J. Basic. Appl. Sci. Res., 3(4)283-291, 2013
© 2013, TextRoad Publication

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

The Effect of Gas Flaring on the Environment and its Utilization (Case Study of Selected Villages in Niger Delta Area of Nigeria)

M. Abdulkadir, A. G. Isah and Y. Sani

Department of Chemical Engineering, Federal University of Technology, Minna, Niger State, Nigeria

ABSTRACT

The effect of gas flaring involving some areas of the Niger Delta in Nigeria has been successfully carried out. Four villages were considered under this work: Aghigho, Obagi, Imeh and Edikan. An analysis of the volume of carbondioxide produced in each of the villages was carried out. The results of the analysis revealed that the effect of flaring associated gas on the environment is high based on the fact that carbondioxide, which is responsible for global warming, is released in large quantities. The least volume of carbondioxide produced was in the month of March in Aghigho and has a flare ratio of 0.15 %. The highest volume of carbondioxide produced on the other hand was in the fields of Imeh and Edikan which both had a flare ratio of 100 %. It was also observed that when the produced gas is not utilized but flared totally, the volume of carbondioxide produced is greater than the critical threshold limit value of carbondioxide (about 30,000 ppm).This is an indication that the volume of carbondioxide produced depends on the volume of gas flared. More ways of utilizing associated gas are proposed.

KEYWORDS: effect, gas flaring, Carbondioxide, Niger Delta, threshold limit, associated gas.

I. INTRODUCTION

The presence in the atmosphere of one or more contaminants in a concentration above the threshold limit value for a long period of time is injurious to human health or welfare, animal or plant life. This is referred to as air pollution. The indiscriminate discharge of industrial wastes into the atmosphere was initiated by the advent of the industrial revolution with continued global industrial growth and the alarming proportions; attention has been drawn towards the dangerous situations [3]. Gas being flared by the oil industry into the atmosphere is one of such indiscriminate discharges [8].

The option to release gas to the atmosphere by flaring is an essential practice in oil and gas production, primarily for safety reasons [14] and [12]. Gas Flaring is the controlled burning of natural gas produced in association with oil in the course of routine oil and gas production operations [6]. The availability of a flare ensures that associated natural gas can be safely disposed off in emergency and shutdown situations. Where gas cannot be stored or used commercially, flaring reduces the risk of fire and explosion. Flaring can have local environmental impacts, as well as producing emissions, which have the potential to contribute to global warming [1], [12] and [13].

Flaring emission data are often presented in terms of the two main greenhouse gases, which are produced: carbon dioxide (CO_2) and methane [9]. The type of emission produced by gas flaring depends on the type of gas flared. Sweet gas, which contains no sulphur, produces predominantly carbondioxide emissions, while sour gas, which contains sulphur, produces predominantly hydrogen sulphide emissions. Gases such as carbondioxide, sulphur dioxide, nitrogen oxide, hydrocarbons and suspended particulate matters are known to cause acid rain, Smog, depletion of ozone layer which is responsible for numerous diseases on plant, animals and human beings [2].

Flaring is both a concern to the public and a government priority because of the potential health risks and environmental concerns associated with the activity and also because it wastes a valuable non-renewable resource. The impact of gas flaring in Nigeria is of local and global environmental concern according to a recent World Bank report; Nigeria currently flares more gas than any other country in the world [11] and [17]. One of the challenges involved in addressing environmental aspects of flaring is identifying how much gas is being released.

Prior to 1999, exploration for gas in Nigeria was limited and much of the gas flared. [5] and [16] noted that about 1000 scf of gas is produced with every barrel of oil. Although, approximately 42.6 % of the associated gas was flared in 2004 versus 70 % in 1999, Nigeria flares more gas than another country in the world. Recognizing the huge financial loss resulting from the flaring of associated gas and the resultant environmental damage, the Government of Nigeria promulgated the Associated Gas Re-injection Act and the Associated Gas Re-injection (Amendment) Act in 2004, which obligated all oil producing companies in Nigeria to submit detailed plans for gas utilization. According to [4], the regulator of the Nigerian Petroleum Industry, the government’s target is to attain zero flaring by 2008 in order to reduce pollution and monetize its gas reserves. Unfortunately, this target was not met according to [9].

***Corresponding Author:** M. Abdulkadir, Department of Chemical Engineering, Federal University of Technology, Minna, Niger State. Nigeria.

