

Impact Of Khartoum Refinery Gaseous By-Products On The Environment

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ABSTRACT

Sudan has become one of the oil producing countries since 2000 . Petroleum as an energy source represents 16 % of the energy balance of the country. The processes of prospecting, transportation, refining and utilization of petroleum may have serious negative impacts on the environment. This study focuses on the determination of the nature and concentration of the main gases ensuing during the process of oil refining, at Khartoum Refinery. Also, investigation into means and ways adopted by the Refinery to reduce the negative impact of gaseous by-products on the environment are reviewed. The gaseous by- products analyzed include SO₂, NO_x and CO. It is found that the analytical results of the gaseous by -products are compatible with the Chinese, Global Bank Guide and The Sudanese Standards.. However, the methods adopted in controlling the pH and the chemical oxygen demand needs revising. Some recommendations are proposed in order to curb the impact of this industry on the environment.

Keywords: Khartoum Refinery, Refinery gaseous by products, Refinery geaseous management , Refinery gaseous Environmental Impact.

1. Introduction

There is increasing concern among scientists and decision-makers about the negative impact created by the use of various types of energy on the environment. Problems of desertification, global heating, climatic changes and drought surmount the deleterious impacts of these activities. Since energy is inevitable in everyday life and in agricultural and industrial activities; and that the need for it is continual, great attention is nowadays being directed towards research into the deleterious impacts of energy use on the environment. The seeking of ways and means for reducing such impacts is becoming of paramount importance. Sudan has become one of the oil producing countries since 2000. Petroleum as an energy source represents 16 % of the energy balance of the country. Taking into account the petroleum industry benefits to the economy of Sudan and the expected amelioration of life standards of its people, the processes of prospecting, exploration, transportation, refining and utilization of petroleum may have serious negative impact on the environment. This study concentrated on determining gaseous by-products at Khartoum Refinery and its impact to the surrounding environment. Samples were tested at the Khartoum Refinery lab equipment official laboratory, permission was given because there was none specialization laboratory in gas monitoring in Khartoum except the refinery labs. Obtained results were compared with Chinese and Sudanese Standards set up for the Refinery by-products.

1.1 The Literature Review

(Hassan, 1981) wrote an M.Sc. thesis on the traffic and noise pollution in central Khartoum city area .The thesis focused on air pollutants such as carbon monoxide and sulphur dioxide and their effects on human beings. (Van, 1982) investigated the air pollution control methods and equipment in the oil

refining industry. (Bakhiet, 1999) studied the effects of the liquid petroleum gas as an engine fuel in Khartoum State. (Mining, 2014) The Ministry of Energy and Mining wrote a general report on the impact of petroleum industry on the environment .The report surveyed the general aspects of the impact without details or emphasis on the gaseous products of the refining process. The Institute of Environmental Studies (Studies, 2014) published the proceedings of the seminar on "Health Education". The seminar dealt with acid rain, greenhouse effect and the gaseous pollutants like NO_x, SO₂ and CO.

1.2 Khartoum Refinery Company (KRC)

Khartoum Refinery Company limited (KRC) is a joint venture between the Chinese National Petroleum Corporation (CNPC) and the Ministry of Energy and Mining (MEM) of Sudan, each holding fifty percent of the shares. The joint venture agreement of the Refinery was signed in March, 1997 and the construction was officially started in May 1998. The plant was formally put into production in 2000, with annual output of 2.2587 metric tons /year. This study focuses on the gaseous pollutants emanating from the Khartoum Refinery situated at Al Gaili town, about 4 Km from Khartoum the Capital of Sudan and flowing directing to the river during the processes of oil refining. (Abdelmoneim, 2015)

1.3 Refinery main production

The annual output is 2.2587 million tons (mt) of oil products such as gasoline, jet fuel, diesel (naphtha), fuel oil, liquefied gas (LPG), kerosene and benzene (mogas). Among them the gasoline is unleaded; the diesel is of high quality with low sulphur, low aromatics and light colour. Due to its low Sulphur content, Liquid Petroleum Gas (LPG) is a clean fuel satisfying the environment protection requirements.

