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Air Pollution at Khartoum Refinery : Analysis and Control Procedures

تلوث الهواء بمصفاة الخرطوم:
إجراءات التحليل والتحكم

A Thesis Submitted in partial Fulfillment for the Requirements of the degree of Master of Science in Environmental Engineering

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Dedication

To my mother, Hadia, who has always been a candle that lights my way and brightens my days,

To my father, El Fadil who always encourages me by being proud of me,

To my brothers, Mohammed, Mussab, Ali who always take care of me,

To my sisters, Selma, Sulafa and Zahra who are the best thing happened to me,

To my friends who always help me,

I dedicated this work.

Acknowledgment

المستخلص

تقييم هذه الدراسة درجة تلوث الهواء الناجم من انشطة صناعة البترول في السودان، والعمل علي ايجاد طرق بديلة للتقليل والحد من مشاكل تلوث الهواء.

وقد ناقشت الدراسة في هذا الاطار تلك الانبعاثات الغازية مع التطبيق علي حالة مصفأة الخرطوم حيث تمت متابعة وتصنيف الغازات المنبعثة من المصفأة بالقياس وتأثيراتها علي البيئة.

اجريت الدراسة في الفترة من 1 يناير الي 22 مايو 2018 بواسطة اجهزة قياس تعمل علي الدوام لقياس ثاني اكسيد الكبريت(SO_2)، كبريتيد الهيدروجين(H_2S)، اول اكسيد الكربون(CO) واكاسيد النتروجين(NO, NO_2, NOx).

وتم حساب متوسطات هذه الغازات فجاءت كما يلي: اكسيد الكبريت(0 mg/m³)، كبريتيد الهيدروجين(0 mg/m³)، اول اكسيد الكربون(0.4061 mg/m³) واكاسيد النتروجين(0.0001 mg/m³).

ومن الدراسة نجد ان القياسات التي تمت علي الغازات المنبعثة كانت مطابقة للمواصفة القياسية الصادرة من الهيئة السودانية للمواصفات والمقاييس والمخصصة لانبعاثات الغازات من مصافي البترول.

وتخلص الدراسة بأن هناك غازات منبعثة من مصفأة الخرطوم وبدرجة تركيز في حدود ماتوصي به الهيئة السودانية للمواصفات والمقاييس($SSMO$).

وتوصي الدراسة بالحفاظ علي درجات التركيز اعلاه والعمل علي اتباع التحوطات اللازمة عند التوسع في عمليات التكرير بنفس المصفأة.

Abstract

This study focuses on   analysis and control procedures of air pollution at Khartoum Refinery Company (KRC). The study aims at analyzing, discussing and assessing the level of emitted gases such as sulfur dioxide (SO_2), hydrogen sulphide (H_2S), carbon monoxide (CO) and nitrogen oxides (NO, NO_2, NOx). It also shows the control procedures followed by KRC to reduce the emitted gases and their impacts. The study was carried out from 1st January 2018 to 22nd May 2018. Sophisticated measuring devices running continuously are used to measure the levels of such gases. The study points out that the level of sulfur dioxide was (0 mg/m³); hydrogen sulphide was (0 mg/m³); carbon monoxide was (0.4061 mg/m³); and nitrogen oxides was (0.0001 mg/m³). It was also found that the measurement procedures of gas emissions taken are with accordance to Sudanese Standards and Metrology Organization (SSMO). The study found that the levels of the measures gases are within the range specified by Sudanese Standards and Metrology Organization (SSMO).

The study recommends that the existing levels of gases emission should be sustained. The study further recommends that improving awareness of local community is also seen as an important step in exposure to such gases.

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Chapter One

Introduction

Introduction

1.1 Introduction

Air pollution is the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odor, smoke or vapor in quantities, of characteristics and of duration, such as to be injurious to human, plant or animal life or to property, or which unreasonably interferes with the comfortable enjoyment of life and property, (Peirce J.J, Weiner F.R & Vensilind, 1998).

Air pollution, by the above concept is not a new or recent phenomenon. "Event in nature always has been the direct cause of enormous amounts of air pollution", (Wang & Pereira, 1979).

Refineries release toxic air pollution, which can cause cancer, birth defects and chronic conditions like asthma.

This study concentrated on determining gaseous waste at Khartoum Refinery and its impact to the surrounding environment.

Samples were tested at the Central Petroleum Equipment official laboratory. Obtained results were compared with Sudanese Standards set up for the Refinery by products.

1.2 Study Area

Khartoum Refinery is located in Khartoum North locality, north of Khartoum state. It is on a semi rocky-desert land about 15 km north-east of Al-Gaili village, and about 13 km East of the River Nile. Small villages are scattered around the Refinery area whose inhabitants are mainly farmers and shepherds, either illiterate or having incomplete primary education.

The area of the refinery is about half a square kilometer, and was reserved eight square kilometers of the refinery and its extensions. The reserved space is for companies and projects associated with the refinery.

The area is located at the intersect of latitudes 16°13´North, longitudes 32°49´ East was shown in figure 1-1. Geomorphologic ally the area is generally flat with some isolated outcrops and is sloping gently towards the south-west direction. The drainage pattern of this area is dendritic at upstream and then change into straight wide shallow valleys through which the whole area is being drained. The climate of the area which is characterized by high temperature, amount of rainfall, wind direction, and low relative humidity as shown in table
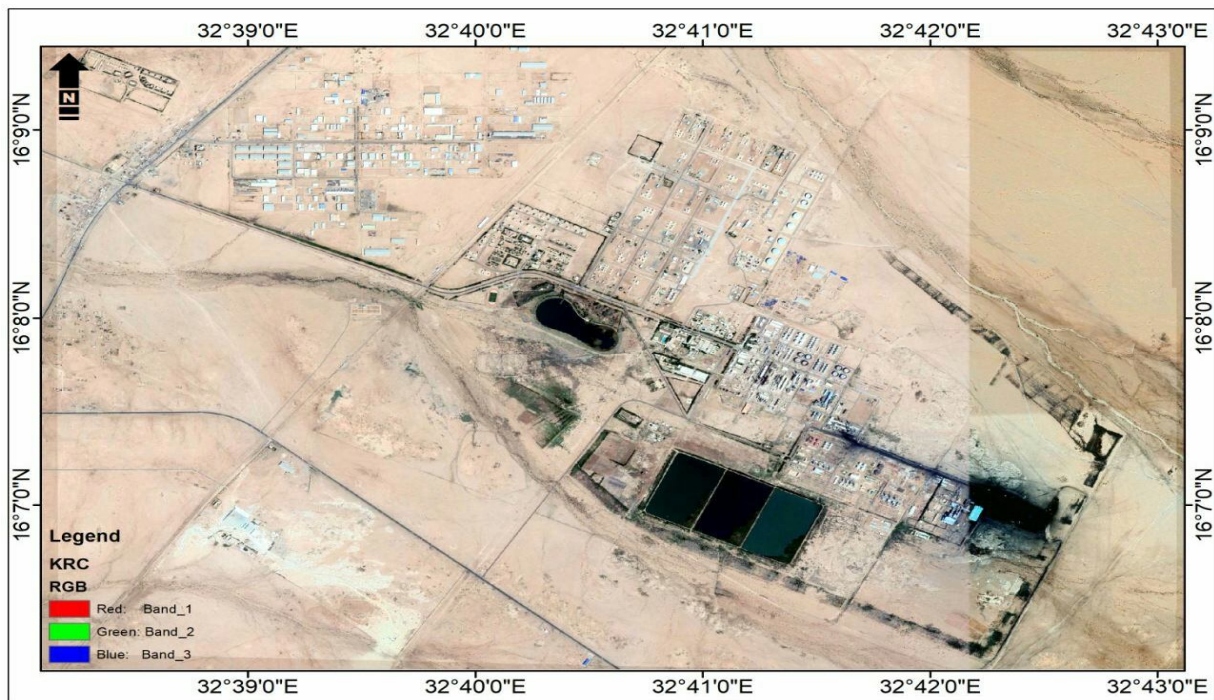
Figure 1-1: Location of the Study Area

Source: Maps, google.com, take out and modify by Researcher, 2018

Table 1-1: Elements of the Climate in the Study Area

Months	temperature	Relative humidity	Precipitation	Wind	Fog
January	temperatures around 32 °C	26%	109 mm	16 km/h	Is not affected by foggy conditions.
February	temperatures around 33 °C	20%	122 mm	16 km/h.	Is not affected by foggy conditions.
April	temperatures around 41°C	15%	83 mm	14 km/h	Is not affected by foggy conditions.
May	temperatures around 42°C	19%	105 mm	13 km/h	Is not affected by foggy conditions.

Source: local weather forecast- climate profile

1.3 Problem Statement

Petroleum refining plays an important role in our lives. Most transportation vehicles are powered by refined products such as gasoline, diesel, kerosene and fuel oil. over the last two years has affected the refining industry in three ways: First is an increased search for fuel products from non-fossil sources such as biodiesel and alcohols from vegetable sources, second is the development of better methods to process tar sand, coal gasification and synthesis of fuels and third is the initiation of long-term plans to look for renewable energy sources.

Petroleum Refining creates air pollution, transforming crude oil into petrochemicals releases toxins into the atmosphere that are dangerous for human and ecosystem.

Oil refineries are major polluters, consuming large amounts of energy and water, producing large quantities of waste waters, realizing hazardous gases into the atmosphere and generating solid waste. The oil industry holds a major potential of hazards for the environment, and may impact it at different levels: air, water, soil and consequently all living beings on our planet. Other environmental impacts include intensification of the green house effect, acid rain, poorer water quality and groundwater contamination, it may also contribute to biodiversity loss as well as the destruction of the ecosystems.

They are also a major source of criteria air pollutants: particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO), hydrogen sulfide (H_2S) and sulfur dioxide (SO_2). Refineries also release less toxic hydrocarbons such as natural gas (methane) and other light volatile fuels and oils.

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, (Moneim Hind, 2005).

The seeking of ways and means for reducing such impacts is becoming of paramount importance.

1.4 Objectives of the Study

This research focuses on air pollution at KRC. The main objective is to study air pollutants emitted by KRC specially SO_2, NO_2, CO, H_2S, NO and NOx.

The emitted pollutants generally need to be studied. KRC is located near Khartoum north town and many villages are surrounding the refinery. KRC as a main petrochemical refining in Sudan emitted such pollutants which may have negative impacts on the surrounding.

The specific objectives are:

- To study the various gases emitted during petroleum refining process at Khartoum Refinery.

- Detection of air pollutants concentrations of Khartoum Refinery Company at the surrounding premises.

- Assessment of the impact of pollutants emissions (SO_2, NO_2, CO, H_2S, NO and NOx) on human health and environment.

1.5 The hypothesis of the Study

This study hypothesis that:

- Emitted pollutants exceeded the SSMO recommend level.
- The emitted pollutants have negative impacts on the inhabitant living around the surrounding KRC.

1.6 Justification for Choosing the Topic of the study

There many factors stand behind the choice of the topic which can summarize as follows:

1- Increased air pollution is considered a current problem faces the area surrounding KRC which need to be assessed and studied.
2- The research emphasizes on the study of air pollution which many sooner or later affect development plans in study area.
3- Air pollution has a set of implications on the demographic and the socio-economic parameters which effects not only in the study area but also in Sudan as general.

1.7 Justification for Choosing the Area of the Study

There are many factors stand behind the choice of the topic which can summarize as follows:

1. The study of air pollution and its effects on the people around KRC are meager. There is very limited research on the topic and the area.
2. The emission of air pollutants has many negative impacts on inhabitants and ecosystem.

1.8 Research Layout

This research is divided into five chapters as follows:

I. Introduction: It includes the introduction of the research and its fundamentals (statement of the problem, the objectives of the study, and information regarding the study area in terms of geographical location, and its environment).

II. Literature Review: present the theoretical framework and previous studies, clarifying concepts, practical applications and definitions of air pollution and control procedures information systems, obtained by various means such as scientific theses, internet, papers and scientific books in the field of specialization, courses and conferences.

III. Materials and Methods: This chapter explains the materials used in the study in the collection of different data and the methods used in its analysis using air quality monitoring system and gas detector.

IV. Results and Discussion: present the final results of the gaseous waste analysis which applied in the collected data and presented it in the tables, graphs and discuss their implications**.**

V. Conclusion and Recommendations: present the researcher's conclusions recommendations from the obtained results for immediate and future proposals.

Chapter Two

Literature Review

Chapter Two
Literature Review

2.1 Introduction

Air pollution is defined as the emission of particulate toxic elements into the atmosphere by natural or anthropogenic sources, (Williams PB., 2004). These sources can be further differentiated into either mobile or stationary sources, (WHO, 2008).