Defaulting companies were given an option to pay a penalty of 20 kobo (0.22 US $ equivalent) per 28 m^3. In April 1992, the penalty rose to 50 kobo (0.03 US $ equivalent) per 28 m^3 and further to ₦10 (0.46 US $ equivalent) per 28 m^3 in January 1998. This step failed because oil and gas companies have found it convenient to simply pay the penalty perhaps because it is not seen as severe [7], [15] and [10]. It is in view of these developments that we decided to carry out this work.

Only the sweet gas would be considered, as Nigeria's crude is sulphur free. Flaring sweet gas produces carbondioxide, water vapour and methane. For the determination of the effects of gas flaring on the environment, carbondioxide data was used for the analysis. It is worth mentioning that the gases being flared can be utilized for other purposes such as electricity generation, liquefying the gas and also used for cooking gas. Harnessing flared gas can be regarded as an economic proposition. For example, methane if processed further produces acetylene, which is used for welding chemicals, ammonia for producing fertilizers etc. This serves to reduce the flaring of this dangerous gas into the atmosphere to a minimum level.

ANALYSIS OF EFFECTS OF GAS FLARING

II. MATERIALS AND METHODS

In order to analyze and determine the effect of greenhouse gases as a consequence of flaring of associated gas on to the environment, four villages where were selected namely, Aghigho, Obagi, Imeh and Edikan fields. The concentration of CO_2 generated at each field was determined and a correlation between gas flared and the volume of CO_2 gas produced was derived.

II.1. DATA

Table 2 shows the monthly gas productions in the four fields from (January – June) 2000.

II.1.1. ASSUMPTIONS

The following were the assumptions made to simplify the analysis of the gas data:

1) There was complete combustion of air (i.e. co-products during combustion are attacked by free Oxygen in the air to form (CO_2).
2) Only associated gas containing methane and the Natural gas liquids were flared. Non- associated gases were collected before flaring. For example sulphur was removed by a process known as desulphurization.
3) Mole fractions were taken as equivalent to volume fraction for gases because most gaseous fuels are a mixture of only a few chemical compounds.
4) The composition of associated gas was taken as 100% hydrocarbon content.

II.1.2. ANALYSIS

During gas flaring, there is a release of large quantities of CO_2 than other gases such as sulphur and nitrogen oxides, which are in small quantities because their concentration in associated flared gas is small. The total hydrocarbon content of associated gas is about 99%.

The composition of the major hydrocarbon is shown below in Table 1:

Table 1: Composition of associated gas in crude oil

COMPOSITION	% MASS
CH_4	47
C_2H_6	18
C_3H_8	20
C_4H_{10}	5
C_5H_{12}	9
Others	1

Alkane's burn exothermically in excess oxygen producing CO_2 and H_2O according to the equation below:

$$C_nH_{2n-2} + 3n + \frac{1}{2}O_2 \rightarrow nCO_2 + (n-1)H_2O \qquad (1)$$

If we consider burning 1m^3 of associated gas, the volume of CO_2 produced can be determined from stoichiometry as follows:

$$CH_4 + O_2 \rightarrow CO_2 + 2H_2O \qquad (2)$$

$$C_2H_6 + \frac{7}{2}O_2 \rightarrow 2CO_2 + 3H_2O \qquad (3)$$

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O \qquad (4)$$

$$C_4H_{10} + \frac{13}{2}O_2 \rightarrow 4CO_2 + 5H_2O \tag{5}$$

$$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O \tag{6}$$

II.1.3. METHOD

The results of the analysis were used to obtain the volumes of CO_2 produced in each field from stoichiometry and comparing with standards to determine its effects on the environment. The limit of volume of gas that can be flared and flare ratio for the data were also obtained.

II.1.3.1. FLARE RATIO

This the ratio of the volume of gas flared to the volume of gas produced. It is a very important ratio in determining the level of gas flared in a particular field. This was obtained in the four different fields from the months of January to June.

III. RESULT AND DISCUSSION

The flaring of associated gases has been carried out in the past for safety reasons, where other available options were not feasible [12]. Retaining these gases could cause fire outbreak and explosion. The high level presence of these gases in the atmosphere has been known to be responsible for global warming and other environmental problem faced by man.

Based on the analysis carried out on each village for different volumes of gas flared, it was observed that the volume of CO_2 (CO_2) produced varies from month to month in the villages under consideration. The measured values of CO_2 were compared against its threshold limit value (TLV standard) of CO_2 in air. It was also observed that the level of CO_2 intoxication varies in each village according to the volume of gas flared and consumed. Based on some of the assumptions considered (earlier stated), the following Table 3 was thus generated which are the data required for obtaining the volume of CO_2 produced.

