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# Emission evaluation of $CO_2$ and $CH_4$ gases in the selected gas pressure booster station in the Bangestan field of the National Iranian Oil Company

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**Abstract**

**Background:** Iran is located in the seventh rank in terms of $CO_2$ emissions resulting from the fuel combustion in the world. Gas compressor booster stations, due to the several sources of contaminants, are causing the release of large amounts of $CO_2$ and $CH_4$, which will cause climate change; therefore, estimating the emissions of the gases from oil and gas, different processing units are necessary.

**Methods:** In this study, the emissions factor method, provided by various organizations, was used for determining emissions of $CO_2$ and $CH_4$ from different sources.

**Results:** According to the results obtained, the total amount of $CO_2$ emissions in selected units is from the selected unit and is a significant contribution to the CH4 emissions, so that the whole amount of $CO_2$ emissions is equal to 7739.027 tons per day and the total amount of $CH_4$ emissions is 4 tons per day.

**Conclusion:** Burner has the highest amount of $CO_2$ emissions among the sources of pollutants in the fixed combustion sources; and, the highest emissions of $CH_4$, among the exit gas sources, belong to the process of removing water. Among the exit gas sources-compressors maintenance activities the highest emissions belong to $CH_4$. The amount of $CO_2$ emissions from indirect sources, including electrical equipment in the studied units, are from natural gas fuel which are much more than those from fuel oils for burning. $CH_4$ gas from volatile sources in the gas compressors have the highest emissions compared to other sources.

**Keywords:** Greenhouse gases, Emission factor, Gas compressor booster station of Bangestan

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## Introduction

Due to growth and expansion of industrialization, the energy demand across the globe is increasing rapidly. This growth in energy consumption has been led to environmental degradation, water and air degradation and greenhouse gases and other pollutants emission (1). Greenhouse gases include $CO_2$, $CH_4$, $N_2O$, $HFC_S$, $PFC_S$, and $SF_6$, the most important of which are respectively $CO_2$ and $CH_4$ (2). According to the evaluations of the Research Center for Energy and Environmental Studies, the share of greenhouse gas emissions in the country's oil industry the most important part of which is burned associated gases and gases burned in oil units, is about 35% of the country's total greenhouse gas emissions (3).

Overview of the gas compressor booster stations shows that the major sources of greenhouse gas emissions ($CO_2$ and $CH_4$) are from various sources of these units such as burner, ray steam boiler, tanks, removing water process, electrical equipment, gas valves and compressors. These resources are of the major share of contribution in the similar units in terms of greenhouse gas emissions. Because these gases are among the most important greenhouse gases, and have a great impact on the global warming, this research becomes more important.

Totally, four types of Emission Estimation Techniques ($EET_S$) that can be used for estimating the emission are: sampling or direct measurement, mass balance, fuel analysis, and other engineering calculations and emission factors. Generally, the direct measurement is the most accurate method for calculating the specific emissions, but it is expensive and difficult to conduct for some resources. The calculating programs and engineering calculations often can provide the exact estimation much more than emission factors; although in some cases they may require a lot more effort. Since the entries in the program require specific data of the process, the results are specific estimations of the process (4). The emission factor is an index value that is in an attempt to link the quantity of a pollutant released in the atmosphere to an activity related to the release of related pollutants. These factors usually expressed as the weight of pollutant are classified into a unit of weight, volume, distance, or duration of an activity of contamination spread (5).