Anthropogenic air pollution commenced with human's systematic use of fire. Its historical development has been characterized by steadily increasing amounts of total emissions, the invention of new sources of pollution emission as well as the emission of pollutants that had not formerly been emitted by man-made sources. Today the major sources of man-made air pollution are motorized street traffic (especially exhaust gases and tire abrasion), the burning of fuels, and larger factory emissions. Depending on the pollutant particles' size, they can be carried for distances of several thousand miles. With decreasing diameter, they are able to infiltrate finer lung structures, (WHO, 2005).

Air emissions from the petroleum industry can be classified as combustion emissions, process emissions, fugitive emissions, emissions from storage and handling of petroleum liquids and secondary emissions, (G.St, 2018).

Combustion emissions are produced with the onsite burning of fuels usually for energy production and transportation purposes. Flaring is a specific source of combustion emissions in the petroleum industry. It is used to control pressure and remove gas, which cannot be otherwise used. Fugitive emissions (equipment leak emissions) are released through leaking valves, pumps, or other

process devices. Process emissions are generated in the process units and released from process vents. Storage and handling emissions are contributed from the storage and manipulation of natural gas and crude oil, as well as their intermediate and finished derivatives. The water systems of a production or processing site (tanks, ponds, sewer system drains, etc.) are the main source of secondary. Major activities in this branch of the petroleum industry include exploration and well site preparation; drilling; crude oil and gas production, enhanced (secondary) recovery and eventually some on-site processing.

Air pollution from the production of oil and gas is with volatile hydrocarbons in fugitive emissions (mainly methane), as well as emissions from storage and manipulation, (G.St, 2018).

Employment of gases in enhanced oil recovery usually leads to increased process emissions, which also come from process vents of production equipment and eventually – from removing of acid gases. Exhaust combustion emissions are generated from compressors, pumps, drill engines and engines of servicing vehicles. Gas flaring is the major source of combustion emissions. The major source of secondary emissions is the water separated from the natural gas and crude oil, (G.St, 2018).

2.2 Composition of the Atmosphere

The atmosphere contains many gases, most in small amounts, including some pollutants and greenhouse gases. The most abundant gas in the atmosphere is nitrogen, with oxygen second. Argon, an inert gas, is the third most abundant gas in the atmosphere. The composition of the atmosphere, among other things, determines its ability to transmit sunlight and trap infrared light, leading to potentially long-term changes in climate. The atmosphere is

concentrated at the earth's surface and rapidly thins as you move upward, blending with space at roughly 100 miles above sea level. The atmosphere is actually very thin compared to the size of the earth, equivalent in thickness to a piece of paper laid over a beach ball. However, it is responsible for keeping our earth habitable and for producing weather, (North Carolina Climate office, ***).

Greenhouse gases whose percentages vary daily, seasonally, and annually have physical and chemical properties which make them interact with solar radiation and infrared light (heat) given off from the earth to affect the energy balance of the globe. This is why scientists are watching the observed increase in greenhouse gases like carbon dioxide and methane carefully, because even though they are small in amount, they can strongly affect the global energy balance and temperature over time. The air components are shown in table 2-1, (North Carolina Climate office,).

Table 2-1: The Air Components

Elements	Concentrations (ppm)
Nitrogen	780,900
Oxygen	209,400
Argon	9300
Carbon dioxide	315
Neon	18
Helium	5.2
Methane	1.0-1.2
Krypton	1.0
Nitrous oxide	0.5
Hydrogen	0.5
Xenon	0.008
Nitrogen dioxide	0.02
Ozone	0.01-0.04

Source: Wright J, 2003

Air or atmosphere is important for life on earth as it acts as a insulating layer that protects the Earth's surface from extreme light and heat, it protects the earth from ultraviolet rays and the short wavelength that may cause significant damage to the DNA of the organism without which it will become very hot in

the daytime, the air is also important because it contains the oxygen that human and other organisms breathe, (Visionlearning).

2.3 Atmosphere and Layers

The atmosphere is separated into four main regions shown in Figure 2-1. The lowest region, the **troposphere**, contains about 90 percent of all of the matter found in the atmosphere.

The troposphere extends to height of between 8 and 15 Km depending upon the latitude – for example, it is higher and colder at the poles. The temperature of the troposphere falls with increasing altitude to minimum of between 200 and 220 K (-73∘C to -53∘C) at the boundary between this layer and the next (the tropo-pause) mixing ratios can show very distinct and abrupt changes at the tropo pause. The next region, the **stratosphere**, extends to height of about 50 Km .the temperature within these regions rises to approximately 290 K (17∘C) until the upper boundary of the stratosphere is reached (the stratopause).

The sun's rays warm the earth s surface, which then warms the air immediately in contact with it. Warmer air is less dense than colder air and so rises causing convection current that warm the base of the troposphere. Thus, the troposphere is warmed from below. The troposphere is therefore characterized by strong vertical mixing, which gives rise to weather pattern and the rapid mixing of its material content. It is within the troposphere that many important chemical reactions occur such as photosynthesis and nitrogen fixation.

Chemical reactions occurring in the troposphere ensure that it is warmer than the troposphere. This change from decreasing temperature at the top of the troposphere to an increasing temperature called **temperature inversion.** The region where this starts to happen is the tropopause. The temperature inversion acts like a porous lid that separates the turbulent troposphere from the calmer

stratosphere. The vertical movement and mixing through the stratosphere is much slower than in the case of tropopause (taking years as opposed to days). Rapidly rising air from the troposphere can penetrate the tropopausal lid and so transfer matter to the stratosphere. Violent tropical storms in particular can contribute to such mixing. Additionally, stratospheric material can be transferred through the tropopause, particularly in the middle latitudes.

There is thus continual, slow exchange of matter between the two regions.

Above the stratosphere, the mesosphere, the mesosphere extends from an altitude of 50 km to about 90 km. this is followed by the thermosphere (90 km about 800 km). In the mesosphere the temperature declines from about

280 to 200 K.

A second temperature inversion occurs at about 90 km where the temperature rises from 200K to 300K. Again, photochemical reactions are responsible for this change in temperature. The study of the movement or "general circulation" horizontally of air in the lower atmosphere is carried out by meteorologist and will not be discussed in any detail here. However, there are pattern to be observed such as the occurrence of prevailing winds and weather condition, which are important in what happens to any matter that enters the atmosphere. The general circulation of air is caused by the temperature difference between the warm low and cold high latitudes. This leads to strong zonal wind movement. Wind moves and help to mix materials in the atmosphere. Zonal mixing is much faster than north-south (medicinal) mixing. The movements of a pollutant, for example, takes approximately one month to uniformly mix along a line of latitude, whilst it takes six months to move and mix throughout a hemisphere. To cover the globe takes between one and two years, (Wright J, 2003).

Degree of penetration of
incoming solar radiation

500 km

thermosphere

Principal chemical
species

N_2, O_2, N, O
N_2^+, O_2^+, NO^+, O^+

pressure   temperature   100 nm to long

85 km
mesopause N_2, O_2, NO
               N_2^+, O_2^+, NO^+

mesosphere
                            220 nm to long
50 km   stratopause

stratosphere N_2, O_2, O_3

15 km   tropopause   330 nm to long
troposphere N_2, O_2, H_2O
               Ar, CO_2

150   200   250   300
Temperature / kelvin

1×10^{-8} 1×10^0 1×10^2 1×10^4 1×10^6
Pressure / Pa

Figure 2-1: The regions of the atmosphere temperature, pressure, chemical
species and solar radiation

Source: Gary W. V. et al., 2000

2.4 Air Pollution

Air pollution is the presence in the outdoor atmosphere of one or more
contaminants (unwanted chemical other materials are released into the air in
amount to harm of people, plants, animals and environment) such as dust,
fumes, gas, mist, odor, smoke or vapor in quantities.

The concentrations of air pollutants are primarily a function of source emissions
and meteorological conditioning and they are closely related to population

density and land use patterns. Generally, there are more man-made pollutants in the air near major cities and heavy industrial areas. These air pollutants also interact with the surface water and soil through precipitation and dry deposition they can cause water pollution and soil contamination as well, (Institute of Technology and Management).

Why then is society so perturbed by air pollution? The concern stems from a combination of several factors:

- Urbanization and industrialization have brought together large concentrations of people in small areas.

- The pollution generated by people is most often released at locations close, which results in their continuous exposure to relatively high levels of the pollutants.

- The human population is still increasing at an exponential rate.

2.5 Sources of Air Pollution

First: Natural sources:

Gases produced by volcanoes, forest fires and storm-based storms. These sources are usually limited in certain areas and seasons and their damage is not severe when compared to the other. Examples of these natural pollutants include:

1. Sulfur dioxide gases, hydrogen fluoride, and hydrogen chloride rising from turbulent volcanoes.

2. Nitrogen oxides resulting from electrostatic discharge of thunder clouds.

3. Hydrogen sulfide resulting from the extraction of natural gas from the ground, volcanoes or the presence of sulfuric bacteria.

4. Ozone gas generated in the air or due to electrostatic discharge in the clouds.

5. Fungi, bacteria and various microbes that spread in the air whether they originate in the soil or as a result of animal rot, dead birds and human waste.

6. Radioactive materials such as those found in some earthworms and rocks of the earth's crust, as well as from the ionization of some gases by cosmic rays.

Second: Non-natural sources:

Causing the occurrence of the human being is more dangerous than the previous and raises concern and concern as the components became multiple and varied and caused imbalance in the composition of natural air and environmental balance.

The general perception is that levels of pollution inside buildings are lower than outside as the walls protect us from external impacts, (European Environment Agency, 2017)

2.6 Air Pollutants

Any substance in air that could, in high enough concentration, harm animals, humans, vegetation, and/or materials. Such pollutants may be present as solid particles, liquid droplets, or gases. Air pollutants fall into two main groups: (1) those emitted from identifiable sources and, (2) those formed in the air by interaction between other pollutants. Over one hundred air pollutants have been identified, which include halogen compounds, nitrogen compounds, oxygen compounds, radioactive compounds, sulfur compounds, and volatile organic chemicals (VOC),(BusinessDictionary).

Gaseous air pollutants can either be primary emitted directly from the source to atmosphere such as gases of power generating plants or secondary from as a result of reactions between primary and secondary in the atmosphere such as ozone. Similarly NO_2 reacts with water in the atmosphere to nitric acid

or sulfur dioxide and water to sulfuric acid (acid rain if pH is less than 5.7), (The Habitable planet).

2.6.1 Characteristic of Air Pollutants

Air pollutants are divided into two main groups:

1- Gases

2- Particulates (solid or liquid material)

2.6.2 Major Classification of Air Pollutants

1- Primary – Secondary

2- Natural – Manmade

3- Criteria Air Pollutants

4- Physical - chemical – biological

2.6.3 Primary pollutants and secondary pollutants

Primary pollutants are substances that are directly emitted into the atmosphere from sources. Primary pollutants are those that are emitted directly from identifiable sources. Secondary air pollutants are those that are produced in the air by the interaction of two or more primary air pollutant, (The Habitable planet).

- **Primary Air pollutants**
1- Fine (less than 100μ) and coarse (more than 100μ) suspended particulate matter
2- Oxides of sulfur
3- Oxides of nitrogen
4- Carbon monoxide
5- Halogens
6- Organic compounds
7- Radioactive compounds

- **Secondary Air pollutants**

1- Ozone

2- PAN (Peroxyacetyl nitrate)

3- Photochemical smog

4- Acid mists

Following are the **main air pollutant gases:**

2.6.4 Sulfur Dioxide (SO$_2$)

Sulfur dioxide or SO$_2$ belongs to the family of sulfur oxide gases (SOx). These gases dissolve easily in water. Sulfur is prevalent in all raw materials including crude oil, coal and ore that contain common metals like copper zinc, lead, and iron. SOx gases are formed when fuel containing sulfur such as coal and oil is burned and when gasoline is extracted from oil or metals are extracted from ore. SO$_2$ dissolves in water vapor to form acid and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment. Over 65% of SO$_2$ released to the air or more than 13 million tons per year comes from electric utilities especially those that burn coal. Other sources of SO$_2$ are industrial facilities that derive their products from raw materials like metallic ore, coal and crude oil or that burn coal or oil to produce process heat. Examples are petroleum refineries, cement manufacturing and metal processing facilities. Also locomotives, large ships and some diesel equipment currently burn high sulfur fuel and release SO$_2$ emissions to the air in large quantities, (EPA, 2008).