AGHIGHO

From the results obtained for Aghigho as depicted in Figure 1, that the month of March was actually the month where low volumes of CO_2 were produced: about 578 ppm which is lower than the threshold limit value for outdoor CO_2 exposure. It can also be observed from the same figure that the gas produced is almost equal to that consumed. It is interesting to observe from the figure that the month of March in Aghigho has a flare ratio of about 0.15 %, which is the least. The Months of January and February recorded a CO_2 production of 24412 and 22578 ppm, respectively. These values are higher than the TLV of 5000 ppm. On the other hand, the month of June produced the highest volume of CO_2, the gas flared almost equaled the total gas flared in the previous months. The CO_2 produced in June is very high, because the because the volume of gas consumed or re-injected as compared to the gas produced is small, hence high volumes are flared resulting into high level of CO_2 exposure.

OBAGI

From Figure 2, it can be observed that the volume of CO_2 is high from the months of January to June. June recorded the highest, though. It can also be observed that almost all the gases produced is flared due to little gas consumption; hence CO_2 produced is high and above the critical TLV. The flare ratio from January to February ranged from 90-98 % as observed in the figure. This shows a high percentage of gas flared in that area.

IMEH

The gas produced from the months of January to June as presented in Figure 3 are almost equal. This shows that no gas is either consumed or re-injected, thus, the volume of gas produced was flared. The flare ratio is 100%; hence the CO_2 produced is high from January to June, about 7,000,000 m^3

EDIKAN

In Figure 4, it can be observed that the gas produced from January to June is almost equal. Also no gas was either consumed or re-injected. Hence, the CO_2 produced is well above 10,000,000 m^3. This is an indication of an un-safe area.

On the basis of the results obtained for the volumes of CO_2 produced from the months of January to June, as depicted in Tables 2 to 5 for each village. It can be concluded that the volume of CO_2 produced depends on the quantity of gas flared. It can also be observed that the volume of gas consumed or re-injected as compared to the gas produced determines the volume of CO_2 produced.

The volume of gas flared is also high compared with the TLV for CO_2 outdoor exposure. The comparison shows that for a volume of gas flared of less than 20,000 m^3, the volume of CO_2 in parts per million is lower than 5000ppm. This is an indication that there is no acute health effect. Also in most of the villages where no gas was utilized, the volume of CO_2 produced in parts per million is more than the critical TLV of about 30,000 ppm, which shows that exposure to CO_2 in these areas are responsible for severe headaches, diffused sweating, laboured breathing e.t.c.

From Tables 4 to 7 as presented in the appendices, it can be observed that the percentage of the volume of CO_2 produced from each hydrocarbon constituent of associated gas is the same irrespective of the volume of gas flared. Methane produced the highest percentage of 45% CO_2 production. Flare ratio obtained are small in Aghigho compared to the other fields as shown in Figure 1, hence the volume of Carbon dioxide produced in that field is small.

From the representation of gas data in Figures 1 to 4, it is observed that in the villages of Imeh and Edikan, no gas was consumed; resulting to all gas produced being flared. Hence, high volumes of CO_2 are produced.

According to [8], if 12% of the gas produced were re-injected, the volume of gas flared will reduce drastically. If more ways of utilizing these gases can be proposed, and more gas are consumed, gas being flared will be reduced and also the volume of CO_2 produced will fall below the threshold limit value of 5000ppm [1].

Therefore, it can be deduced that large volumes of gas (above 20,000m^3) flared has a dangerous effect on the environment; hence more ways of utilizing associated gases must be proposed.

IV. Conclusions

The effect of gas flaring on selected villages in the Niger Delta has been successfully carried out. The work showed that the effect of flaring associated gas on the environment is high based on the fact that carbon dioxide, which is responsible for global warming, is released in large quantities. The least volume of carbon dioxide produced was in the month of March in Aghigho which has a flare ratio of 0.15 %. The highest volume of carbon dioxide produced was in the fields of Imeh and Edikan which both had a flare ratio of 100 %. It was therefore concluded that the volume of gas flared determines the volume of CO_2 produced. Also, if gas should at all be flared, the volume flared must not be more than 20,000 m^3. More utilization of these associated gases will reduce these dangerous effects on the environment. In the light of this, the following recommendations are made on how to utilize the gas rather than flaring it.