In a study to fit the quantity of reducing greenhouse gas emissions of Carbon Capture and Storage (CCS) conducted through the project guidelines, the oil and natural gas industry project, it was determined that technology for collecting carbon dioxide from large point sources, compression, transportation, and its long-term injection in the storage places provides the potential to play a key role in reducing greenhouse gas emissions and affordable energy (6). Evaluation of $CO_2$ emissions and the potential for reducing it in oil refining industry of Korea using energy-environment models showed that new technology and alternative scenarios can reduce carbon dioxide emissions in the national and industrial sectors respectively up to 0.048% and 0.065% (1). To estimate the amount of $CO_2$ in the peripheral area of a selected unit of gas and liquefied gas in the National Iranian Oil Company (NIOC) based on the analysis of fuel showed that acid gas burners with a 63% share have the most share in $CO_2$ emissions (7). The results of the estimation of pollutant emissions in one of the oil and gas operation units of NIOC using the Environmental Protection Agency's (EPA) emission factors indicated that the amount of $CO_2$ emissions and $CO_2$ in gas turbines and burner are far more than the amount estimated by the EPA (8).

Regarding economic justification of the project it can also be noted that the potential measurement of greenhouse emissions is considered as the first stage in the development of business support through Clean Development Mechanism (CDM). The output of this project will help decision makers to assess the possibility of entering the CDM cycle, and if there is the possibility, it can help them enjoy economic advantage arising from the reduction in the production of these gases and as a result of carbon concession sales in international markets.

## Methods

In this study, one of the gas compressor booster stations of Bangestan of NIOC in Southwest Iran was investigated. The gas compressor booster stations, which have been constructed adjacent to operating plants, receive rich gases, which are separated from oil during the second, third and fourth stages of breakdown in the operating unit of oil separators. After compressing and separating liquids from them, these gases' final products in the form of gas and gas liquids are sent to the gas and liquid gas plants to receive further refining and processing. In this way in order to calculate emissions, first, the overall process of gas compressor booster station in relation to the sources of production of the pollution was detected. After identifying these sources, they were categorized as follows: fixed combustion sources, exit gas sources, repair and maintenance activities, indirect sources, and volatile sources. Type and rate of fuel consumed in the designated unit is provided by various organizations according to the emission factors, and these have been presented in the Table 1. Emissions for each of the sources spreading pollution was estimated using equation 1:

$$E = A \times EF \times [1-(ER/100)] \qquad \text{(Eq. 1)}$$

Where:

E is the emission pollutant rate (the amount of pollutant mass); A is the activity rate; EF is an emission factor (the amount of pollutant mass emitted per the amount of product produced or the activity rate); ER is the overall percentage of the emission reduction the value of it is considered to be zero, due to the lack of using pollutant reduction systems in the studied unit (5). Finally, the data were examined and analyzed using Excel software by comparing a variety of sources of pollutants in a studied unit.

### *Characteristics of fuel used in the study unit*

To estimate the amount of emissions of pollutants ($CO_2$ and $CH_4$), fuel type and the amount of fuel consumed in each resource should be determined separately. Since fuel consumed for the sources of pollutants in the study unit is fuel gas, the data contained in the gas compressor station (presented in Table 2) have been used.

## Results

### *The amount of $CO_2$ and $CH_4$ emissions from the gas flares*

The amount of emissions calculated for two gas burners with an average dB of 0.3 million cubic feet per day has been presented in Table 3.

### *The amount of $CO_2$ and $CH_4$ gas emissions caused by the reboiler*

The amount of emissions calculated for a gas ray boiler of this unit with a dB of 0.1 million cubic feet per day has been presented in Table 4, and emissions arising from the process of removing water from gas in gas pressure booster station in Bangestan have been calculated. The amount of gas in the processing station is an average of 15 million cubic feet a day, we multiply this amount by the CO2 and CH4 molar percentage (Table 2) (To removing water, gases of all the steps of breakdown in this stage are accumulated), the amount of emissions of this source of the pollutants is obtained.