Sulfur dioxide and nitrogen dioxide are often lumped together in air pollutant control because of the similarity between them; hence their control will be presented together. Increasingly strict standards for control have prompted the development of a number of options and techniques for reducing SO$_2$ emissions. Among these options are:

- Change to low-sulfur fuel (0.3 % and 4%)

- Desulfurization
- Tall stacks

2.6.5 Nitrogen Oxides (NOx)

Nitrogen oxides (NOx) are the generic term for a group of highly reactive gases all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO_2) along with particles in the air can often be seen as a reddish-brown layer over many urban areas.

Nitrogen oxides form when fuel is burned at high temperature as in a combustion process. The primary manmade sources of NOx are motor vehicles, electric utilities and other industrial sources that burn fuels (NOx can also be formed naturally), (adcapitalindustries, 2009).

Air pollution and pollutants control depends on selection of sights of thermal plants, refineries, industrial complexes and intensive live- stock and poultry production in relation to urban settlement. The wind direction and velocity should be taken into consideration. Fuels non-pollutant or low sulfur content and high stacks should be used, (EPA, 2008).

2.6.6 Carbon Monoxide (CO)

Carbon monoxide (CO) is a colorless, odorless gas that is formed when carbon in fuel is not burned completely. It is a component of motor vehicle exhaust which contributes about 56 percent of all CO emissions. Other non-road engines and vehicles (such as construction equipment and boats) contribute about 22 percent of all CO emissions. Higher levels of CO generally occur in areas with heavy traffic congestion. In cities 85 to 95 percent of all CO emissions may come from motor vehicle exhaust. Other sources of CO emissions include industrial processes (such as metals processing and chemical manufacturing), residential wood burning and natural sources such as forest

fires. Woodstoves, gas stoves, cigarette smoke, unvented gas and kerosene space heaters are sources of CO indoors.

The highest levels of CO in the outside air typically occur during the colder months of the year when inversion conditions are more frequent. The air pollution becomes trapped near the ground beneath a layer of warm air, (EPA, 2008).

2.6.7 Hydrogen Sulfide (H_2S)

Hydrogen sulfide is heavier than air and may travel along the ground. It collects in low-lying and enclosed poorly-ventilated areas such as basements, manholes, sewer lines, underground telephone vaults and manure pits. For work within confined spaces use appropriate procedures for identifying hazards, monitoring and entering confined spaces.

The primary route of exposure is inhalation; the gas is rapidly absorbed by the lungs and absorption through the skin is minimal. People can smell the "rotten egg" odor of hydrogen sulfide at low concentrations in air. A level of H_2S gas at or above 100 ppm is Immediately Dangerous to Life and Health (IDLH), (United State Department and Labor).

Control of H_2S

1- Air must be tested for the presence and concentration of hydrogen sulfide by a qualified person using air monitoring equipment such as hydrogen sulfide detector tubes or a multi-gas meter that detects the gas.

2. If the gas is present the space/area must be ventilated continually to remove the gas.

3. If the gas cannot be removed the person entering the space/area must use appropriate respiratory protection and any other necessary personal protective equipment.

2.8 Effect of Air Pollution (Heath Effect of Some Air Pollutants)

Air pollution causes damage to humans, animals, plants, and material possessions and produce adverse effects on the environment. Air pollution can be a contributing factor to chronic bronchitis, emphysema, and lung cancer. It can increase the discomfort of those suffering from allergies, colds, pneumonia, and bronchial asthma. It can also cause dizziness, headaches, eye, nose and throat irritations, increased nasal discharges, nausea and vomiting, coughing, shortness of breath, constricted airway passages, chest pains, cardiac problems, and poisons in the stomach, blood stream, and organs, (Wang K. L et al., 1979).

2.8.1 Carbon Monoxide (CO)

Carbon monoxide is a primary pollutant. The immediate effect of CO is that it chemically binds with hemoglobin in the blood to form carboxyhemoglobin (COHb). Carbon monoxides affinity for hemoglobin is 200 times greater than that of oxygen (O_2), and it tends to remain more tightly bound. Carbon monoxide is highly toxic at concentration>1,000 ppm, leading to death from asphyxiation because the body, particularly the brain, is deprived of sufficient O_2.

Death by CO poisoning is not uncommon, and it is frequently the cause of death in structural fires, including home fires (CO asphyxiation). The amount of COHb produced in the blood is directly related to CO dose (concentration and duration of exposure). Exposures to 35 ppm CO for 1 hr or 9 ppm for 8hr will result in 1.3% COHb saturation. These two exposure values represent the ambient air quality standard for CO in the United States in 1995 to protect human health, (Krupa V. S., 1997).

2.8.2 Nitrogen Oxides (NOx)

Nitric oxide (NO) at current ambient concentrations is not considered a threat to human health; however, it is rapidly converted to NO_2 (nitrogen dioxide) in the atmosphere. In contrast to SO_2, which is rapidly absorbed by the

fluids in the upper tracheobronchial zone, NO_2 is less soluble and therefore can deeply penetrate the lungs, leading to tissue damage. Adverse effects such as pulmonary edema (an abnormal, excess accumulation of watery fluids in the connective tissue) usually do not appear until many hours after exposure to high concentrations. Such exposures are known to occur during the manufacture of nitric acid (HNO_3), during electric arc welding, and in farm silos.

Animal toxicological studies show that exposures to > 0.50 ppm NO_2 can result in destruction of cilia, disruption of alveolar tissue, and that NO_2 may cause or aggravate respiratory bronchioles. Such studies also show that NO_2 may cause or aggravate respiratory infections, (Krupa V. S., 1997).

2.8.3 Sulfur Dioxide (SO_2)

Because of its solubility in water and related fluids, inhaled SO_2 is almost entirely removed in the mouth, throat, and nose; therefore, <1% of the SO_2 reaches the lung tissue. The principal effect of SO_2 is the alteration of the mechanical function of the upper airway. This includes an increase in nasal flow resistance and a decrease in nasal mucus flow rate. Exposure strenuously exercising asthmatic subjects to relatively low levels of SO_2 (0.25 and 0.50 ppm) produces acute bronchial constriction on inhalation.

This hypersensitive response can also be caused by the use of sodium bisulfate as a food preservative (on salad greens) in restaurants and in the production of wine, since SO_2 is produced upon the decomposition of the sodium bisulfate. This has led the U.S. Food and Drug Administration (FDA) to apply restrictions on the use of sodium bisulfate in restaurants. Some of the health effects attributed to SO_2 most likely result from its conversion to fine-particle sulfate aerosols such as sulfuric acid (H_2SO4), (Krupa V. S., 1997).

2.8.4 Hydrogen Sulfide (H_2S)

Hydrogen sulfide is both an irritant and a chemical asphyxiant with effects on both oxygen utilization and the central nervous system. Its health effects can vary depending on the level and duration of exposure. Repeated exposure can result in health effects occurring at levels that were previously tolerated without any effect. Low concentrations irritate the eyes, nose, throat and respiratory system (e.g., burning/ tearing of eyes, cough, shortness of breath). Asthmatics may experience breathing difficulties. The effects can be delayed for several hours, or sometimes several days, when working in low-level concentrations. Repeated or prolonged exposures may cause eye inflammation, headache, fatigue, irritability, insomnia, digestive disturbances and weight loss.

Moderate concentrations can cause more severe eye and respiratory irritation (including coughing, difficulty breathing, and accumulation of fluid in the lungs), headache, dizziness, nausea, vomiting, staggering and excitability. High concentrations can cause shock, convulsions, inability to breathe, extremely rapid unconsciousness, coma and death. Effects can occur within a few breaths, and possibly a single breath, (United State Department and Labor).

2.9 Potential Environmental Impacts

- Human, Socio-Economic and Cultural Impacts:

Changes in traditional lifestyle of indigenous people, (Sudanese Petroleum Corporation Report, 2000)

- Atmospheric Impacts :

Principal pollutants: CO_2, CO, CH_4, VOC, NOX, SOx and H_2S.

The volumes of atmospheric emissions and their potential impact depend upon the nature of the process under consideration, (Sudanese Petroleum Corporation Report, 2000)

- Aquatic Impacts*:*

    - Produced water, Process, wash and drainage water, Sewerage etc.

The high PH and salt content of certain drilling fluids and cuttings, (Sudanese Petroleum Corporation Report, 2000)

- Terrestrial Impacts:

    - Impacts to flora and fauna

    - Constructions disturbance Contaminations to soil

- Ecosystem Impacts:

Plant and animals communities, (Sudanese Petroleum Corporation Report, 2000)

2.10 Air Pollution Control

Limiting emissions into the air is both technically difficult and expensive. However, since rain is the only air-cleaning mechanism available and not very efficient, good air quality depends on pollution prevention and on limiting what is emitted, (Peirce J.J , Weiner F.R & Vesilind A.P, 1998)

Reducing pollutants in the air is important for human health and the environment. Poor air quality has harmful effects on human health, particularly the respiratory and cardiovascular systems. Oil Industries can use pollution control devices to remove pollutants by absorbing, filtering, diluting or dispersing them. Government licensing and regulation are effective ways to minimize emissions from industry. There are some of the most common devices used to control industrial pollution as shown in figure, (Queensland Government, 2013).

2.10.1 Particle Removal- Cyclone

A cyclone works on the principle of creating high-speed spiral airflow to remove particles. This spiral motion applies a centrifugal force on the particles as shown in figure 2-2.

The inertia of the particles forces them to the outside walls of the cyclone, where they fall to the bottom and are collected. The speed of the air flow and the width of the cyclone influence particle removal- the smaller the diameter the more efficient the particle removal.

The conical section at the base of the cyclone gradually decreases the diameter of the spinning gas stream, resulting in better removal of smaller particles.

However, in practice, reducing the diameter increases the pressure drop across the cyclone. Combining several units together as a 'multi cyclone' can prevent this.

Pollutants can also damage plants and buildings, and smoke or haze can reduce visibility, (Queensland Government, 2013).
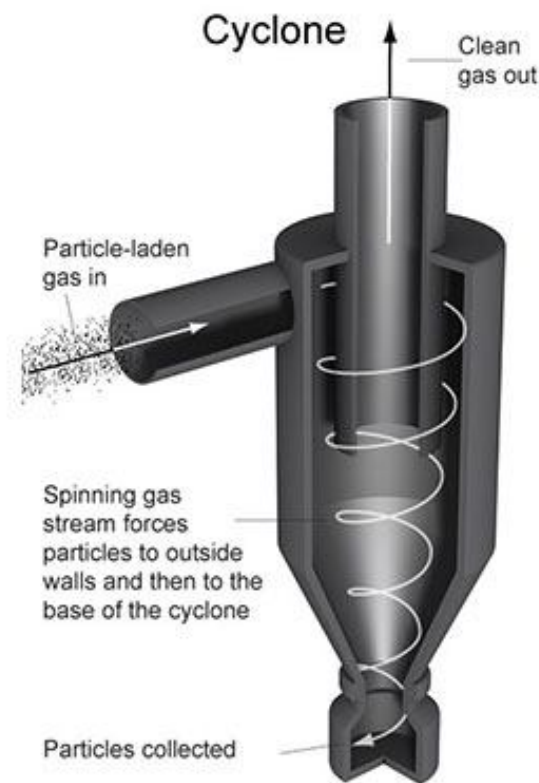
Figure 2 - 2: Cyclone Device

Source: Queensland Government, 2013

2.10.2 Particle Removal - Electrostatic Precipitator

The electrostatic precipitator works by removing particles and smoke from a gas stream using an electrostatic charge as shown in figure 2-3.

Dust particles travel past wires that have a high direct current (DC) voltage applied, which ionizes the surrounding gas. This corona discharge causes the particles to pick up a small electrostatic charge.

An oppositely-charged plate attracts the particles, neutralizes and retains them. A regular tapping (rapping) of the plates then physically removes the collected particles.

Introducing a water spray can reduce the electrical resistance of the dust particles, allowing them to accept the charge more easily. Electrostatic precipitators are an efficient way of removing particles, (Queensland Government, 2013).
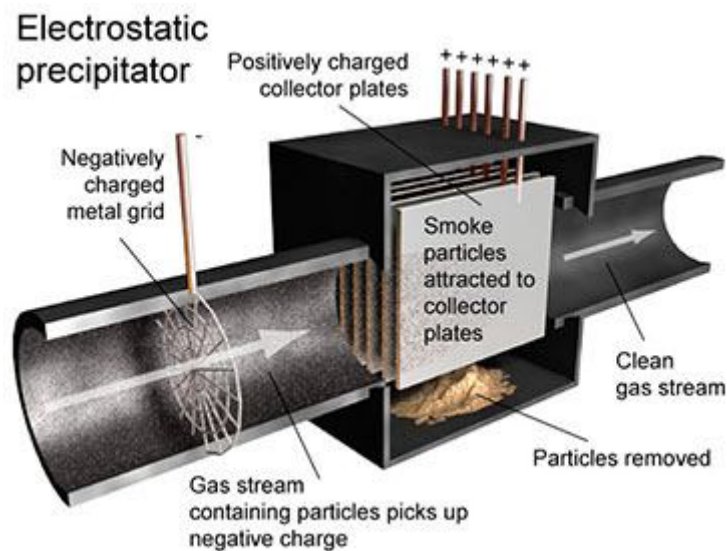
Figure 2-3: Electrostatic precipitator

Source: Queensland Government, 2013

2.10.3 Particle Removal - Bag Filters

Bag filters use fabric bags to remove particles from dust-laden gas. They can achieve high efficiencies for fine particles because of the build-up of particles on either the inside or outside surface of the bag depending on the design.