Recommendation

Associated gas is natural gas produced in association with oil accumulations, either dissolved in oil or found as a cap of free gas above oil in the reservoir. If the gas is left, it will cause fire or explosion, hence the need for it to be utilized or flared. Nigeria of her estimated over 120 trillion cubic feet of natural gas reserves currently flares about 2 billion standard cubic meter of gas [4]. The gas consists of methane and the Natural gas liquids such as ethane, propane, pentane and butane. Methane gas for instance, if further treated can be used as feedstock for:-

1. Acetylene used in welding chemicals
2. Ammonia used in Fertilizer, plastics, explosives
3. Methanol used in Adhesives, fuel, polyesters fibres
4. Carbon Black used in Tyre, rubber, paint, and printing ink.
5. Oxo Alcohols used in detergents and lubricants
6. Hydrogen cyanide used in nylon
7. Iron-Ore Reduction used in iron and steel

The natural gas liquids have high market values can find applications either in their raw forms as solvents, feedstock for production of various chemicals and liquid fuels or fractionated into their components.

For the effective or complete utilization of associated gas, the following are hereby recommended: -

- Government and other relevant stakeholders should encourage small industries that will make use of the associated gases e.g. methane and natural gas liquids for various purposes as stated above. This can be achieved by establishing NGL extraction plants. Also industries such as the power generating company, fertilizer Company, aluminum and steel plants and other small industries can be encouraged to use gas as their major source of fuel.
- Government should ensure that its plan to raise domestic consumption of gas and eliminate flaring in the country by 2008 should still be enforced despite missing the target. Companies that do not meet the deadline should be made to pay much higher fines.
- Government should encourage independent ownership of natural gas distribution systems that will purchase natural gas from Natural Gas Company's at various city gates and distribute the gas through pipelines for sale to domestic and industrial consumers in a specified area. Also gas could be distributed as Compressed Natural Gas (CNG) using tube trailers to users who may not be within easy reach or close enough to the existing gas facilities.
- The use of gas should be encouraged as an energy source in the home and industries as it will go a along way not only to reduce gas flaring but also solve the problems of deforestation.
- Existing Technology that is being used over the world should be looked into such as the gas to liquid conversion technology, mason power generation plant e.t.c.

- Allowances should be made in fiscal and gas pricing policies and in operating agreements to ensure the price is right for the consumer and the supplier. This will therefore allow investments to flourish, i.e. harnessing flared gas should be made an economic proposition.
- Oil companies should include gas collection facilities to all fields and installation of pipeline network that will link the gas station to process industries for industrial utilization of gas.
- Oil companies should also try and re-inject gas back into the ground where technically possible, and should selectively close oil wells that produce high proportions of gas.

REFERENCES

[1] J. Argo, Unhealthy effects of upstream oil and gas flaring, (http://www.sierraclub.ca/national/oil-and-gas-exploration/soss-oil-and-gas-flaring.pdf, 2001)

[2] Anonymous, (2002). Retrieved June 5 2004 from Exploration & Petrochemical Consultancy Associates

[3] P. Commery, Special report oil and gas: major projects in Africa, New African, 2002).

[4] DPR, Department of Petroleum Resources, Nigeria, Nigeria Gas Resources and Investment Opportunities, (DPR Report, 2003)

[5] I. Egbert, Why we must turn to gas, (Nigerian Oil and Gas monthly journal, pp. 11-12, September, 1998)

[6] M. D. John, Encyclopedia of Science and Technology, 5th ed., Vol. 4, (McGraw-Hill, USA, pp. 647, 1982)

[7] B. Manby, The price of oil: corporate responsibility and human rights violations in Nigeria's oil producing communities, (Human Rights Watch, New York, pp.202, 1999)

[8] Mbendi, (http://www.mbendi.co.za/index.htm, 2000)

[9] NNPC, Report on Operations of Nigerian National Petroleum Corporation, Lagos, Nigeria, (2002)

[10] M. T. Odubela, and I. Omoniyi, Compliance monitoring in Nigeria's industries, 4th International Conference on Environmental Enforcement, Chiang Mai, Thailand, (April 22-26, 1996)

[11] G. O. Onosode, Keynote address presented at the international seminar on the petroleum industry and the Nigerian environment in Port Harcourt (1996).