1.4 The Environmental Impact of gaseous by products

This work focuses on the gaseous pollutants, namely nitrogen oxides, sulphur dioxide, sulphur trioxide and carbon monoxide produced during oil refining at the Refinery. All the above, so called, green house gases pollute the atmosphere during combustion of petroleum products, whether during transportation, electricity generation or during crude oil refining. The main stream view among the scientific community is that increase in the emission of green house gases will lead to rise in global temperature beyond normal levels. Over 50% of these gases are produced from the combustion of fossil fuels. The consequences of higher temperatures will lead to gradual rise in sea level as well as in changes in global climate, which could result in the flooding of many coastal areas and disruption of various agricultural schemes (e.g. Institute of Environmental Studies, 2002).

In the following account the negative impact of these gases will be reviewed.

1.4.1 Carbon monoxide

It is a colorless, odourless gas of molecular weight 28 and specific gravity the same as that of air. Carbon monoxide affects human and animal health by combining more readily than oxygen with the haemoglobin in the red blood cells. This reduces the normal supply of oxygen to the body tissues. However, the resultant oxygen deficiency is reversible, but sometimes-severe exposures may not be reversible.

The effect of carbon monoxide on humans is categorized as acute or chronic. Acute effects depend on the concentration of carbon monoxide, length of time of exposure, the degree of exertion and personal susceptibility.

Exposure to carbon monoxide for 10-45 minutes in a concentration of 10,000 ppm leads to unconsciousness and death. Levels of carbon monoxide concentration between 100 and 10,000 ppm for 3-15 minutes can cause headache, dizziness and nausea. At lower levels, although no obvious symptoms occur, possible effects on the central nervous system may in some cases lead to impaired vigilance or delayed reaction time (Hassan, 1981).

1.4.2 Sulphur dioxide

It is a colorless, irritant gas having a characteristic odour and taste and a molecular weight of 64.07. An average individual can detect Sulphur dioxide concentrations of 0.3 to 1 ppm by taste rather than smell. A concentration of 3 ppm has an easily detectable odour. Concentrations of 6-12 ppm in the atmosphere cause immediate irritation to the nose and throat. Irritation of the eyes occurs at a concentration of about 20 ppm. If inhaled, the gas dissolves readily and affects the upper respiratory tract. In acute cases it may cause odema of the lungs and respiratory paralysis. Chronic effects on the senses of smell and taste are likely to occur on exposure for a period of over a year to variable concentrations from 30 ppm with occasional peaks of 100 ppm. The maximum permissible average concentration for ambient air three hours is 0.5 ppm, while the maximum permissible for 24 hours is 0.14 ppm; and the permissible annual arithmetic mean is 0.03 ppm (Hassan, 1981).

1.4.3 Nitrogen oxides

Nitrogen combines with oxygen to form the most common of the conventional pollutants - oxides of nitrogen (NO_x) indoors exposures occur because NO_x is produced in unventilated rooms where gas-fires, stoves, as well as kerosene heaters are used.

In fact NO_x is a threat to human and animal health as follows:-

- Exposure to high levels of NO_x commonly impairs lung defenses to common infections.
- Long-term studies indicated that exposures to high levels of NO_2 can lead to chronic respiratory bronchiolitis by impairing the expiratory flow rate. This effect is reversible if the level of NO_2 exposure is reduced.
- Acute exposures to high levels of NO_2 may cause changes within the lung that, in turn, could increase bronchial responsiveness, particularly in asthmatics.
- Any inhaled substance (including NO_2) that can cause an inflammatory response, will enhance the susceptibility to allergens.
- Animals exposed to NO_x are less able to ward off bacterial infections.
- NO_x affects ozone layer. Fine particles and acids require strict controls to minimize death and serious illness.

2. Objectives/Purpose of the study

1. To study of the nature and concentration of the various gases ensuing during the processes of refining at Khartoum Refinery.
2. To review methods of treatment and management procedure followed by Khartoum Refinery in decreasing pollutants to the minimum possible level.
3. To propose recommendations to curb any possible environmental hazards.

