace before renovation. This occurred because the fuel consumption of unit 200 furnace was approximately 4 times as much as it was for furnace of unit 75. However, the SO_2 emission coming from stack of unit 200 was significantly higher than that of unit 75 due to complete combustion of fuel gas. This led to total conversion of H_2S (that is present in fuel gas) to sulfur dioxide.

Fig. 6 shows that the renovation of unit 75 increased the emission rate of CO_2 up to 14%. This occurred because fuel gas burnt in the new furnace of 75 more complete than the old one. Therefore, this leads to conversion of most hydrocarbons of fuel gas to carbon dioxide. The renovation of unit 75 can be similarly carried out at the other furnaces of Abadan refinery. There are more than 11 old furnaces with average fuel consumption of 700-3500 kg/h. they function similarly to unit 75 furnace. Comparing the fuel consumption of these furnaces and unit 75 furnace, it is predicted that, if each furnace is renovated based on unit 200 furnace design, the total annual rate of pollutant such as CO, C_xH_x and H_2S will decrease 320 ton, 94 ton and 76 tons, respectively.

The comparison of emission factor of renovated furnace of unit 75 and the American standard refineries revealed that almost four pollutants out of five had normal emission factor. As shown in Fig. 7, the emission factor of CO, NO_x and C_xH_x leaving the renovated furnace of unit 75 were less than the standard values and they were both zero at hydrogen sulfide emission factor. Although the fuel consumption of unit 200 furnace was nearly 4 times as much as it was in furnace of unit 75, the annual emission rate of CO_2 would be more than that of unit 75 furnace if their fuel consumption were equated. This happen because fuel gas combustion of unit 200 furnace was more complete that that of unit 75 furnace before renovation.

Otherwise, considering sulfur dioxide, it showed that the rate of emission of pollutants coming from upgraded furnace of unit 75 outweighed the American standard values. This happened due to the high concentration of H_2S that existed in fuel gas; this was completely converted to SO_2 through complete combustion process. Therefore, the use of gas with the minimum amount of H_2S was more effective in reducing the pollution of sulfur dioxide. The emission limit of SO_2 was 0.09 according to American pollution standards. Odorant injected into the natural gas to determine the gas leaks contains sulfur elements (Kilgallonmade *et al.,* 2015). This usually converts to hydrogen sulfide that emits from refinery furnaces.

Methods of controlling and decreasing refinery furnace pollutants

When considering the reason for the presence of more pollution at the stacks of old furnaces at unit 75 to the new furnace of unit 200, in most cases designing and the age of the equipment including burners' damper of inlet air and stack of furnace are concerned. Moreover, lack of control system including oxygen analyzer at the furnace stack and lack of devices for provision of the needed excess air of complete combustion of fuel gas at the furnace were considered as the additional reasons for higher pollution of unit 75. The provision of extra air for the use of the furnace of the unit 75 caused complete combustion of fuel gas; this leads to decrease of dangerous pollutants like CO and C_xH_x and increase of sulfur dioxide which is produced because of burning of hydrogen sulfide that is present in the fuel gas of the furnace. Therefore, SO_2 emission rate would be decreased significantly at the stack of unit 75 furnace by refining the fuel gas for eliminating H_2S.

CONCLUSION

Innovation of old furnace of unit 75 decreased the emission factor and rate of dangerous pollutant. New and old furnaces of units 200 and 75 were selected at the Abadan refinery in order to examine the amount of pollutant decrease and environmental benefits. The measured data was collected for 6 months. The emission factors of pollutant were computed. Results showed that the emission factor and emission rate of hazardous pollutants coming from unit 75 furnace were more than that of unit 200. Despite, the fuel gas consumption of unit 75 furnace was nearly a quarter of unit 200 furnace, its annual emission rate of CO and H_2S was significantly higher than that of unit 200 furnace. The study suggested the installation of a controlling system of furnace fuel consumption based on the feed temperature leaving the furnace and using forced draft fan to make the fuel combustion complete. This leads to annual decrease of CO, H_2S, and C_xH_x emission up to 66 ton, 3 ton and 800 kg, respectively. However, it increased the emission rate of SO_2 and NO_x. Finally, new emission factor of pollutants emitting from the renovated furnace of unit 75 was compared to environmental standard of American refineries; this was done in order to consider the statue of Abadan refinery pollution in comparison with US standards. Results showed that most pollutant had lower emission rate except SO_2. Sulfur dioxide could be decreased by refining fuel gas to be free of H_2S. It is predicted that upgrading the design of all 11 old furnaces that are present in Abadan refinery can decrease annual pollution rate of CO, C_xH_x and H_2S to approximately 320, 94 and 76 tons, respectively.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