**Table 1.** Presents emission factors for emission sources by various reference

| | References | Emission Factor | | | |
|---|---|---|---|---|---|
| | | $CH_4$ | | $CO_2$ | |
| **Gas Flares** | ARPEL, 1998 (lb/MMBtu) (9) | - | | 0.61 | |
| | CAPP, 2003 (g/m$^3$ gas) (10) | 1853 | | 13.6 | |
| | EEA, 2006 (lb/MMBtu) (11) | - | | 0.12 | |
| | EIA, 2006 (lb/MMBtu) (12) | 120.72 | | - | |
| | IPCC, 1996 (lb/MMBtu) (13) | 141.01 | | - | |
| | NAEI, 2007 (lb/MMBtu) (14) | 105.01 | | 0.389 | |
| | The Norwegian Oil industry Association, 1993 (lb/MMBtu) (15) | 148.98 | | 0.012 | |
| | United Kingdom Offshore Association, 1993 (lb/MMBtu) (16) | 144.76 | | 0.61 | |
| **Reboilers** | MDEQ, 2011(Ib/MMscf) (17) | 116.78 | | 0.011014 | |
| **Dehydration** | API, 2009 (tonnes/10$^6$ scf) (18) | Due to the modulus $CH_4$ emissions Calculated | | 0.0023315 | |
| **Maintenance activities Tanks** | API, 2009 (tonnes/vessel-year) (18) | Due to the modulus $CH_4$ emissions Calculated | | 0.0015 | |
| **Compressors** | API, 2009 (tonnes/compressor-year) (18) | Due to the modulus $CH_4$ emissions Calculated | | $2.42\times10^{-2}$ | |
| **Maintenance activities Compressor** | API, 2009 (tonnes/compressor-year) (18) | Due to the modulus $CH_4$ emissions Calculated | | 0.1620 (Start)<br>0.07239 (Blodown) | |
| **Valves/Valves-Gas** | API, 2009 (tonnes/Valves-year) (18) | - | | $4.5\times10^{-6}$ | |
| **Electrical equipment** | **Type of fuel** | Mazout | Natural gas | Mazout | Natural |
| | *AGO, 2001(tonne/MMBTU) (19) | - | 0.0542 | - | |
| | *API, 1999 ( tonne/MMBTU)] (19) | 0.0743 | 0.0531 | - | - |
| | *API, 2009 (tonne/MMBTU)] (19) | same | same | $3.17\times10^{-6}$ | $1.06\times10^{-6}$ |
| | *CIEEDAC, 2001 (tonne/MMBTU)] (19) | - | 0.052 | - | - |
| | *DEFRA, 1999 (tonne/MMBTU) (19) | 0.0703 | 0.0556 | - | - |
| | *EPA, 1998 (lb/10$^6$scf) (19) | - | 120000 | - | 2.3 |
| | IPCC, 2001(tonne/MMBTU)* (19) | 0.0743 | 0.0532 | - | - |
| | *WRI/WBCSD, 2000 (tonne/MMBTU) (19) | - | 0.0531 | - | - |

**Table 2.** Characteristics of composition of the gas used in the combustion sources and emission sources studied at different stages of differentiation in gas compressor station (20).

| Characters Stages | | Stages 1 | Stages 2 | Stages 3 | Stages 4 |
|---|---|---|---|---|---|
| **Molly components** (%) | Methane | 392.3 | 54.1 | 2.2 | 13.6 |
| | Ethan | 76.7 | 26.8 | 5.7 | 3.5 |
| | Propane | 33.1 | 17.3 | 1.5 | 1.8 |
| | Iso-butane | 3.7 | 2.2 | 1.6 | 0.6 |
| | Normal butane | 9.2 | 5.7 | 1.1 | 2.1 |
| | Ayzvpntan | 2.3 | 1.5 | 0.7 | 1 |
| | Normal pentane | 2.6 | 1.6 | 0.2 | 1.2 |
| | Hexane | 1.7 | 1.1 | 3.5 | 0.9 |
| | Normal butane | 1.5 | 0.7 | 0.3 | 0.8 |
| | Hydrogen sulfide | 0.7 | 0.2 | 0 | 0 |
| | Carbon dioxide | 16.5 | 3.5 | 0 | 0 |
| | Water | 6.4 | 4.5 | 2.4 | 4.4 |
| | The total gas flow (MMSCFD) | 11.1 | 2.4 | 59.9 | 0.6 |
| | The molecular weight of the gas | 22.62 | 29.66 | 54.1 | 31.67 |
| | Temperature (°C) | 63.3 | 59.4 | 59.4 | 55.6 |
| | Pressure (bar) | 21.01 | 5.15 | 5.15 | 1.06 |