3. Methodology

Khartoum Refinery Gaseous By Products

Location and accessibility of the study area

The Khartoum Refinery is located on a semi rocky-desert land 15 km Northeast of Al-Gaili village, and about 12 km. East of the River Nile (Fig. 1). Small villages are scattered around the Refinery area whose inhabitants are mainly farmers and shepherders, either illiterate or having incomplete primary education. However, some young men work as casual labourers in the Refinery (Mining, 2014)

3.1 The Refinery Units

The Refinery consists of the following production units (Mining, 2014):

- Crude Distillation Unit (CDU), capacity: 2.5 mt/y, consisting of an electric desalter and crude distillation products refining.
- Residual Fuel Oil Catalytic Cracking Unit (RFCC), capacity: 1.8 m t/y, consisting of reaction and regeneration, distillation, absorption and stabilizatin, energy recovery, Sulphur and mercaptan removal sections.
- Reforming Unit, capacity: 150000 t/y and consisting of pre-treatment and reforming sections.
- Diesel Hydro Treating Unit (DHT), capacity: 500000 t/y, consisting of hydrogen recovery and diesel hydrogenation sections.

- Sour Water Stripping Unit, capacity: 400000 t/y. Utilities include: a power plant, a waste water plant, an air separation and compression unit and a river water purification plant (1500 m³/h). (Abdelmoneim, 2005, 2015)

4. Process Description

4.1 The Refinery Gaseous by products

It is expected that the Refinery can cause gaseous and liquid pollution ,bad smells and noise .The major gas pollutants include hydrocarbon vapours, nitrogen oxides, Sulphur dioxide, Sulphur trioxide, hydrogen sulphide and carbon monoxide (Mining, 2014) The major potential sources of some gaseous effluents from the Refinery are shown in Table 1.

- This study monitored nitrogen oxides, Sulphur dioxide and carbon monoxide.
- The measured was taken during the period 2/August/2014 to 24/August/2014.
- Using the records adopted by Khartoum Refinery Company in the Gaseous laboratory. The researcher asked for permission to record the analysis by (KRC) because there are no gases laboratory specialist in Refinery by product at Khartoum.

- Daily records was obtained at 12.00 pm mid-day directly from the screen device. The methodology revised the method applied by Khartoum Refinery Company, The Nile Blende Crude Oil contains about 0.04-0.06 wt % sulphur, ending up in the sour water coming from the Crude Distillation Unit overheads (CDU), Residual Fuel-oil Catalytic cracking unit Condensates (RFCC) and The Diesel Hydro Treating Unit (DHT). It is degassed as H₂S at the Sour Water Stripping Unit which has a capacity of 0.4 mt/y . The H₂S obtained is then sent straight to the flare. In addition to that, the Nile Blende Crude Oil contains only traces of nitrogen. The gas is stripped from the collected waste sour water at the Waste Water Stripping Unit where it is transformed into NH₃ gas and later mixed with water to form ammonia liquid and the CO gas coming from the combustion of crude oil in CDU and RFCC is burnt in the flare.
- The results were presented in tables and figures
- The results were compared and discussed in accordance to Sudanese, Global Bank and Chinese Standards for Refinery Gas Monitoring.
- A set of conclusion was written.



Refinery at sunset



Crude distillation Unit (CDU)



Residual oil catalytic cracking Unit (RFCC) .
and Reforming Unit(REF)



Distillation Columns Building (DCS)
(Fr actionator)



Tanks of Liquid petroleum gaz.
(Spherical tanks)

Figure 1: Showing the Refinery and its main units

Table 1: Main gaseous effluents from the Refinery

Effluents	Potential sources
SO ₂ , SO ₃ , H ₂ SO ₄	Combustion furnaces and boilers, H ² S flares, catalyst regenerators heating System
hydrogen sulphide	Vent from CDU, deSulphurizer plant, waste water
Hydrocarbons	Flares, storage tanks, sampling operations, open effluent water separators ,catalyst regenerators
Carbon monoxide	Catalyst regenerators, decocking operation, motor-driven compressors
Dusty materials	Catalyst regenerators, combustion in boilers and Furnaces, decocking
Nitrogen oxide	Combustion processes , flares, catalyst regeneration
Bad smelling gas	Storage tanks, open waste water separators, Plant sections

Source: (Mining, 2014)

4.2 Analytical equipment

See appendix-1 for the equipment

This work is concerned with the analysis of the gaseous by-products, resulting from crude oil refining at Khartoum Refinery. The gaseous by- products analyzed include SO₂, NO_x and CO. These were analyzed at the Refinery laboratories using SO₂ analyzer (for SO₂ determination), NO_x analyzer (for NO_x determination) and CO analyzer (for CO determination).