NOMENCLATURE

A mass flow of fuel gas (g/h)
a stack sectional area (m^2)
C pollutant concentration (ppm or mg/m^3)
E pollutant emission rate (mg/h)
EF pollutant emission factor (mg/g)
EPA Environmental Protection Agency
ER total percentage of emission
M molecular weight (g/mol)
m_f mass flow rate of fuel gas (g/h)
m_p mass flow of pollutant at the point of pollutant concentration measurement (mg/h)
P pressure of stack gas at the point of pollutant concentration measurement (atm)
PM particulate matter, a complex mixture of extremely

small particles and liquid droplets
R molar gas constant (atm.L/mol.k)
Q stack gas volume flow at the point of pollutant concentration measurement (m3/h)
T temperature of stack gas at the point of pollutant concentration measurement (k)
T.C temperature controller
v velocity of stack gas at the point of pollutant concentration measurement (m/s)

REFERENCES

AORED, (2015). Handbook of units 200 and 75 operation instruction, instructions, Integrated Management Systems. 2nd. Ed., Abadan Oil Refinery Engineering Department.

Ahmadi, M.; Roz Khosh, M.; Jaafarzadeh, N., (2016). Emission of CO_2 and CH_4 in Asmari gas compressor station in national Iranian south oil company using emission factor, J. Air Pollut. Health, 1: 35-42 (**8 pages**).

Abdul-Wahab, S.A.; Al-Alawi, S.M.; El-Zawahry, A., (2006). Patterns of SO_2 emissions: a refinery case study, Environ. Modell. Softw, 17 (6): 563–570 (**8 pages**).

Al-Salem, S.M., (2015). Carbon dioxide emission sources in Kuwait from the downstream industry: Critical analysis with a current and futuristic view. Energy, 81: 575–587 (**13 pages**).

CCOHS, (2016). Converting occupational exposure limits. Canadian Center for Occupational Health and Safety. www.ccohs.ca/oshanswers/chemicals/convert.html.

Carugnoa, M.; Consonnib, D.; Randia, G.; Catelanc, D.; Grisottoc, L.; Bertazzia, A.; Biggeric, A.; Baccinic, M., (2016). Air pollution exposure, cause-specific deaths and hospitalizations in a highly polluted Italian region, Environ. Res., 147: 415–424 (**10 pages**).

Chavoshi, B.; Massodnejad, M.R.; Adibzadeh A., (2011). Evaluation the amount of emission and sulfur dioxide emission factor from Tehran oil refinery. J. Air Pollut. Health, 4:233-236 (**4 pages**).

Dios, m.; M., Souto, M.; Casares, J.J., (2013). Experimental development of CO_2, SO_2 and NO_x emission factors for mixed lignite and subbituminous coal-fired power plant. J. Energy, 53: 40-51 (**10 pages**).

Ditaranto, M.; Anantharaman, R.; Weydahl, T., (2013). Performance and NOx emissions of refinery fired heaters retrofitted to hydrogen combustion. Energy. Procedia, 37: 7214 – 7220 (**7 pages**).

EEA, (2009). An air pollutant emission inventory guidebook. Technical Report No 6/2009. Copenhagen. European Environment Agency. (www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook).

Gadallaa, M.; Olujiæb Z.; Jobsonc, M.; Smithc, R., (2006). Estimation and reduction of CO_2 emissions from crude oil distillation units. Energy, 31(13): 2398–2408 (**11 pages**).

Hall, R.; Earnest, S.; Hammond, D.; Dunn, K.; Garcia, A., (2014). A summary of research and progress on carbon monoxide exposure control solutions on houseboats. J. Occup. Environ. Hyg., 11(7): 92–103 (**12 pages**).

Hansard, R.; Maher, B.A; Kinnersley, R., (2011). Biomagnetic monitoring of industry–derived particulate pollution. Environ. Pollut., 159: 1673-1681 (**9 pages**).

Heinrich, J.; Thiering, E.; Rzehak, P.; Krämer, U.; Hochadel, M.; Rauchfuss, KM.; Gehring, U.; Wichmann, HE., (2013). Long-term exposure to NO_2 and PM_{10} and all-cause and cause-specific mortality in a prospective cohort of women. Occup. Environ. Med., 70 (3):179-186 (**8 pages**).

Jafarigol, F.; Atabi, F.; Moatar, F.; Nouri, J., (2015). Estimating emission factors of pollutant gases in a gas refinery in south of Iran. Adv. Biores., 6: 72-77 (**6 pages**).