[12] D. Shore, Making the flare safe, Vol. 9, No. 6, (Journal of Loss Prevention in Process Industries, pp. 363-381, 1996)

[13] K. R. Smith, Fuel emission, health and global warming, a paper presented at the United Nations Food and Agriculture Organization's Regional Wood Energy Development Programme meeting on wood energy, climate, and health, (Phuket, Thailand, October, 1999)

[14] SPDC, Shell Petroleum Development Company of Nigeria Limited, People and the environment annual report, (SPDC, Nigeria, pp. 52, 2002)

[15] J. A. Sonibare and F. A. Akeredolu, National gas domestic market development for total elimination of routine flares in Nigeria's upstream petroleum operations, Vol. 34, (Energy Policy, pp. 743-753, 2006)

[16] I. O. Stanley, Gas-to-Liquid Technology: Prospect for natural gas utilization in Nigeria, Vol. 1, (Journal of Natural Gas Science and Engineering, pp. 190-194, 2009)

[17] World Bank report, a twelve year record of national and global gas flaring volumes estimated using satellite data, (http:// www.worldbank.org/ogmc/global_gas.htm, 30 May, 2007).

Authors Information

Dr. M. Abdulkadir is an indigene of Sokoto State, Nigeria. His educational background is as follows:
B. Eng (Chemical Engineering) from the Federal University of Technology, Minna, Niger State, Nigeria (1998-2004)
M. Sc (Oil and Gas Engineering) from the Robert Gordon University, Aberdeen, United Kingdom (2006-2007)
PhD (Chemical Engineering) from the University of Nottingham, United Kingdom (2008-2011)
He is both an Associate member Institution of Engineering and Technology (AMIET) and Institution of Chemical Engineers (AMIChemE)

Dr. A. G. Isah is an indigene of Niger State, Nigeria. His educational background is as follows:
B. Eng and M.Eng (Chemical Engineering) from the Federal University of Technology, Minna, Niger State, Nigeria

PhD (Chemical Engineering) from the Federal University of Technology, Minna, Niger State, Nigeria. He undertook a one year M.Phil research for his PhD at the University of Birmingham, United Kingdom, 2013.
He is a Corporate Member, Nigerian Society of Engineers (NSE).

Dr. Y. Sani is an indigene of Federal Capital Territory (FCT), Nigeria. His educational background is as follows:
B. Sc (Geography) from the University of Abuja, FCT, Nigeria
M. Sc (Remote Sensing) from University Putra Malaysia (2005-2007)
PhD (Remote Sensing) from the University of Nottingham, United Kingdom (2009-2012.)
He is an Associate Member of American Society for Photogrammetry and Remote Sensing, Royal Geographical Society, UK, Institute of Environmental Management and Assessment, UK.

APPENDIX A

Table 2 present the monthly gas productions and utilization for the months of January to June from AGHIAHO, OBAGI, IMEH, and EDIKAN fields.

Table 2

Monthly Gas Productions and Utilization (Associated gas) $(\times 1000m^3)$

FIELD	AGHIAHO	OBAGI	IMEH	EDIKAN
JANUARY				
GAS PRODUCED	343.43	21469	5257.74	6887.10
GAS CONSUMED	314.14	730.82	0.00	0.00
GAS RE-INJECTED	0.00	0.00	0.00	0.00
GAS FLARED	29.29	20738.18	5257.74	6887.10
FEBRUARY				
GAS PRODUCED	355.13	11731.85	4986.63	7283.40
GAS CONSUMED	328.04	506.83	0.00	0.00
GAS RE-INJECTED	0.00	0.00	0.00	0.00
GAS FLARED	27.09	11225.02	4986.63	7283.40
MARCH				
GAS PRODUCED	461.07	13414.40	4545.47	7708.90
GAS CONSUMED	460.38	817.04	0.00	0.00
GAS RE-INJECTED	0.00	0.00	0.00	0.00
GAS FLARED	0.69	12597.36	4545.47	7708.90
APRIL				
GAS PRODUCED	536.32	13737.03	5443.15	7432.40
GAS CONSUMED	431.29	794.03	0.00	0.00
GAS RE-INJECTED	0.00	0.00	0.00	0.00
GAS FLARED	105.03	12943	5443.15	7432.40
MAY				
GAS PRODUCED	636.00	25564.50	5115.7	7433.3
GAS CONSUMED	439.90	850.60	0.00	0.00
GAS RE-INJECTED	0.0	0.0	0.00	0.00
GAS FLARED	196.10	24713.90	5115.7	7433.3
JUNE				
GAS PRODUCED	1252.20	40779.93	5003.66	6838.8
GAS CONSUMED	410.58	744.44	0.00	0.00
GAS RE-INJECTED	0.00	0.00	0.00	0.00
GAS FLARED	841.62	40035.49	5003.66	6838.8

Based on some of the assumptions stated earlier, the following table was generated which are the data required for obtaining the volume of CO_2 produced.