As dust builds up, the pressure across the bag increases, so the filters need regular cleaning. Usually bag filters work in tandem - one filter is working while the other filter is being cleaned.

Mechanical shaking, using a reverse airflow or a pulse of compressed air are used to dislodge the dust from the fabric surface, which then falls by gravity into a collection system, (Queensland Government, 2013).

2.10.4 Particle and Gas Removal - Packed Bed Wet Scrubber

A packed bed wet scrubber removes gaseous and particle contaminants from a gas stream. It works by bringing the gas stream into contact with a scrubbing liquid (usually water) as shown in figure 2-4.

The scrubbing liquid absorbs the gaseous pollutants, and the spray droplets physically capture the particles.

The packed bed of non-reactive material gives a greater gas-to-liquid contact which improves the removal of particle pollutants.

Although the packed bed wet scrubber can remove gaseous *and* particle pollutants, the particular design makes it more efficient at one or the other. Using certain scrubbing liquids can increase gaseous pollutant removal, e.g. using an alkaline liquid to remove acidic pollutants.

Trapping and treating droplets of the scrubbing liquid can allow it to be recycled, (Queensland Government, 2013).
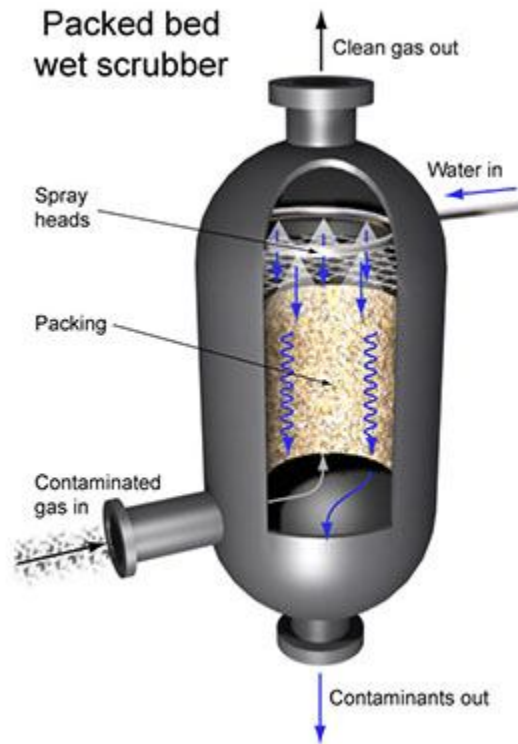
Figure 2-4: Packed Bed Wet Scrubber

Source: Queensland Government, 2013

2.11 Measures to Control Air Pollution

- Activated carbon: is one of the most popular forms of air pollution control. This type of control involves the use of a pollution filter, carbon to reduce the amount of pollutants that are allowed to escape into the air, (Han Dawei, 2012).

- Bio filtration: is another effective type of air pollution control. It uses microorganisms often bacteria and fungi to dissolve pollutants, (Han Dawei, 2012).

- Change in Fuel: This technique involves the use of less polluting fuel to reduce air pollution (Use of low sulfur fuel instead of high sulfur fuel), (Han Dawei, 2012).

- Nuclear power plants are relatively pollution free when compared to the coal fired power plants. The emissions from the plant are passed through a control device before releasing to atmosphere, (Han Dawei, 2012).

- Improve Dispersion: This approach is based on the concept that dilution of air contaminants before they reach ground will lower the concentrations to which the population is exposed, (Han Dawei, 2012).

- The emissions from the plant are passed through a control device before releasing to atmosphere. The pollutants are removed, destroyed or transformed in the control device before discharging into ambient air, (Han Dawei, 2012).

- The scrubbing or flue gas desulphurization (FGD) processes can be classified as (i) Throwaway or regenerative processes or (ii) wet or dry processes, (Han Dawei, 2012).

2.12 Measurement of Air Quality

Air quality measurements are designed to measure all types of air contaminants with no attempt to differentiate between naturally occurring contaminants and those that result from human activity. Measurements of air quality fall into three classes:

- Measurement of air quality: This is called stack sampling when a stationary source is analyzed. Samples are drawn out through a hole or vent in the stack for on-the spot analyses. Mobile sources like automobiles are tested by sampling exhaust emissions while the engine is running and working against a load.

- Meteorological measurements: The measurement of meteorological factors- wind speed, wind direction and lapse rates (is necessary to determine how pollutants travel from source to recipient).

- Measurement of ambient air quality: Ambient air quality is measured by a variety of monitors. Almost all evidence of the health effects of air pollution is based on correlation of these effects with measured ambient air quality.

2.13 Emission Estimation

Mass balance involves the quantification of total materials into and out of a process. The differences between their inputs and outputs are accounted for in terms of releases to the environment or as part of the facility waste. Mass balance is particularly useful when the input and output streams can be quantified, and this is most often the case for individual process units and operations, (National Pollutant Inventory, 1999).

2.14 Cleaner Production

Is to improve the design continually to use clean energy and raw materials to adopt advanced technology and equipment and improve management utilization and other measures. Cleaner production includes none or less pollution, the product itself "green" and the non- pollution of the recycle and processing of the products after their end of life.

2.14.1 Basic Content of Cleaner Production

1- Clean energy

2- Clean production process

3- Clean product

2.14.2 The Implementation of Cleaner Production

- Auditing (planning, organizing, pre-evaluation, evaluation, program generation and selection, feasibility analysis, program implementation, continual cleaner production).

- Program development (program collection, program screening, program evaluation).

2.15 Petroleum Refining

The petroleum industry is organized into four broad sectors: exploration and production of crude oil and natural gas; transport; refining; marketing and distribution. Crude oil is fractionated into liquefied petroleum gas, naphtha (used to produce gasoline by blending with octane boosters), kerosene/aviation turbine fuel, diesel oil and residual fuel oil. Catalytic cracking and reforming, thermal cracking and other secondary processes are used to achieve the desired product specifications. Certain refineries also produce feedstock for the manufacture of lubricating oils and bitumens. Some refineries also manufacture coke. Flow sheet of petroleum production, refining and distribution systems are shown in figure 2-5

Petroleum refineries are complex plants and the combination and sequence of processes is usually very specific to the characteristics of the raw materials (crude oil) and the products. Specific pollution prevention or source reduction measures can often be determined only by the technical staff. However, there are a number of broad areas where improvements are often possible and site-specific waste reduction measures in these areas should be designed into the plant and targeted by management of operating plants, (The World Bank Group, 1998).
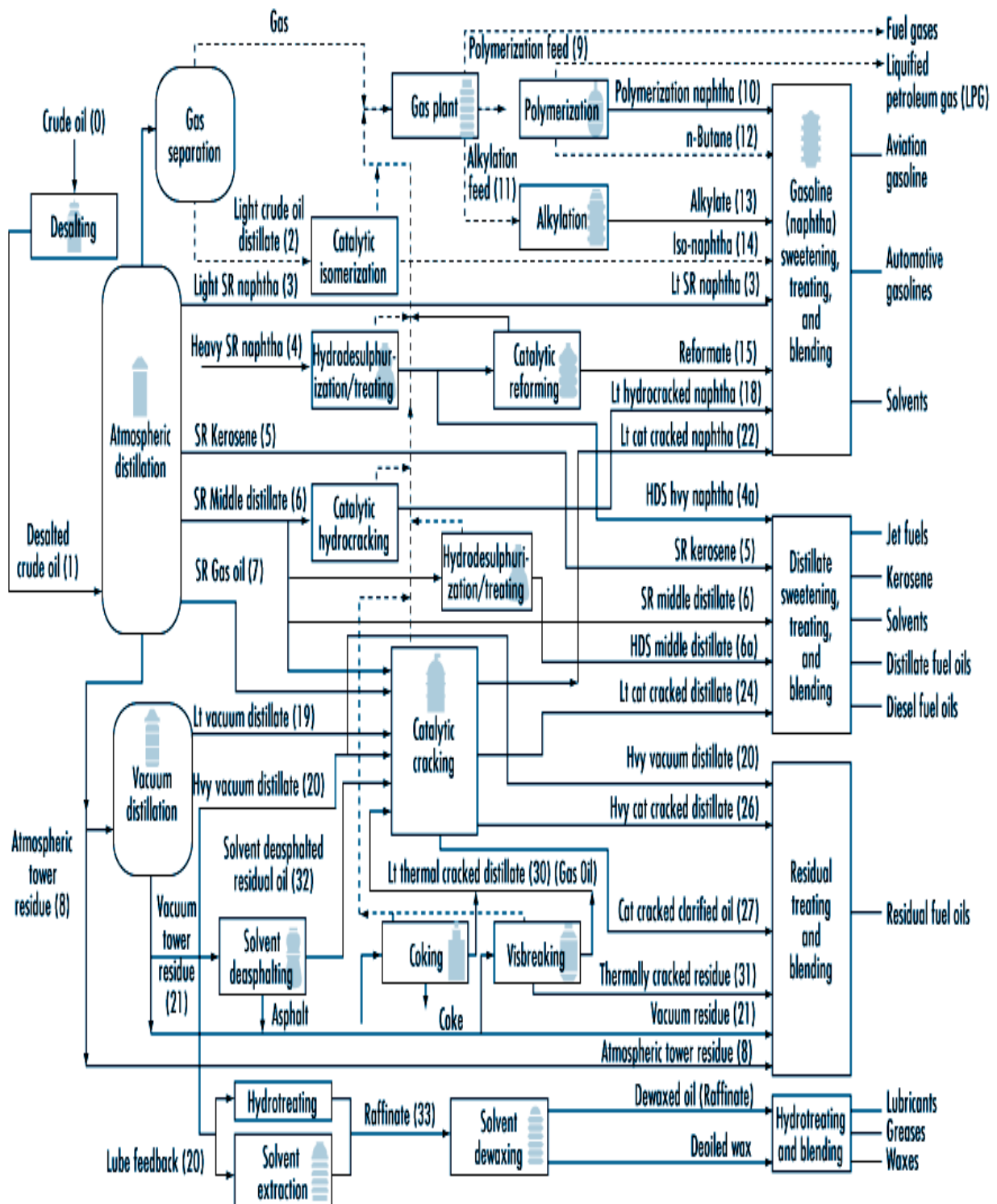
Figure 2-5: Flow sheet of petroleum production, refining and distribution systems

Source: OSHA, 1996

2.16 Waste Characteristics

Boilers, process heaters, and other process equipment are responsible for the emission of particulates, carbon monoxide, nitrogen oxides (NOx), sulfur oxides (SOx), and carbon dioxide. Catalyst changeovers and cokers release particulates.

Volatile organic compounds (VOCs) such as benzene, toluene and xylene are released from storage, product loading and handling facilities and oil-water separation systems and as fugitive emissions from flanges, valves, seals, and drains.

2.17 Air pollution (around the refinery)

It is expected that the Refinery can cause gaseous and liquid pollution, bad smells and noise .The major gas pollutants include hydrocarbon vapors, nitrogen oxides; Sulfur dioxide, hydrogen sulphide and carbon monoxide (KRC, 2002).The major potential sources of some gaseous effluents from the Refinery are shown in Table 2-2

Table 2-2: Major Gaseous Effluents from the Refinery

Effluents	Potential sources
SO_2, SO3, H_2SO4	Combustion furnaces and boilers, H_2S flares, catalyst regenerators heating System.
hydrogen sulphide	Vent from CDU ,desulphurizer plant, waste water
Hydrocarbons	Flares, storage tanks, sampling operations, open effluent water separator, 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: Khartoum Refinery Company, 2003

2.18 Environmental Management in Sudan's oil industry

2.18.1 Regulatory Framework

- Urge environment conservation and promotion.

- Penalize the act which causes any sort of Pollution to natural resources or the cause of imbalance.

- Serve restitution of any damage to the environment and natural resources.

- Encourages sustainable development.