The measurements were taken during the period 02/August/2014 to 24/August /2014 when NO_x, SO₂ and CO were recorded at midday as average readings. During the field visits, the results of the analysis are read off directly from the smart screen attached to each device.

SO₂, NO_x and CO were analyzed using the following monitor lab analyzers at Khartoum Refinery Company (KRC):

- ML 9850-sulphur dioxide analyze.
- Carbon Monoxide analyzer.
- Nitrogen oxides analyzer, (See Appendix-1)

The measurements were taken during the period 2/August/2014 to 24/August/2014 when SO₂, NO_x and CO were recorded midday as average readings.

5. Result/Findings

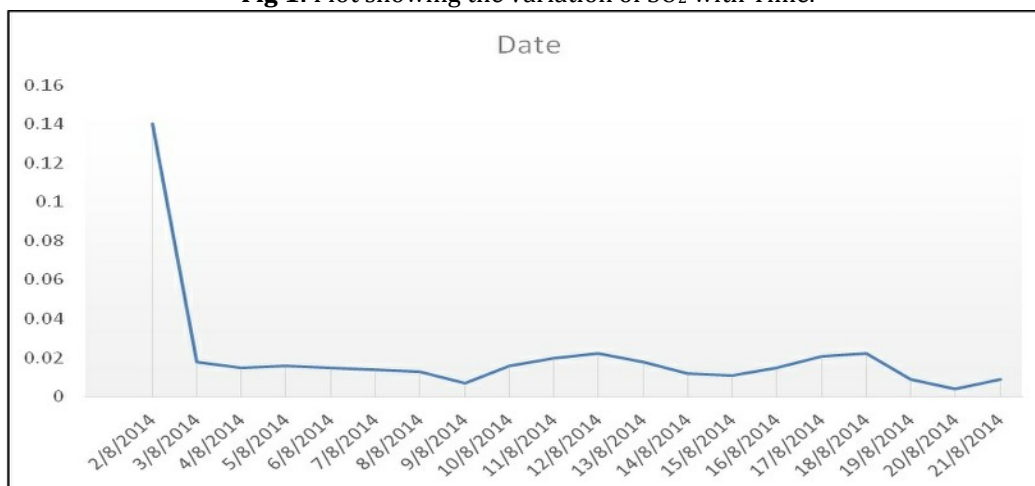
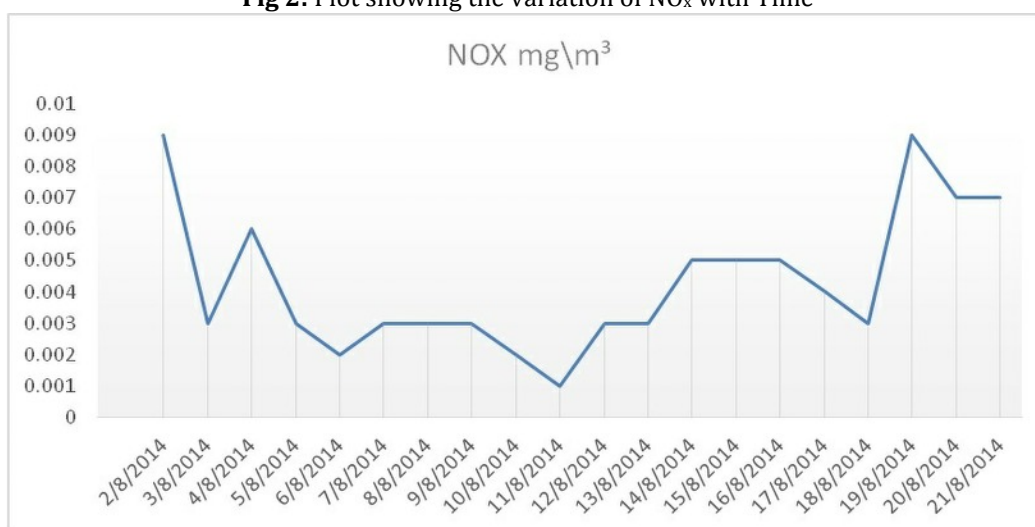
1. Table 2 shows the results of analyses of the gases SO₂, NO_x and CO. The records was done during the period 2/08/2014 to 24/08/2014. Using the equipment available on Khartoum Refinery Company, which had screen. The records was taken at 12.00 pm at mid-day.
2. The SO₂ values range between 0.004 mg/m³ and 0.14 mg/m³, with the majority of readings falling between 0.11 and 0.18 mg/m³. Comparing the result by Chinese, Sudanese and the Glogal Bank standards for