Table 3

Data for the combustion of 1m^3 of associated gas

Composition	% Mass	Mass	Molecular Mass	No of Moles	Mole fraction	% Mole/ Volume	Volume of CO_2
CH_4	47	47.47	16	2.97	0.70	70	0.70
C_2H_6	18	18.18	30	0.61	0.14	14	0.28
C_3H_8	20	20.20	44	0.46	0.11	11	0.33
C_4H_{10}	5	5.05	58	0.09	0.02	2	0.08
C_5H_{12}	9	9.10	72	0.13	0.03	3	0.15
Total	99	100		4.26	1.00	100	1.54

The volume fractions were assumed to be equivalent to mol fractions for gases, up to moderate pressures. The data obtained were analyzed and the volume of CO_2 obtained from each hydrocarbon constituent of associated gases for each field are as shown in Tables 4 to 7

Table 4
CO_2 gas produced from associated gas flared in AGHIGHO (m^3)

ASSOCIATED GAS	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	TOTAL
JANUARY						
GAS FLARED	20.5030	4.1006	3.2219	0.5858	0.8787	29.2900
CO_2 PRODUCED	20.5030	8.2012	9.6657	2.3432	4.3935	45.1066
FEBRUARY						
GAS FLARED	18.9630	3.7926	2.9799	0.5418	0.8127	27.0900
CO_2 PRODUCED	18.9630	7.5852	8.9397	2.1672	4.0635	41.7186
MARCH						
GAS FLARED	0.4830	0.0966	0.0759	0.0138	0.0207	0.6900
CO_2 PRODUCED	0.4830	0.1932	0.2277	0.0552	0.1035	1.0626
APRIL						
GAS FLARED	73.5210	14.7042	11.5533	2.1006	3.1509	105.0300
CO_2 PRODUCED	73.5210	29.4084	34.6599	8.4024	15.7545	161.7462
MAY						
GAS FLARED	137.2700	27.4540	21.5710	3.9220	5.8830	196.1000
CO_2 PRODUCED	137.2700	54.9080	64.7130	15.6880	29.4150	301.9940
JUNE						
GAS FLARED	589.1340	117.8268	92.5782	16.8324	25.2486	841.6200
CO_2 PRODUCED	589.1340	235.6536	277.7346	67.3296	126.2430	1296.0948

Table 5
CO_2 gas produced from associated gas flared in OBAGI (m^3)

ASSOCIATED GAS	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	TOTAL
JANUARY						
GAS FLARED	14516.7260	2903.3452	2281.1998	414.7636	622.1454	20738.1800
CO_2 PRODUCED	14516.7260	5806.6904	6843.5994	1659.0544	3110.7270	31936.7972
FEBRUARY						
GAS FLARED	7857.5140	1571.5028	1234.7522	224.5004	336.7506	11225.0200
CO_2 PRODUCED	7857.5140	3143.0056	3704.2566	898.0016	1683.7530	17286.5308
MARCH						
GAS FLARED	8818.1520	1763.6304	1385.7096	251.9472	377.9208	12597.3600
CO_2 PRODUCED	8818.1520	3527.2608	4157.1288	1007.7888	1889.6040	19399.9344
APRIL						
GAS FLARED	9060.1000	1812.0200	1423.7300	258.8600	388.2900	12943.0000
CO_2 PRODUCED	9060.1000	3624.0400	4271.1900	1035.4400	1941.4500	19932.2200
MAY						
GAS FLARED	17299.7300	3459.9460	2718.5290	494.2780	741.4170	24713.9000
CO_2 PRODUCED	17299.7300	6919.8920	8155.5870	1977.1120	3707.0850	38059.4060
JUNE						
GAS FLARED	28024.8430	5604.9686	4403.9039	800.7098	1201.0647	40035.4900
CO_2 PRODUCED	28024.8430	11209.9372	13211.7117	3202.8392	6005.3235	61654.6546

Table 6
CO_2 gas produced from associated gas flared in IMEH (m^3)