2.18.2 Acts and Legislations

- The Environmental Protection Act 2001:

  Framework law for policy and harmonization of the multidisciplinary efforts in the field of management of the environment and natural resources to achieve sustainable development

- Sudanese Petroleum Corporation Regulations, 2002:

  The regulations for Protection of the Environment in Petroleum industry, was established basing on exercising article 35 of the Petroleum Resources Act 1998.

- Sudanese Oil Standards:

  Issued by Sundaes Standardization Metrological Organization (SSMO) Cover:

      - Air pollution limits
      - Water pollution limits
      - Soil pollution limits
      - Noise pollution

2.19 Environmental Mitigation measures in Sudan oil industry

- Submit EIA.

- Establish well equipped Environmental occupational and safety units (HSE).

- Sustain water quality.

- Air quality monitoring.

- Vegetation cover.

- Wildlife and grazing animals.

- Ground water.

2.20 Management of Environmental Hazards Caused by Oil Refining

- Water usage is reduced by using cooling towers and water circulation.

- A sour water treatment unit is added in order to remove H_2S and NH_3 gases.

- Water proofing of ponds by plastic sheets and construction of concrete paving of areas vulnerable to oil spills.

- Pollutants such as mineral oil, pH, suspended solids, NH_3, Sulfides and COD are monitored daily, while BOD is monitored weekly by the Refinery waste water analysis plant and the Health Safety and Environment (HSE) unit.

- Water from the Nile to the Refinery is not affected by any pollutants.

2.21 Management of Environmental Hazards Produced by Gaseous Products

The major gas pollutants produced at Khartoum Refinery are nitrogen oxides (NOx), sulfur dioxide (SO_2), hydrogen sulfide (H_2S) and carbon monoxide (CO). The Refinery is well designed and equipped with laboratories that monitor the waste gases continuously. In this study an average reading at mid-day is given for comparison with the Sudanese Standards and Metrology Organization (SSMO).The gas detectors are installed all over the Refinery units for instantaneous measurements.

2.21.1 Reduction of Air Emission

- Minimize losses from storage tanks and product transfer areas by methods such as vapor recovery systems and double seals.

- Minimize SOx emissions either through desulfurization of fuels to extent feasible or by directing the use of high-sulfur fuels to units equipped with SOx emissions controls.

- Recover sulfur from tail gases in high-efficiency sulfur recovery units.

- Recover non-silica-based (metallic) catalysts and reduce particulate emissions.

- Use low-NOx burners to reduce nitrogen oxide emissions.

- Avoid and limit fugitive emissions by proper process design and maintenance.

- Keep fuel usage to a minimum, (The World Bank Group, 1998).

2.21.2 Recycling and Reuse

- Recycle cooling water and treated wastewater.

- Maximize recovery of oil from oily wastewater and sludge.

- Minimize losses of oil to the effluent system.

- Recover and reuse phenols, caustics and solvents from their spent solutions.

Return oily sludge to coking units or crude distillation units, (The World Bank Group, 1998).

2.21.3 Treatment Technologies

Control of air emissions normally includes the capture and recycling or combustion of emissions from vents, product transfer points, storage tanks and other handling equipment. Boilers, heaters, other combustion devices, Coker and catalytic units may require particulate matter controls. Use of a carbon monoxide boiler is normally a standard practice in the fluidized catalytic

cracking units. Catalytic cracking units should be provided with particular removal devices.

Steam injection in flaring stacks can reduce particulate matter emissions, (The World Bank Group, 1998)

2.21.4 Emission Guidelines

The guidelines given below represent emission levels normally acceptable to the World Bank Group in making decisions regarding provision of World Bank Group assistance. Any deviations from these levels must be described in the World Bank Group project documentation. The emission levels given here can be consistently achieved by well-designed, well-operated, and well-maintained pollution control systems.

The guidelines are expressed as concentrations to facilitate monitoring. Dilution of air emissions or effluents to achieve these guidelines is unacceptable. All of the maximum levels should be achieved for at least 95% of the time that the plant or unit is operating to be calculated as a proportion of annual operating hours, (The World Bank Group, 1998).

2.21.5 Emission Monitoring

Continuous emission monitoring is recommended for petroleum refinery air emission point sources for gas temperature and gas flow rate as well as for NOx, SOx, CO, VOCs and total reduced sulphur concentration. In refinery steam boilers process heaters and process furnaces, it is required to monitor CO, NOx and Sox emissions. Catalytic cracking units have to monitor both NOx and SOx in certain locations. Air emissions from stacks should be monitored once every shift, if not continuously, for opacity (maximum level, 10%). Air emissions of hydrogen sulfide from a sulfur recovery unit should be monitored on a continuous basis. Annual emission monitoring of combustion sources should be carried out for sulfur oxides (sulfur content of the fuel monitored on a supply-tank basis) and for nitrogen oxides. Major potential Air Contaminants Petroleum Refineries are shown in table 2-3, (The World Bank Group, 1998)

Table 2-3: Major potential Air Contaminants from Petroleum Refineries

Air Contaminants	Major Sources
Hydrocarbon vapour, compound of carbon and hydrogen	- Transferred and loading operations - Storage tank - Crude unit, Cracking unit, cracking unit - heat exchangers - boilers and heaters - pumps, valves, cooling towers
Sulfur dioxide (SO_2)	- Boilers - cracking unit regeneration - treating operations, Flares
Carbon monoxide (CO)	- catalyst regeneration - Flares - Boilers, Furnaces
Nitrogen dioxide (NO_2	- Flares, Boilers
Hydrogen sulphide (H_2S)	- sour crude, liquid wastes, Pumps ,crude tower, cracking operations - hydrogenation
Particulates	- Catalyst dusts – cracking units, catalyst regeneration, and rearranging and combining processes such as reformers and alkylation units. - petroleum coke dust- cracking units
Chlorine	caustic unit
Ammonia	Compressors

Source: Alec Groysman, 2017

2.21.6 Treatment and Control

Air pollution control equipment should be designed and operated in such a way that the substances released from the equipment have the minimum influence on the environment.

The major NOx emission sources in a petroleum refinery are combustion processes. NOx emissions are usually the result of the reaction between oxygen and nitrogen at temperatures above 1093_C (2000_F) in the air/fuel combustion flame. NOx emission control technologies applicable to these sources include combustion controls Selective Catalytic Reduction (SCR) systems, Selective Non Catalytic Reduction (SNCR) systems and a combination of these techniques.

Most SCR systems use anhydrous ammonia as a reducing agent to convert any NOx in a flue gas stream into nitrogen over a catalyst.

CO Emission Treatment CO incinerators or boilers generally oxidize 95% or more of the CO emissions to carbon dioxide. Wet gas scrubbing (WGS) technology allows refiners to meet FCC emission regulations.WGS advantages are:

-    Replaces costly CO boiler

-    Reduces particulate and SOx emission

-   Produces environmentally safe wastewater discharge

-    Collects catalyst

After effective separation from the scrubbing liquid, the clean flue gas is vented to the atmosphere and the liquid containing the particulates. SO_2 and NOx are disposed in an environmentally acceptable manner, (The World Bank Group, 1998)

2.22 Waste Management (gaseous waste)

Air emissions include point and non-point sources. Point sources are emissions that exit stacks and flares which can be monitored and treated.

Nonpoint sources are fugitive emissions which are difficult to locate and capture.

Fugitive emissions in refineries arise from valves, pumps, tanks, pressure relief valves, flanges. For example steam generators are potential sources of SOx, NOx, CO, particulates and hydrocarbons emissions. When operating properly and when burning cleaner fuels such as refinery fuel gas, fuel oil or natural gas these emissions are relatively low. If combustion is not complete, emissions can be significant for non-burn hydrocarbons.

The refinery industry has demanding environmental management challenges to protect water (petroleum refineries use relatively large volumes of water especially for cooling systems), soil and the atmosphere from refinery pollution.

2.23 Waste Minimization and Prevention

The main advantage of the pollution prevention approach is that it improves production and reduces the adverse impacts of pollution before they happen.

Pollution prevention options are source reduction and recycle/reuse.

Source reduction includes actions to reduce the quantity or the toxicity of the waste at the source. Separation technologies are key elements in recycle/reuse systems to recover valuable materials such as solvents, metals, inorganic species and water.

Chapter Three

Materials and Methods

Chapter Three
Materials and Methods

3.1 Introduction

This chapter deals with the materials and methods used to collect data and information and methods of data analysis, which can be summarized as follows. The major parameters are nitrogen oxides (NO, NO_2, NOx), sulfur dioxide (SO_2) carbon monoxide (CO) and hydrogen sulfide (H_2S).

3.2 Method of Data Collection

The data and information are collect from primary and secondary sources include:

1- secondary sources:

a) Scientific library and books and references, reports and published and unpublished materials to collect any relevant data.

b) Information network: to obtain up to date references articles.

2- primary sources include: Field observation

3- Verification of data and information: to verity data and information several methods were adopts this includes:

- Direct personal contact with the administrators of the environmental management system at the study site.

- Field visits to the study site.

- Interviews with relevant officials and consultants in this field.

- Using the views and opinion of the population through field survey,   interviews and questionnaires.

3.3 Determination of Gaseous Waste from the Refinery

The following instruments were used for the collection and analysis of gaseous waste from the refinery.

3.4 Waste gases analyses and equipment used (AQMS)

Ambient air quality system Measured parameters include Ozone (O_3), Nitrogen Dioxide (NO_2), Nitric Oxide (NO), Carbon Monoxide (CO), Carbon Dioxide (CO_2), Sulfur Dioxide (SO_2), Hydrogen Sulfide (H_2S) and other toxic gases.

The other measured particulate matters are $PM_{2.5}$, PM_{10} and total suspended particles (TSP). This was done through using of Electrochemical and Optical Sensor technology which deliver high performance within a flexible platform. External sensors can be integrated that measure temperature, humidity, wind speed, wind direction, environmental noise, solar radiation and other meteorological parameters.

3.4.1 Nitrogen Oxides Analyzer

The method of measuring the concentration of nitrogen oxides, the principle of the analyzer is based on the chemiluminescent reaction as shown in figure 3-2.

Figure 3-1: Air Quality Monitoring Station

3.4.2 Sulfur Dioxide Analyzer (UV Fluorescent)

The method of measuring the concentration of sulfur dioxide based on the optical fluorescent base is determined by the Sulfur Dioxide Analyzer as shown in figure 3-2

Figure 3-2: Air Quality Monitoring Station

3.5 Portable Gas Analyzer

3.5.1 Hydrogen Sulfide

Hydrogen sulfide was analyzed by Portable gas analyzer as shown in figure 3-3 the portable gas analyzer is highly water-resistant, built-in concussion-proof boot and heavy-duty, stainless steel, alligator style belt-clip. An extra-loud audible alarm, flashing LED light bars, and built-in vibrator alert users to hazardous conditions. Easy-to-read display includes a built-in backlight that ensures readings are legible even in dim light conditions.

Figure 3-3: Hydrogen Sulfide Gas Instrument used in KRC

3.5.2 Carbon Monoxide

Carbon Monoxide was detected and measured by The M40 instrument. Its four-button interface provides simple, intuitive operation and calibration, measuring CO in the range 0-999 ppm, as shown in figure 3-4

Figure 3-4: M40 used for reading CO in KRC

Chapter Four

Results and Discussion

Chapter Four
Results and Discussion

4.1   Preface

Measurement of air pollution generally fall into two categories: ambient and source.

The measurements were taken during the period 1/1/2018 to 22/5/2018. The results of the analysis are discussed in the light of the Sudanese Standard Limit for Gaseous Emission from petroleum refining. Gaseous waste analysis results are shown in tables 4-1 to 4-8

4.2   Results of Gaseous Analysis using Monitor Lab Analyzers

The obtained results of nitrogen oxides (NO, NO_2, NOx), sulfur dioxide (SO_2) carbon monoxide (CO) and hydrogen sulfide (H_2S) emission are presented in figures 4-1 to 4-12.