gaseous by-products the result was compatible to the maximum level of the standards which are: 0.25 mg/m³, 0.35 mg/m³ and < 0.04 ppm respectively.

3. The NO_x values range between 0.001mg/m³ and 0.009mg/m³, with about 70% of the analyses ranging between 0.003-0.007 mg/m³. Comparing the result by Chinese, Sudanese and Glogal Bank standards for gaseous by-products the result was compatible to the maximum level of the standards which are: 0.15 mg/m³, 0.40 mg/m³ <0.40 respectively.
4. On the other hand, the CO values range between 0.15 mg/m³ and 0.49 mg/m³, with about 60% of the readings falling between 0.21-0.34 mg/m³. Comparing the result by Chinese, Sudanese and Global Bank standards for gaseous by-products, the result was compatible to the maximum level of the standards, which are 6.00 mg/m³, 10.00 mg/m³ and 10.00 mg/m³. respectively.
5. On the other hand it was founds that the instruments need maintaining and upgrading to the most efficient equipment's (see appendix-1).
6. On addition to that, the instrument (data sheet) should be available on the gaseous laboratory.
7. The study recommended increasing the plantation around and inside the refinery and make a green buffer zone between the employee housing compound and the refinery process and working areas.

Table 2 on the appendix: Results of gaseous analysis using Monitor Lab Analysers.

The temporal variations in the SO₂, NO_x and CO contents graphically represented in Figs. 1, 2 and 3, respectively.

Fig 1: Plot showing the variation of SO₂ with Time.**Fig 2:** Plot showing the variation of NO_x with Time**Fig 3:** Plot showing the variation of CO with Time

6. Discussion

As mentioned earlier the gases SO₂, NO_x and CO liberated during petroleum distillation at Khartoum Refinery were analysed in the period from 2/08/2014 to 24/08/2014. The analysis was taken directly from smart screen in the instruments inside gaseous labs during this period. The

Chinese standards have been applied in the design construction and processing technology at Khartoum Refinery. However, the results of the analyses will be discussed in the light of the Chinese Standards, the Global Bank Guide for Air Quality and the Sudanese Standard Limit for Gaseous Emissions from petroleum refining.

6. Discussion

As mentioned earlier the gases SO₂, NO_x and CO liberated during petroleum distillation at Khartoum Refinery were analysed in the period from 2/08/2014 to 24/08/2014. The analysis was taken directly from smart screen in the instruments inside gaseous labs during this period. The Chinese standards have been applied in the design construction and processing technology at Khartoum Refinery. However, the results of the analyses will be discussed in the light of the Chinese Standards, the Global Bank Guide for Air Quality and the Sudanese Standard Limit for Gaseous Emissions from petroleum refining.

6.1. The SO₂ gas

Table 2 shows the results of analyses of the gases SO₂, NO_x and CO. The SO₂ values range between 0.004 and 0.14 mg/m³, with the majority of the readings falling between 0.11 and 0.18 mg/m³.

Comparing these results with the Chinese standards shown in (Table 3), the maximum permissible limit of SO₂ emission is 0.25 mg/m³; while it is <0.04ppm in the Global Bank Guide (Table 4), and 0.36 mg/m³ in the Sudanese Standards (Table 5).