Jaramillo, P.; Muller, N., (2016). Air pollution emissions and damages from energy production in the U.S.: 2002–2011. Energ. Policy, 90: 202–211 (**10 pages**).

Kilgallon, R.; Gilfillan, S.M.V.; Haszeldine, R.S.; McDermott, C.I., (2015). Odourisation of CO_2 pipelines in the UK: Historical and current impacts of smell during gas transport. Int. J. Greenhouse Gas. Con., 37: 504–512 (**9 pages**).

Khodabandeh, E.; Pourramezan, M.; Pakravan, M., (2016). Effects of excess air and preheating on the flow pattern and efficiency of the radiative section of a fired heater in a petroleum refinery, Appl. Therm. Eng., doi:10.1016/j.applthermaleng.2016.03.038.

Liu, C.; Li Z.; Kong, W.; Zhao, Y.; Chen, Z., (2010). Bituminous coal combustion in a full-scale start-up ignition burner: influence of the excess air ratio. Energy, 35(10): 4102-4106 (**7 pages**).

Lohe, R.N.; Tyagi, B.; Singh, V.; Kumar, P.; Tyagi, P.; Khanna, D.R.; Bhutiani, R., (2015). A comparative study for air pollution tolerance index of some terrestrial plant species. Global J. Environ. Sci. Manage., 1(4): 315-324 (**10 pages**).

Ma, J.; Yi, H.; Tang, X.; Zhang, X.; Xiang, Y.; Pu, L., (2013). Application of AERMOD on near future air quality simulation under the latest national emission control policy of China: A case study on an industrial city. J. Environ. Sci., 25: 1608–1617 (**10 pages**).

Nakomcic-Smargdgkis, B.; Cepic, Z.; Cepi, M.; Stajic, T., (2014). Data analysis of the flue gas emissions in the thermal -power plant firing fuel oil. J. Environ. Sci. Technol., 11 (2): 269-280 (**12 pages**).

Nguyen, H.T.; Kim, K.H.; Kim, M.Y., (2009). Volatile organic compounds at an urban monitoring station in Korea. J. Hazard. Mater., 161:163–174 (**12 pages**).

Ruei-Hao, S.; Chana, C., (2013). Tracking hazardous air pollutants from a refinery fire by applying on-line and off-line air monitoring and back trajectory modeling. J. Hazard. Mater., 261: 72– 82 (**11 pages**).

Shtripling, L.O.; Bazhenov, V.V., (2015). Emission process system organization of pollutants into the atmosphere for refinery enterprises. J. Procedia Eng., 113: 349 – 356 (**8 pages**).

Tang, Y.; Ma, X.; Lai, Z.; Zhou, D.; Lin, H.; Chen, Y., (2012). NOx and SO_2 emissions from municipal solid waste combustion in CO_2/O_2 atmosphere. Energy, 40(1):300-306 (**7 pages**).

US Environmental Agency, (2015). Technology transfer network clearinghouse for inventories and emissions

factors, stationary internal combustion sources. AP 42, 5th Edition, 1(3): 1-18 (**18 pages**).
Willers, S.; Jonker M.; Klok, L.; Keuken, M.; Odink, J.; Elshout, S.; Sabel, C.; Mackenbach, J.; Burdorf, A., (2016). High resolution exposure modelling of heat and air pollution and the impact on mortality. Environ. Int., 89: 102–109 (**8 pages**).
Yaseen, S.; Skinder, B.; Ahmad, S.; Khoiyangbam R.S., (2014). Temporal variation of SO_2 and NO_2 cocentration around Parichha thermal power plant. India, J. Environ. Chem. Tox., 6 (2): 6-12 (**7 pages**).
Zhao, Y.; Wang, S.; Nielsen, CS.; Li, X.; Hao, J., (2010). Establishment of a database of emission factors for atmospheric pollutants from Chinese coal-fired power plants. Atmos. Environ., 44: 15-23 (**9 pages**).

AUTHOR (S) BIOSKETCHES

Zabihi, A., M.Sc., Mazandaran Gas Company, Taleghani Street, Sari, Iran. Email: *azabihirami@gmail.com*

Raazaitabari, M.R., M.Sc., Department of Environmental Engineering, Islamic Azad University, Ahvaz Branch, Ahvaz, Iran. Email: *tabari83@yahoo.com*

HOW TO CITE THIS ARTICLE

Zabihi, A.; Raazaitabari, M.R., (2016). Decreasing emission factor of pollutants in an oil refinery by renovating the furnace design. Global J. Environ. Sci. Manage., 2(3): 299-310.

DOI: 10.7508/gjesm.2016.03.009

URL: http://gjesm.net/article_19411.html