Table 4-1: Gaseous Waste Analysis Result at KRC, January - 2018

Date	CO mg/m³		SO₂ mg/m³		NO mg/m³	
	detected	SSMO	Detected	SSMO	detected	SSMO
31/1/2018	0.412	500	0	500	0.001	450
30/1/2018	0.270	500	0	500	0.001	450
29/1/2018	0.350	500	0	500	0.001	450
28/1/2018	0.414	500	0	500	0.001	450
27/1/2018	0.613	500	0	500	0.001	450
26/1/2018	0.190	500	0	500	0.001	450
25/1/2018	0.625	500	0	500	0.001	450
24/1/2018	0.304	500	0	500	0.001	450
23/1/2018	0.61	500	0	500	0.001	450
22/1/2018	0.625	500	0	500	0.001	450
21/1/2018	0.901	500	0	500	0.001	450
20/1/2018	0.164	500	0	500	0.001	450
19/1/2018	0.347	500	0	500	0.001	450
18/1/2018	0.463	500	0	500	0.001	450
17/1/2018	0.307	500	0	500	0.001	450
16/1/2018	0.304	500	0	500	0.001	450
15/1/2018	0.467	500	0	500	0.001	450
14/1/2018	0.357	500	0	500	0.001	450
13/1/2018	0.341	500	0	500	0.001	450
12/1/2018	0.390	500	0	500	0.001	450
11/1/2018	0.431	500	0	500	0.001	450
10/1/2018	0.275	500	0	500	0.001	450
9/1/2018	0.587	500	0	500	0.001	450
8/1/2018	0.253	500	0	500	0.001	450
7/1/2018	0.394	500	0	500	0.001	450
6/1/2018	0.301	500	0	500	0.001	450
5/1/2018	0.152	500	0	500	0.001	450
4/1/2018	0.460	500	0	500	0.001	450
3/1/2018	0.513	500	0	500	0.001	450
2/1/2018	0.489	500	0	500	0.001	450
1/1/2018	0.283	500	0	500	0.001	450

The daily concentrations of CO, SO₂, and NO were measured for a period of time of sixty days as:

CO: the detective value exceeded the limits.

SO₂: the detective values all fall bellow standard (SSMO)

NO: The detective value is zero

Table 4-2: Gaseous Waste Analysis Result at KRC, January - 2018

Date	NOx mg/m³		NO$_2$ mg/m³		H$_2$S mg/m³	
	detected	SSMO	detected	SSMO	Detected	SSMO
31/1/2018	0	450	0	450	0	10
30/1/2018	0	450	0	450	0	10
29/1/2018	0	450	0	450	0	10
28/1/2018	0	450	0	450	0	10
27/1/2018	0.004	450	0.005	450	0	10
26/1/2018	0	450	0	450	0	10
25/1/2018	0	450	0	450	0	10
24/1/2018	0	450	0	450	0	10
23/1/2018	0	450	0	450	0	10
22/1/2018	0	450	0	450	0	10
21/1/2018	0	450	0	450	0	10
20/1/2018	0	450	0	450	0	10
19/1/2018	0	450	0	450	0	10
18/1/2018	0	450	0	450	0	10
17/1/2018	0	450	0	450	0	10
16/1/2018	0	450	0	450	0	10
15/1/2018	0	450	0	450	0	10
14/1/2018	0	450	0	450	0	10
13/1/2018	0	450	0	450	0	10
12/1/2018	0	450	0	450	0.00	10
11/1/2018	0	450	0	450	0	10
10/1/2018	0	450	0	450	0	10
9/1/2018	0	450	0	450	0	10
8/1/2018	0	450	0	450	0	10
7/1/2018	0	450	0	450	0	10
6/1/2018	0	450	0	450	0	10
5/1/2018	0	450	0	450	0	10
4/1/2018	0	450	0	450	0	10
3/1/2018	0	450	0	450	0	10
2/1/2018	0	450	0	450	0	10
1/1/2018	0	450	0	450	0	10

The daily concentrations of NOx, NO$_2$, and H$_2$S were measured for a period of time of sixty days as:

NOx: the detective values all fall below the standard (SSMO)

NO: the detective values all fall bellow standard

H$_2$S: the detective value is zero.

Table 4-3: Gaseous Waste Analysis Result at KRC, February – 2018

Date	CO mg/m³		SO₂ mg/m³		NO mg/m³	
	detected	SSMO	detected	SSMO	Detected	SSMO
28/2/2018	0.400	500	0	500	0.002	450
27/2/2018	0.388	500	0	500	0.002	450
26/2/2018	0.495	500	0	500	0.002	450
25/2/2018	0.330	500	0	500	0.002	450
24/2/2018	0.563	500	0	500	0.001	450
23/2/2018	0.242	500	0	500	0.002	450
22/2/2018	1.013	500	0	500	0.002	450
21/2/2018	0.307	500	0	500	0.001	450
20/2/2018	0.398	500	0	500	0.002	450
19/2/2018	0.446	500	0	500	0.002	450
18/2/2018	0.405	500	0	500	0.002	450
17/2/2018	0.523	500	0	500	0.002	450
16/2/2018	0.281	500	0	500	0.002	450
15/2/2018	0.412	500	0	500	0.002	450
14/2/2018	0.384	500	0	500	0.002	450
13/2/2018	0.359	500	0	500	0	450
12/2/2018	0.192	500	0	500	0.002	450
11/2/2018	0.008	500	0	500	0.001	450
10/2/2018	0.036	500	0	500	0.002	450
9/2/2018	0.108	500	0	500	0.002	450
8/2/2018	0.308	500	0	500	0.002	450
7/2/2018	0.394	500	0	500	0	450
6/2/2018	0.198	500	0	500	0	450
5/2/2018	0.329	500	0	500	0.001	450
4/2/2018	0.181	500	0	500	0	450
3/2/2018	0.666	500	0	500	0.001	450
2/2/2018	0	500	0.001	500	0	450
1/2/2018	0.407	500	0	500	0.002	450

The daily concentrations of CO, SO₂, and NO were measured for a period of time of sixty days as:

CO: the detective value exceeded the limits.

SO₂: the detective values all fall bellow standard (SSMO)

NO: the detective value is zero.

Table 4-4: Gaseous Waste Analysis Result at KRC, February – 2018

Date	CO mg/m³	SO₂ mg/m³	NO mg/m³	NOx mg/m³	NO₂ mg/m³	H₂S mg/m³
28/2/2018	0.400	0	0.002	0	0	0
27/2/2018	0.388	0	0.002	0	0	0
26/2/2018	0.495	0	0.002	0	0	0
25/2/2018	0.330	0	0.002	0	0	0
24/2/2018	0.563	0	0.001	0	0	0
23/2/2018	0.242	0	0.002	0	0	0
22/2/2018	1.013	0	0.002	0	0	0
21/2/2018	0.307	0	0.001	0	0	0
20/2/2018	0.398	0	0.002	0	0	0
19/2/2018	0.446	0	0.002	0	0	0
18/2/2018	0.405	0	0.002	0	0	0
17/2/2018	0.523	0	0.002	0.004	0.006	0
16/2/2018	0.281	0	0.002	0.004	0.006	0
15/2/2018	0.412	0	0.002	0	0	0
14/2/2018	0.384	0	0.002	0	0	0
13/2/2018	0.359	0	0	0	0	0
12/2/2018	0.192	0	0.002	0	0	0
11/2/2018	0.008	0	0.001	0	0	0
10/2/2018	0.036	0	0.002	0.004	0.006	0
9/2/2018	0.108	0	0.002	0	0	0
8/2/2018	0.308	0	0.002	0	0	0
7/2/2018	0.394	0	0	0	0	0
6/2/2018	0.198	0	0	0	0	0
5/2/2018	0.329	0	0.001	0	0	0
4/2/2018	0.181	0	0	0	0	0
3/2/2018	0.666	0	0.001	0	0	0
2/2/2018	0	0.001	0	0	0	0
1/2/2018	0.407	0	0.002	0	0	0

The daily concentrations of NOx, NO₂, and H₂S were measured for a period of time of sixty days as:

NOx: the detective values all fall bellow standard (SSMO)

NO₂: the detective values all fall bellow standard (SSMO)

H₂S: the detective value is zero.

Table 4-5: Gaseous Waste Analysis Result at KRC, April – 2018

Date	CO mg/m³		SO₂ mg/m³		NO mg/m³	
	detected	SSMO	detected	SSMO	Detected	SSMO
30/4/2018	0.497	500	0	500	0	450
28/4/2018	0.156	500	0	500	0	450
27/4/2018	0	500	0	500	0	450
26/4/2018	0	500	0	500	0	450
25/4/2018	0.235	500	0	500	0.006	450
24/4/2018	0.097	500	0	500	0.004	450
23/4/2018	0.723	500	0	500	0.003	450
21/4/2018	0.215	500	0	500	0.003	450
20/4/2018	0.312	500	0	500	0	450
19/4/2018	0.149	500	0	500	0.002	450
18/4/2018	0.153	500	0	500	0.002	450
17/4/2018	0.173	500	0	500	0.002	450
16/4/2018	0.002	500	0	500	0.002	450
15/4/2018	0.289	500	0	500	0.001	450
14/4/2018	0.181	500	0	500	0.002	450
13/4/2018	0.75	500	0	500	0	450
12/4/2018	0	500	0	500	0.002	450
11/4/2018	0.258	500	0	500	0.002	450
10/4/2018	0.440	500	0	500	0.002	450
9/4/2018	0.366	500	0	500	0.002	450
8/4/2018	0.449	500	0	500	0.001	450
7/4/2018	0.217	500	0	500	0.002	450
6/4/2018	0.181	500	0	500	0.002	450
5/4/2018	0.352	500	0	500	0.003	450
4/4/2018	0.187	500	0	500	0.002	450
3/4/2018	0.373	500	0	500	0.002	450
2/4/2018	0.109	500	0	500	0.002	450
1/4/2018	0.258	500	0	500	0.002	450

The daily concentrations of CO, SO₂, and NO were measured for a period of time of sixty days as:

CO: the detective value exceeded the limits.

SO₂: the detective values all fall bellow standard (SSMO)

NO: the detective value is zero.

Table 4-6: Gaseous Waste Analysis Result at KRC, April – 2018

Date	NOx mg/m³		NO₂ mg/m³		H₂S mg/m	
	detected	SSMO	detected	SSMO	Detected	SSMO
30/4/2018	0.033	450	0.043	450	0	10
28/4/2018	0.051	450	0.079	450	0	10
27/4/2018	0.01	450	0.073	450	0	10
26/4/2018	0.080	450	0.020	450	0	10
25/4/2018	0	450	0	450	0	10
24/4/2018	0	450	0	450	0	10
23/4/2018	0	450	0	450	0	10
21/4/2018	0	450	0	450	0	10
20/4/2018	0	450	0	450	0	10
19/4/2018	0	450	0	450	0	10
18/4/2018	0	450	0	450	0	10
17/4/2018	0	450	0	450	0	10
16/4/2018	0	450	0	450	0	10
15/4/2018	0	450	0	450	0	10
14/4/2018	0	450	0	450	0	10
13/4/2018	0	450	0.004	450	0	10
12/4/2018	0	450	0	450	0	10
11/4/2018	0	450	0	450	0	10
10/4/2018	0	450	0	450	0	10
9/4/2018	0	450	0	450	0	10
8/4/2018	0	450	0	450	0	10
7/4/2018	0	450	0	450	0	10
6/4/2018	0	450	0	450	0	10
5/4/2018	0	450	0	450	0	10
4/4/2018	0	450	0	450	0	10
3/4/2018	0	450	0	450	0	10
2/4/2018	0	450	0	450	0	10
1/4/2018	0	450	0	450	0	10

The daily concentrations of NOx, NO₂, and H₂S were measured for a period of time of sixty days as:

NOx: the detective values all fall bellow standard (SSMO).

NO₂: the detective values all fall bellow standard (SSMO).

H₂S: the detective value is zero.

Table 4-7: Gaseous Waste Analysis Result at KRC, May– 2018

Date	CO mg/m³		SO₂ mg/m³		NO mg/m³	
	detected	SSMO	Detected	SSMO	Detected	SSMO
22/5/2018	0	500	0	500	0	450
21/5/2018	0.232	500	0	500	0	450
20/5/2015	0.612	500	0	500	0	450
19/5/2018	0.344	500	0	500	0	450
18/5/2018	0.326	500	0	500	0	450
17/5/2018	0.624	500	0	500	0	450
16/5/2018	0.246	500	0	500	0	450
15/5/2018	0.454	500	0	500	0	450
14/5/2018	0.064	500	0	500	0	450
13/5/2018	0.355	500	0	500	0	450
12/5/2018	0.411	500	0	500	0	450
11/5/2018	0.251	500	0.00	500	0.014	450
10/5/2018	0.268	500	0	500	0	450
9/5/2018	0.234	500	0	500	0.072	450
8/5/2018	0.385	500	0	500	0	450
7/5/2018	0.737	500	0	500	0	450
5/5/2018	0.347	500	0	500	0	450
4/5/2018	0.386	500	0	500	0.049	450
3/5/2018	0.438	500	0	500	0	450
2/5/2018	0.427	500	0	500	0	450
1/5/2018	0	500	0	500	0.070	450

The daily concentrations of CO, SO₂, and NO were measured for a period of time of sixty days as:

CO: the detective value exceeded the limits.

SO₂: the detective values all fall bellow standard (SSMO).

NO: the detective value is zero.