So the SO₂ emission levels are compatible with those standards and consequently, there are no serious SO₂ levels

emitting from the Refinery. However, The Nile Blende Crude Oil contains about 0.04-0.06 wt % sulphur, ending up in the sour water coming from the Crude Distillation Unit overheads (CDU), Residual Fuel- oil Catalytic cracking unit Condensates (RFCC) and The Diesel Hydro Treating Unit (DHT). It is degassed as H₂S at the Sour Water Stripping Unit which has a capacity of 0.4 mt/y. The H₂S obtained is then sent straight to the flare.

6.2 The NO_x gases

NO_x values range between 0.001 and 0.009 mg/m³, with about 70% of the results falling between 0.003 and 0.007 mg/m³. Comparing these results with the Chinese standards (Table 3), the maximum permissible limit of NO_x emission is 0.15 mg/m³; while it is <0.05ppm in the Global Bank Guide (Table 4) and 0.40 mg/m³ in the Sudanese Standards (Table 5). So the NO_x standards and consequently there are no serious levels of NO_x emitting from the Refinery. In fact, the Nile Blende Crude Oil contains only traces of nitrogen. The gas is stripped from the collected waste sour water at the Waste Water Stripping Unit where it is transformed into NH₃ gas and later mixed with water to form ammonia liquid.

6.3 CO gas

CO values range between 0.15 and 0.49 mg/m³, with about 60% of the analyses falling between 0.21 and 0.34 mg/m³.

Table 3: Chinese standards used for SO₂, NO_x and CO gases

Parameter	Hazardous limit for humans
SO ₂	0.25 mg/m ³
NO _x	0.15 mg/m ³
CO	6.00 mg/m ³

Table 4: Global Bank Guide for Air Quality (Mining, 2005)

Parameter	Hazardous limit for humans
SO ₂	<0.04 ppm
NO _x	00.05 ppm (24 hrs)
CO	10.00 ppm (8 hrs)

Table 5: Sudanese Standards Limits of Gaseous Emissions Resulting From Petroleum Refining (Mining, 2005)

Parameter	Hazardous limit for humans
SO ₂	00.36 mg/m ³
NO _x	00.40 mg/m ³
CO	10.00 mg/m ³

Table 6: Comparison of the Maximum values determined for SO₂, NO_x and CO gases with the Chinese, the Global Bank Guide and the Sudanese Standards. (Mining, 2005)

Parameter	Maximum Value mg/m ³	Chinese Standards mg/m ³	Sudanese Standard mg/m ³	Global bank guide ppm
SO ₂	0.14	0.25	0.36	< 0.04
NO _x	0.009	0.15	0.4	< 0.05
CO	0.49	6	10	10

Acknowledgement

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Appendix

APENDIX-1

SUGGESTED EQUIPMENT FOR UPGRADING AND THEIR DATA SHEET



Refinery gases arise from refining operations on liquid hydrocarbon feed stocks. Composition of these gases varies

widely depending on what process generates them. Typically refinery gases consist of hydrogen, oxygen, nitrogen, carbon

monoxide, carbon dioxide, and C₁-C₅ saturated and unsaturated hydrocarbons. Some C₆'s and H₂S may also be present. Refinery gas analyzers are an integral part of any refinery lab and provide valuable information that allow refiners to monitor and optimize catalytic and other processes, establish market value of a gas when sold to the chemical industry and enable the study of gaseous products from the process under study or development. Agilent provides a family of factory tested - ready to use GC analyzers for refinery gases that provide the accurate and reliable results required.

- Range of analyzers for refinery and other petroleum gases containing H₂, O₂, N₂, CO, H₂S, CO₂ and C₁-C₅ plus higher chain length hydrocarbons

- Easy "out-of-the-box" operation including pre-set method parameters, data files, and checkout samples for performance verification
- Time-saving, customized reports including calculations for mole %, weight %, or volume %, and calorific value
- Laboratory applications based on Agilent's 7890 GC, the market leading gas chromatograph, and out of laboratory applications build around Agilent's 490 MicroGC system
- An optional micro-gasifier expands the analytical capabilities to liquefied gases
- A factory certified technician will perform installation and familiarization confirming that your analyzer meets Agilent's analytical performance criteria and "ready to go" for calibration and validation by your team
- The highly efficient and rigorous packing technology used in Agilent J&W packed GC columns assures column-to-column reproducibility and ultimate efficiency.