**Table 3.** Emissions of $CO_2$ and $CH_4$ from gas flares

| Emission factor (tonne/day) | | | | Reference |
|---|---|---|---|---|
| $CO_2$ | | $CH_2$ | | |
| High-pressure flares | Low-pressure flares | High-pressure flares | Low-pressure flares | |
| - | - | 0.027 | 0.055 | ARPEL, 1998 |
| 5.247 | 10.494 | 0.038 | 0.077 | CAPP, 2003 |
| - | - | 0.005 | 0.01 | EEA, 2006 |
| 5.475 | 10.951 | - | - | EIA, 2006 |
| 6.395 | 12.792 | - | - | IPCC, 1996 |
| 4.767 | 9.534 | 0.017 | 0.035 | NAEI, 2007 |
| 6.757 | 13.515 | 0.0005 | 0.001 | The Norwegian Oil industry Association, 1993 |
| 6.563 | 13.126 | 0.027 | 0.055 | United Kingdom Offshore Association, 1993 |

Note: for flares efficiency of 98% is assumed.

**Table 4.** Emissions of $CO_2$ and $CH_4$ from reboilers and arising from removing water process

| Emission factor (tonne/day) | | Reference |
|---|---|---|
| $CO_2$ | $CH_4$ | |
| $5.301\times10^{-3}$ | $4.955\times10^{-7}$ | Re-Boilers (MDEQ, 2011) |
| $5.761\times10^{-3}$ | 0.05 | Removing water process (Reference API, 2009) |

### *The $CO_2$ and $CH_4$ emissions resulting from repair and maintenance activities of compressor and tanks*

As it can be seen in Table 5, the amount of CO2 emissions resulting from CH4 compressors, compressor and tank maintenance activities, and valves for each maintenance activity have been calculated. To calculate the amount of emissions from all kinds of valves according to the emission factors provided by API, the number of each of the various types of valves in the unit is multiplied by the relevant emission factors; thus, emissions from these sources are calculated as well. Also to calculate the amount of emissions from all kinds of valves according to the emission actors provided by API (Table 5), the number of each of the various types of valves in the unit is multiplied by the relevant emission factors; thus, emissions from these sources are calculated as well.

### *The $CO_2$ and $CH_4$ emissions resulting from natural gas and fuel oils for burning*

To calculate emissions from indirect sources, first, we must know the amount of fuel consumed by power plants to supply the unit's electricity for every megawatt hour of electricity consumption at the unit that is 2500 MW per hour; then it is multiplied by the emission factors provided by different organizations for fuel oils and gas for burning (Table 6), and thus emissions from indirect sources, which include electrical equipment, can be calculated.

**Table 5.** Emissions of CO2 and CH4 from gas compressors, maintenance activities compressors, maintenance activities tanks and valves

| Emission factor (tonne/day) | | Reference API, 2009 |
|---|---|---|
| $CO_2$ | $CH_4$ | |
| 0.42 | 3.642 | Emission gas compressors |
| 0.167 | 1.502 | Emissions maintenance activities compressors |
| $3.713\times10^{-3}$ | 0.033 | Emissions maintenance activities tanks |
| - | 0.1 | Valves |