Table 4-8: Gaseous Waste Analysis Result at KRC, May– 2018

Date	NOx mg/m³		NO₂ mg/m³		H₂S mg/m³	
	detected	SSMO	detected	SSMO	Detected	SSMO
22/5/2018	0.022	450	0.149	450	0	10
21/5/2018	0.002	450	0.106	450	0	10
20/5/2015	0	450	0.044	450	0	10
19/5/2018	0.097	450	0.047	450	0	10
18/5/2018	0.007	450	0.079	450	0	10
17/5/2018	0	450	0.064	450	0	10
16/5/2018	0	450	0.039	450	0	10
15/5/2018	0	450	0.119	450	0	10
14/5/2018	0.071	450	0.152	450	0	10
13/5/2018	0	450	0.037	450	0	10
12/5/2018	0.011	450	0.144	450	0	10
11/5/2018	0.072	450	0.100	450	0	10
10/5/2018	0.037	450	0.098	450	0	10
9/5/2018	0.04	450	0	450	0	10
8/5/2018	0.023	450	0.061	450	0	10
7/5/2018	0.096	450	0.002	450	0	10
5/5/2018	0	450	0.07	450	0	10
4/5/2018	0.064	450	0.154	450	0	10
3/5/2018	0	450	0	450	0	10
2/5/2018	0	450	0.023	450	0	10
1/5/2018	0.097	450	0.027	450	0	10

The daily concentrations of NOx, NO₂, and H₂S were measured for a period of time of sixty days as:

NOx: the detective values all fall bellow standard (SSMO).

NO₂: the detective values all fall bellow standard (SSMO).

H₂S: The detective value is zero.

4.3 The Temporal variations in the SO$_2$, NO, NO$_2$, H$_2$S, NOx and CO contents are graphically represented in figures 4-1 to 4-12

Fig 4-1: indicated that detected values of CO for a period of sixty days, 85% of the values meet standard limits while 15% exceeded the limits.
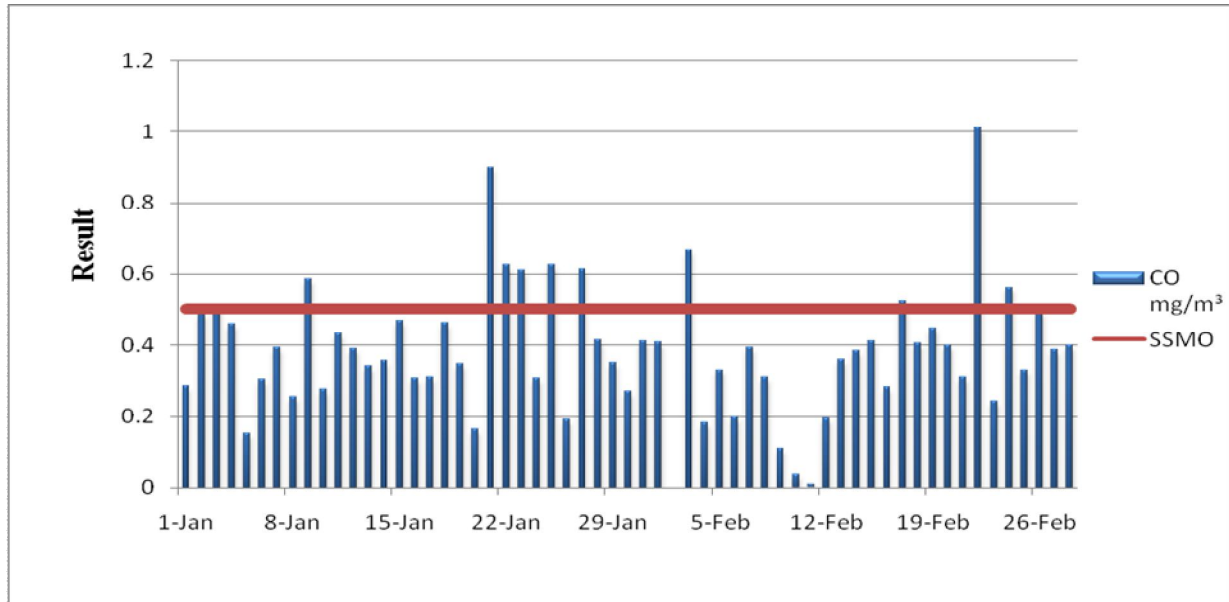

Fig 4-1: Variation of CO with Time (January –February, 2018)

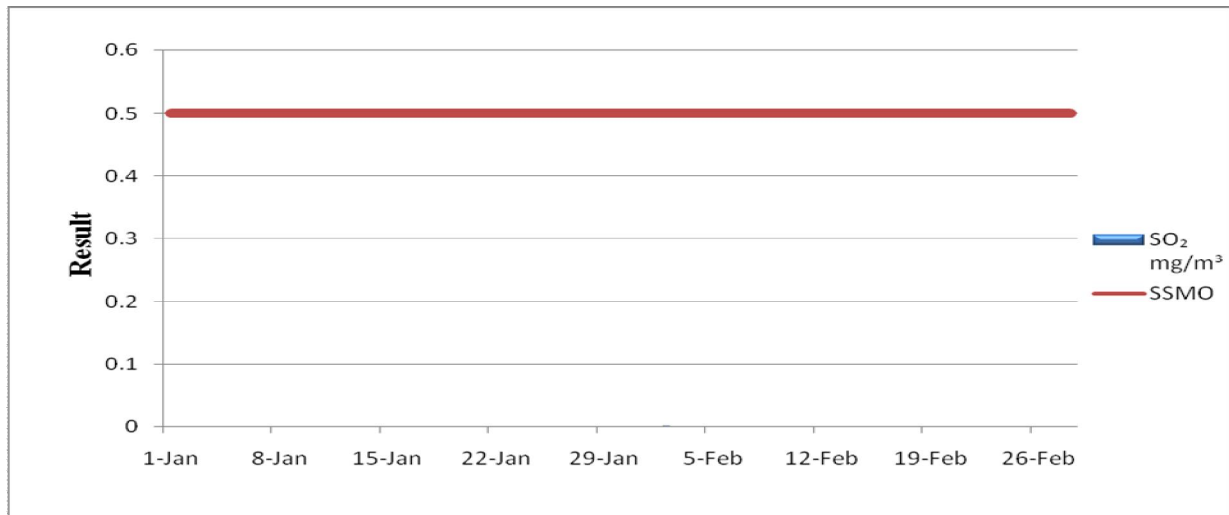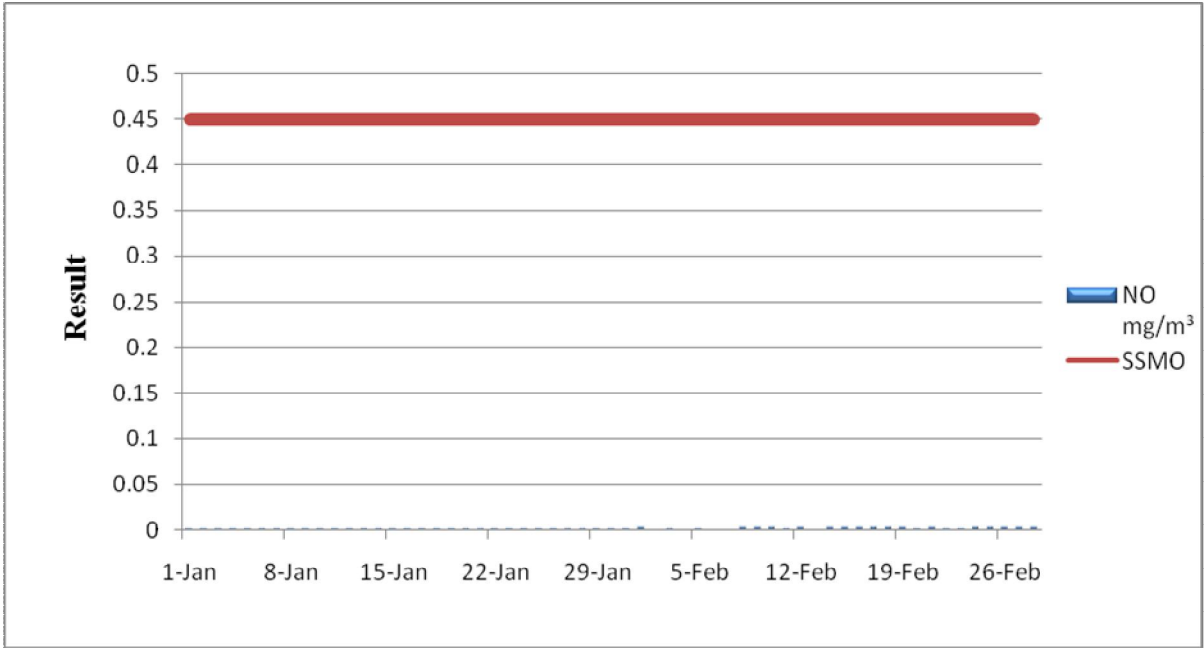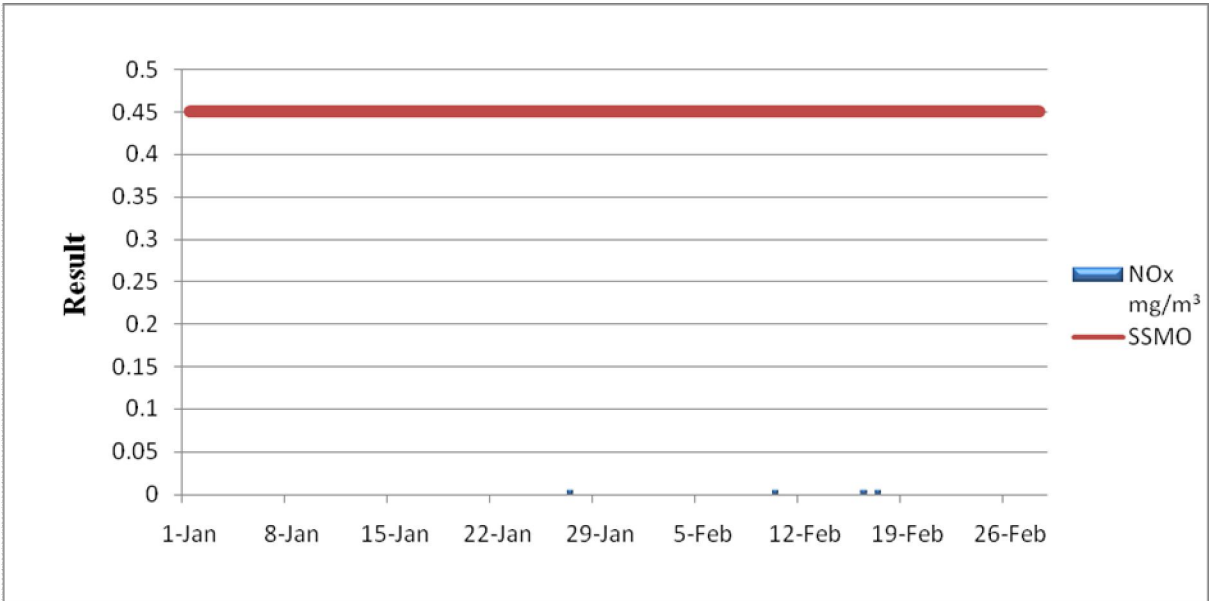Fig 4-2: indicated that detected values of SO$_2$ for a period of sixty days, is zero.

Fig 4-2: Variation of SO$_2$ with Time (January –February, 2018)

Fig 4-3: indicated that that detected values of NO for a period of sixty days, the detective values were all fall below the standard (SSMO).

Fig 4-3: Variation of NO with Time (January –February, 2018)

Fig 4-4: indicated that detected values of NOx for a period of sixty days were all fall below the standard (SSMO).