System GC Solution for Refinery Gas Analysis



Gas compositions produced in refinery plants consist of hydrocarbons, permanent gases, H₂S, etc. Analyzing these gases is essential to control the quality of chemical products and plant operation. Shimadzu's RGA systems, available in numerous configurations, are designed to analyze various compositions in a variety of processes. In research and development for petrochemical and its catalysis field, target compounds often contain high-boiling point compounds and isomers. The Shimadzu CERGA makes it possible to precisely analyze those samples. In addition, calorific value calculation software is compliant with various calculation methods such as BTU and ISO-6976. (Shimadzu, 2015)

Trace CO and CO₂ Analysis System GC-2014TCC

This system is designed to measure trace amount of carbon monoxide (CO), methane (CH₄) and carbon dioxide (CO₂) in a gas sample. The sample is loaded into a loop and injected through a 10-port valve automatically. CO and CO₂ are reduced to CH₄ by means of nickel catalyst and detected by flame ionization detector (FID).

Content Type: Application

Document Number: SGC-ADS-0065

Product Type: System GC,

Gas Chromatography keywords: CO, CO₂, CH₄, Petrochemical, Chemical, Petroleum refinery, GC-2014

Language: English

File Name: hkc114065.pdf

File Size: 149kb

(Shimadzu, 2015)

H₂S and SO₂ in C₂, C₃, and C₄ Analysis System GC-2014SUL2

This instrument is designed to analyze for H₂S and SO₂ in C₂, C₃, and C₄ hydrocarbon streams. A Sunpak-S and silicagel packed column are used to separate the sulfur components from the hydrocarbons, avoiding the quenching phenomenon which can result in the loss of detector signal thus poor sensitivity. The method can analyze both inorganic and organic sulfur compounds, providing an ideal solution that can be applied to the analysis of both natural gas and refinery gas as well as liquid samples such as organic solvents. This system may not be suitable for gasoline analysis.

Content Type: Application

Document Number: SGC-ADS-0073

Product Type: System GC,

Gas Chromatography keywords: H₂S, Petrochemical, Chemical, Petroleum refinery, Petrochemicals, Polymer, GC-2014

Language: English

File Name: hkc114073.pdf

File Size: 130kb

(Shimadzu, 2015)

NO_x and Oxygen Analyzer for Flue Gas NOA-3030



NO_x contained in flue gas is a cause of air pollution and is measured according to the air pollution control act. Shimadzu applied its extensive experience with chemiluminescence NO_x measurements to develop the NOA-3030 NO_x and Oxygen Analyzer for Flue Gas. A high-performance CPU offers self-calibration, self-diagnosis, and alarm functions. This

NO_x-O₂ analyzer combines a simple configuration with high performance and good functionality, and represents a large step forward in automatic measurement functions. (Shimadzu, 2015)

Table 2: Showing the date analysed of gases (SO₂, NO_x and CO)mg/m³

Date	SO ₂ mg\m ³	NO _x mq\m ³	CO mg\m ³
2/8/2014	0.14	0.009	0.49
3/8/2014	0.018	0.003	0.38
4/8/2014	0.015	0.006	0.34
5/8/2014	0.016	0.003	0.18
6/8/2014	0.015	0.002	0.19
7/8/2014	0.014	0.003	0.24
8/8/2014	0.013	0.003	0.41
9/8/2014	0.007	0.003	0.34
10/8/2014	0.016	0.002	0.36
11/8/2014	0.02	0.001	0.35
12/8/2014	0.022	0.003	0.28
13/8/2014	0.018	0.003	0.33
14/8/2014	0.012	0.005	0.21
15/8/2014	0.011	0.005	0.34
16/8/2014	0.015	0.005	0.31
17/8/2014	0.021	0.004	0.22
18/8/2014	0.022	0.003	0.19
19/8/2014	0.009	0.009	0.27
20/8/2014	0.004	0.007	0.32
21/8/2014	0.009	0.007	0.21
22/8/2014	0.007	0.006	0.16
23/8/2014	0.013	0.007	0.17
24/8/2014	0.01	0.006	0.15