## Discussion

According to the calculations and investigations performed, as it can be seen in Figure 1, a total of 7739.027 tons of $CO_2$ gas is released per day when indirect emissions sources, including electrical equipment, with a 94% share have the largest share of $CO_2$ emissions in the station. Then the rest of the sources compared to the source with a share less than 1% are awarded respectively to the gas burners, gas compressors, the process of removing water, ray boiler, and finally the exit gas resources at the time of the activity related to the repair and maintenance of compressors and reservoirs. In a study carried out to estimate the amount of $CO_2$, $SO_2$ and CO in the peripheral environment in one of the units, it was found that the estimated total amount of each of the gases $SO_2$, $CO_2$ and CO were respectively equal to 741620.49 kg/day, 3650.09 kg/day, and 1136.24 kg/day. According to the results obtained, maximum rate of emissions was related to the $CO_2$ gas that is consistent with the study's results so that the amount of $CO_2$ emissions with 7739027 kg/day is more than $CH_4$ gas with 4001 kg/day in the selected station (9). The results of another study to estimate the amount of $CO_2$ and $NO_2$ and CO gases in the peripheral environment in one of the units of Karun's oil and gas exploitation showed

**Table 6.** Emissions of $CO_2$ and $CH_4$ from electrical equipment

| $CO_2$ | $CH_4$ | $CO_2$ | $CH_4$ | Reference |
|---|---|---|---|---|
| Mazout | Natural gas | Mazout | Natural gas | |
| - | 7809.893 | - | - | AGO, 2001 (tonne/MMBTU) |
| 11.808 | 7651.292 | - | - | API, 1999 (tonne/MMBTU) |
| 11.808 | 7651.292 | - | - | API, 2009 (tonne/MMBTU) |
| - | 7492.791 | $5.037\times^{10-4}$ | 0.15 | CIEEDAC, 2001 (tonne/MMBTU) |
| 11.172 | 8011.552 | - | - | DEFRA, 1999 (tonne/MMBTU) |
| - | 7842.093 | - | - | EPA, 1998 (lb/$10^6$scf) |
| 11.665 | 7665.701 | - | 0.15 | IPCC, 2001 (tonne/MMBTU) |
| - | 76.7.628 | - | - | WRI/WBCSD, 2000 (tonne/MMBTU) |

that the total amount of $CO_2$ emissions of the gas and liquid gas unit and gas sweetening is respectively equal to 449946.9 kg/day and 922212.97 kg/day. According to the results obtained from the amount of $CO_2$ emissions in the studied unit, it is more than the gas and liquid gas unit and gas sweetening with 7739027 kg/day (8).
As Figure 2 shows, totaling 4 tons per day of gas-$CH_4$ can