ASSOCIATED GAS	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	TOTAL
JANUARY						
GAS FLARED	3680.4180	736.0836	578.3514	105.1548	157.7322	5257.7400
CO_2 PRODUCED	3680.4180	1472.1672	1735.0542	420.6192	788.6610	8096.9196
FEBRUARY						
GAS FLARED	3490.6410	698.1282	548.5293	99.7326	149.5989	4986.6300
CO_2 PRODUCED	3490.6410	1396.2564	1645.5879	398.9304	747.9945	7679.4102
MARCH						
GAS FLARED	3181.8290	636.3658	500.0017	90.9094	136.3641	4545.4700
CO_2 PRODUCED	3181.8290	1272.7316	1500.0051	363.6376	681.8205	7000.0238
APRIL						
GAS FLARED	3810.2050	762.0410	598.7465	108.8630	163.2945	5443.1500
CO_2 PRODUCED	3810.2050	1524.0820	1796.2395	435.4520	816.4725	8382.4510
MAY						
GAS FLARED	3580.9900	716.1980	562.7270	102.3140	153.4710	5115.7000
CO_2 PRODUCED	3580.9900	1432.3960	1688.1810	409.2560	767.3550	7878.1780
JUNE						
GAS FLARED	3502.5620	700.5124	550.4026	100.0732	150.1098	5003.6600
CO_2 PRODUCED	3502.5620	1401.0248	1651.2078	400.2928	750.5490	7705.6364

Table 7
CO_2 gas produced from associated gas flared in EDIKAN (m^3)

ASSOCIATED GAS	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	TOTAL
JANUARY						
GAS FLARED	4820.9700	964.194	757.581	137.742	206.613	6887.1000
CO_2 PRODUCED	4820.9700	1928.3880	2272.7430	550.9680	1033.0650	10606.134
FEBRUARY						
GAS FLARED	5098.3800	1019.6760	801.1740	145.6680	218.5020	7283.4000
CO_2 PRODUCED	5098.3800	2039.3520	2403.5220	582.6720	1092.5100	11216.4360
MARCH						
GAS FLARED	5396.2300	1079.2460	847.9790	154.1780	231.2670	7708.9000
CO_2 PRODUCED	5396.2300	2158.4920	2543.9370	616.7120	1156.3350	11871.7060
APRIL						
GAS FLARED	5202.6800	1040.5360	817.5640	148.6480	222.9720	7432.4000
CO_2 PRODUCED	5202.6800	2081.0720	2452.6920	594.5920	1114.8600	11445.8960
MAY						
GAS FLARED	5203.3100	1040.6620	817.6630	148.6660	222.9990	7433.3000
CO_2 PRODUCED	5203.3100	2081.3240	2452.9890	594.6640	1114.9950	11447.2820
JUNE						
GAS FLARED	4787.1600	957.4320	752.2680	136.7760	205.1640	6838.8000
CO_2 PRODUCED	4787.1600	1914.8640	2256.8040	547.1040	1025.8200	10531.7520

Table 8
Flare ratios of the various fields
The flare ratio obtained in the various field is given below in percentage

FIELD	AGHIAHO	OBAGI	IMEH	EDIKAN
JANUARY				
FLARE RATIO	9%	97%	100%	100%
FEBRUARY				
FLARE RATIO	8%	96%	100%	100%
MARCH				
FLARE RATIO	0.15%	94%	100%	100%
APRIL				
FLARE RATIO	20%	94%	100%	100%
MAY				
FLARE RATIO	31%	97%	100%	100%
JUNE				
FLARE RATIO	67%	98%	100%	100%

APPENDIX B

Figures 1 to 4 present representations of gas data for the months of January to June as obtained from fields AGHIGHO, OBAGI, IMEH and EDIKAN.