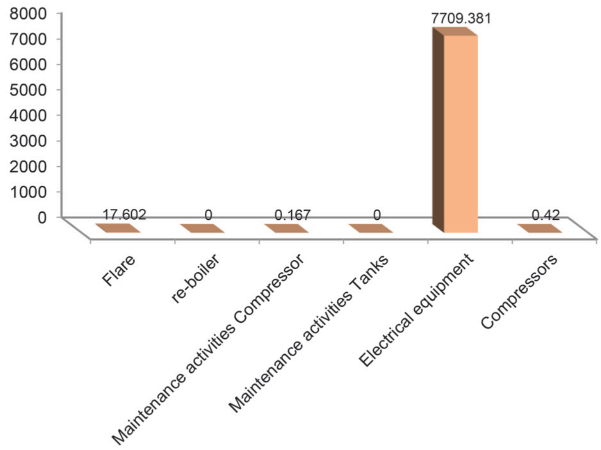


**Figure 1.** Comparison of the $CO_2$ emissions of each pollutant sources in the selected unit

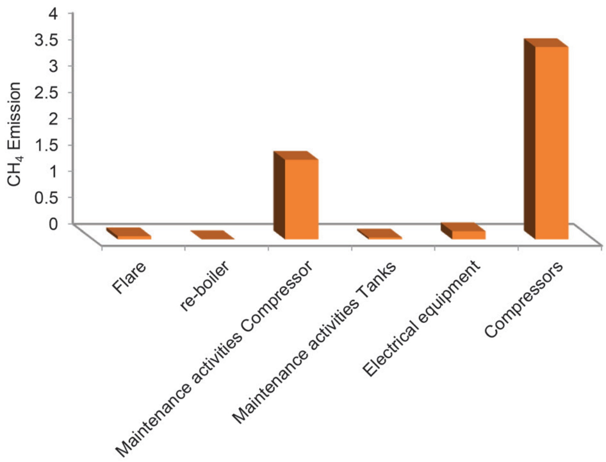


**Figure 2.** Compare the $CH_4$ emissions of each pollutant sources in the selected unit

be released from the selected station that gas compressors with 91% emissions have most emissions of $CH_4$ gas. Then the electrical equipment with 4%, volatile emissions from valves with 3% of emissions, burners with 1%, the other 1%, the process of removing water by 1%, and in the end ray boilers, activities related to maintenance and repair of compressors and tanks with the lowest emissions with a share close to 1% of the emissions have the lowest share in the unit. A study conducted to measure the Differential Absorption Lidar (DIAL) volatile emissions in the gas plant of Alberta, Canada showed that gas compressors are the most important source of $CH_4$ emissions. Then the operation of the burner in the pilot mode is another important source of emissions of this gas in the plant. According to the results obtained from the study, $CH_4$ emissions from compressors is 1272 kg/day and from the burners is 650.4 kg/day that is consistent with the results of the research so that the emissions from compressors of selected units with 3642 kg/day tons per day is more than burners with 57 kg/day per day (21). The results of another study entitled "test of emission factor for burners in a refinery" showed that the emission rate from burners on one of the refineries for the $CO_2$ and $CH_4$ gases, which have been calculated by EPA and API emission factors, were 124880 and 134.209 tons respectively in 2002. Compared with the results obtained from the amount of the emissions of the gases studied, it is less with 20.805 tons per year of $CH_4$, and 6424.73 tons per year of CO2 (22).
According to the conducted studies, the total amount of $CO_2$ emissions in the world is 28999. 4 million tons per year. Iran's part of the sector is 1.83% and the share of emissions of the gas from the petroleum sector in the world is 10630.8 million tons per year, 2.48 % of which is share of Iran (23). The selected gas station emits 2824806.905 tons per year or 1% of $CO_2$ compared to Iran's oil sector. The main focus of this section is more on carbon dioxide gas because the global warming potential of the $CO_2$ is more than $CH_4$.

## Conclusion

According to the conducted calculations and inquiries, the highest share of $CO_2$ emissions from indirect emission sources include electrical equipment with 99%, and the biggest share of $CH_4$ gas release is for the burners from fixed sources of combustion with 65%. Some of the guidelines that can be provided in order to reduce the sources of emissions mentioned in the studied unit are: the use of low-consumption light bulbs and a new system of uploading and downloading operation of electric motors, reduction or removal of the feasibility of the combustion of gases in the gas burners and ray boilers, recovery and use of emissions from oil wells, replacing a hydrogen fuel with gaseous fuel to improve the operations of maintenance and basic repair and maintenance operations in a timely manner for the equipment diffusing pollutant gases, new lighting control systems, the use of nanotechnology in the exact detection of leakage and its location, acceleration in the process of the development of CCS technology, the feasibility of $CO_2$ injection for the land areas, creation of awareness among the owners of the industries in order to participate in the CDM projects and benefit from the environmental benefits in the local and global levels resulting from the reduction in greenhouse gas emissions, the benefits of economic and social development for the implementation of the project in the host country, and the transfer of technology and economic benefits due to the economic progress of the related technologies to release less greenhouse gas.

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**Ethical issues**

We certify that all data collected during the study is presented in this manuscript and no data from the study has been or will be published separately.

**Competing interests**

The authors declare that they have no competing interests.

**Authors' contributions**

MA, MR and NJ conceived and designed the study. MR performed the literature search and wrote the manuscript. All authors participated in the data acquisition, analysis and interpretation. All authors critically reviewed, refined and approved the manuscript.

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