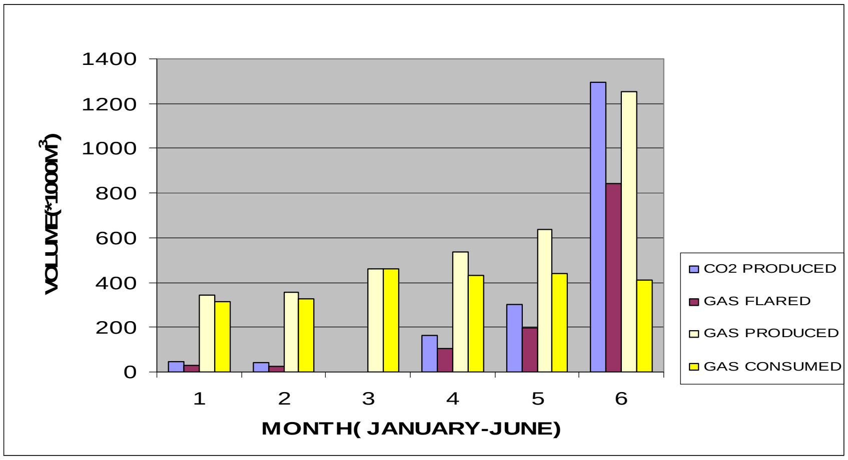

Fig.1: Representation of gas data in AGHIAHO Field

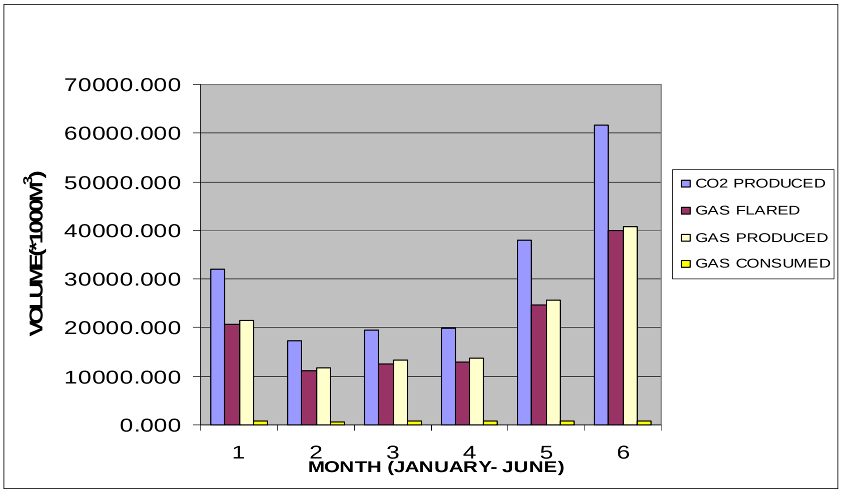

Fig. 2: Representation of gas data in OBAGI Field

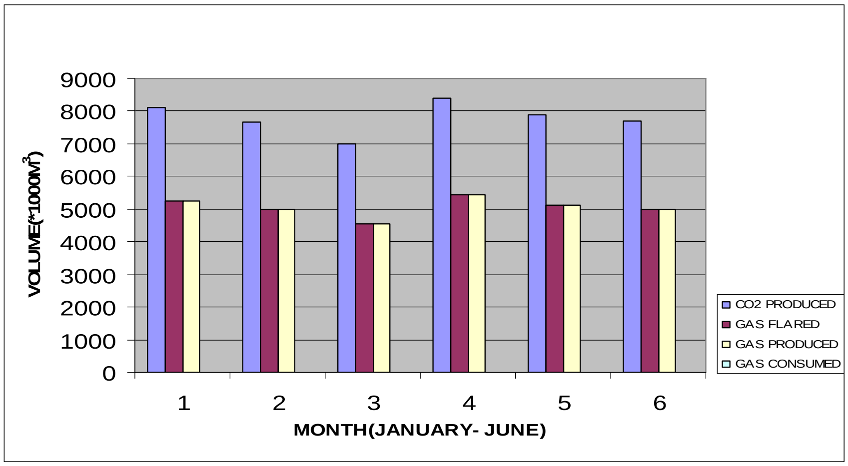

Fig. 3: Representation of gas data in IMEH Field

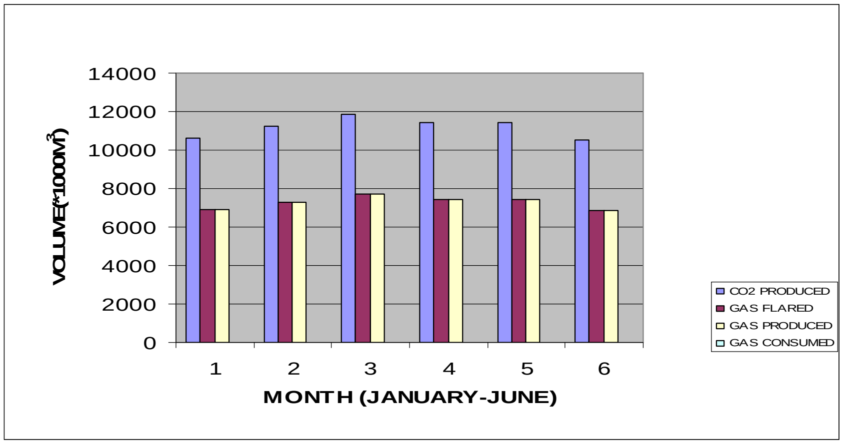

Fig. 4: Representation of gas data in EDIKAN Field