Fig 4-4: Variation of NOx with Time (January –February, 2018)

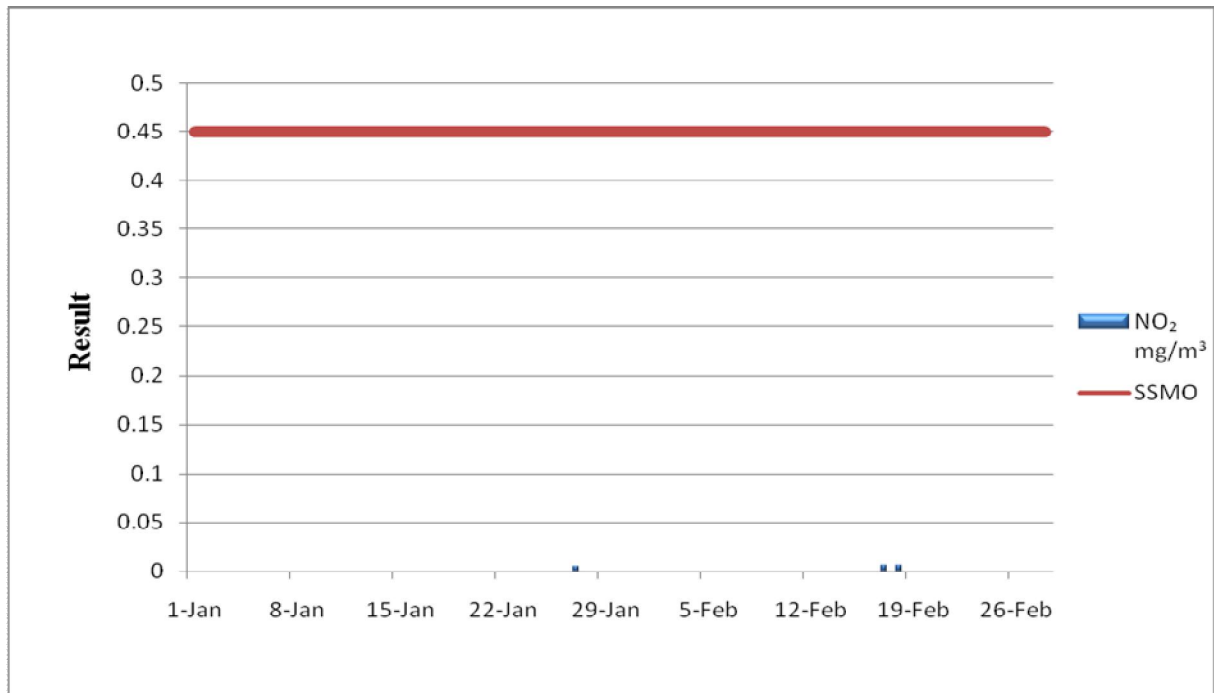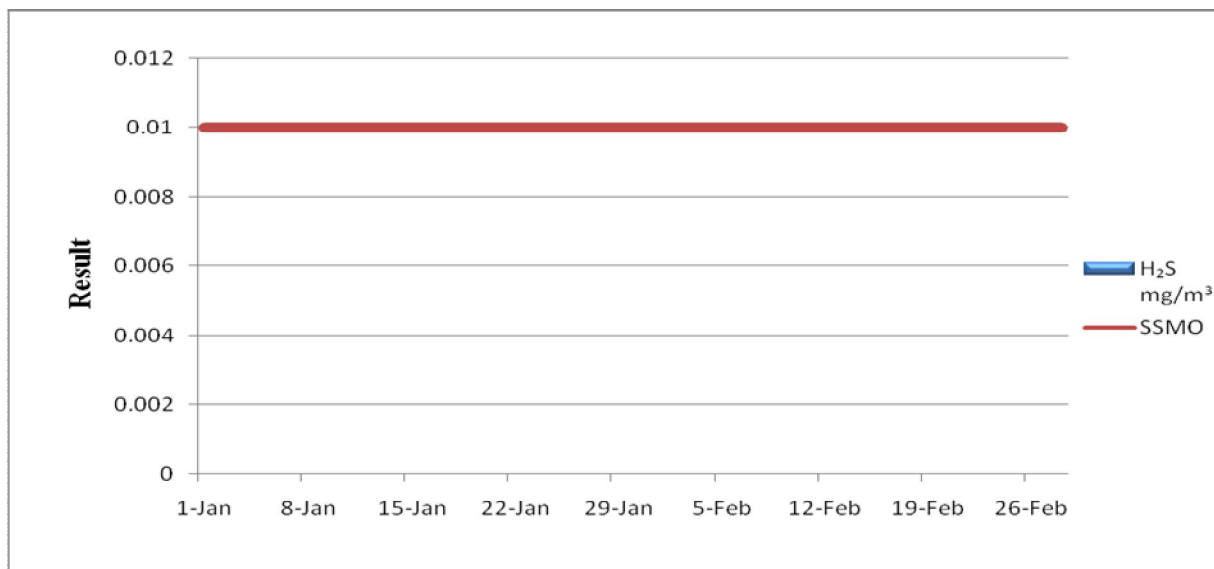Fig 4-5: indicated that detected of NO₂ for a period of sixty days were all fall below the standard (SSMO).

Fig 4-5: Variation of NO₂ with Time (January –February, 2018)

Fig 4-6: indicated that detected values of H₂S for a period of sixty day, the recorded value is zero.

Fig 4-6: Variation of H₂S with Time (January –February, 2018)

Fig 4-7: indicated that detected values of CO for a period of sixty days, 92% of the values meet standard limits while 8% exceeded the limit.
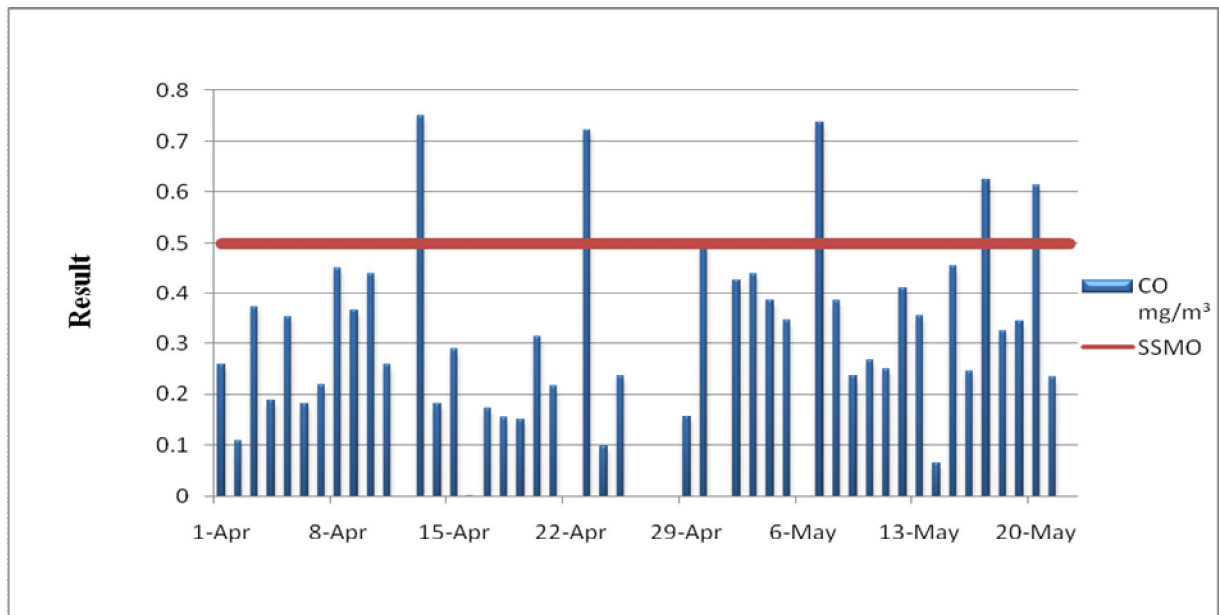

Fig 4-7: Variation of CO with Time (April- May, 2018)

Fig 4-8: indicated that detected values of SO_2 for a period of sixty days are zero.
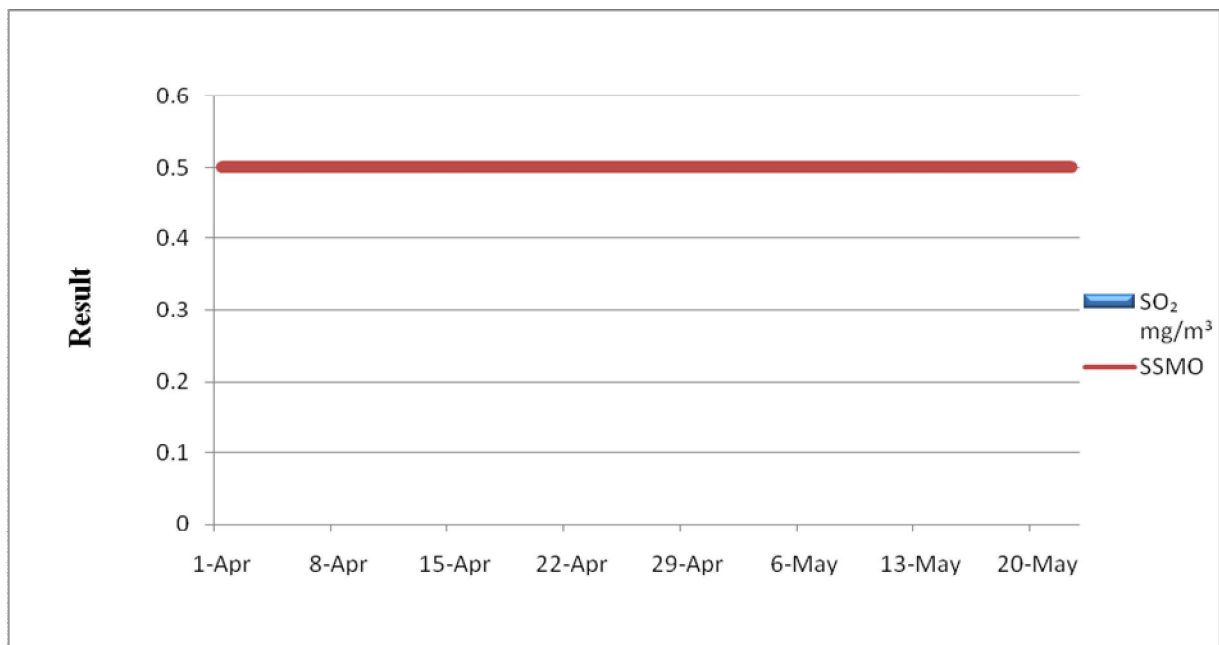

Fig 4-8: variation of SO_2 with Time (April- May, 2018)

Fig 4-9: indicated that detected values of NO for a period of sixty days, the detective values were all fall below the standard (SSMO).
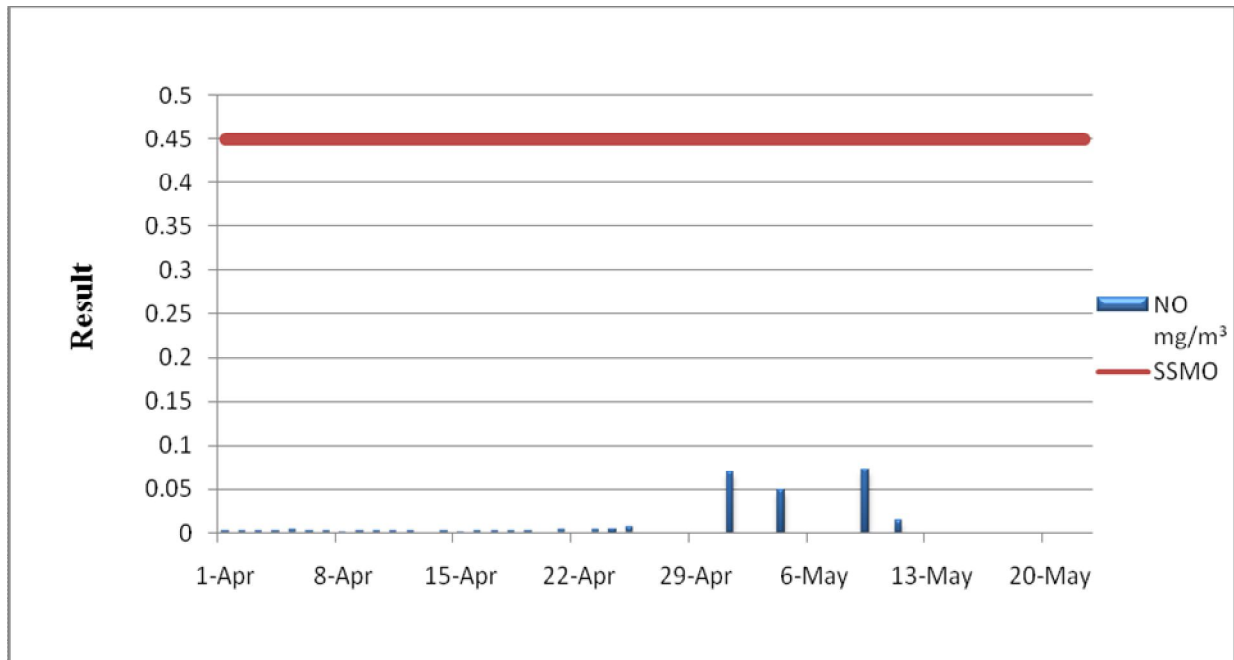

Fig 4-9: Variation of NO with Time (April- May, 2018)

Fig 4-10: indicated that detected values of NOx for a period of sixty days were all fall below the standard (SSMO).).
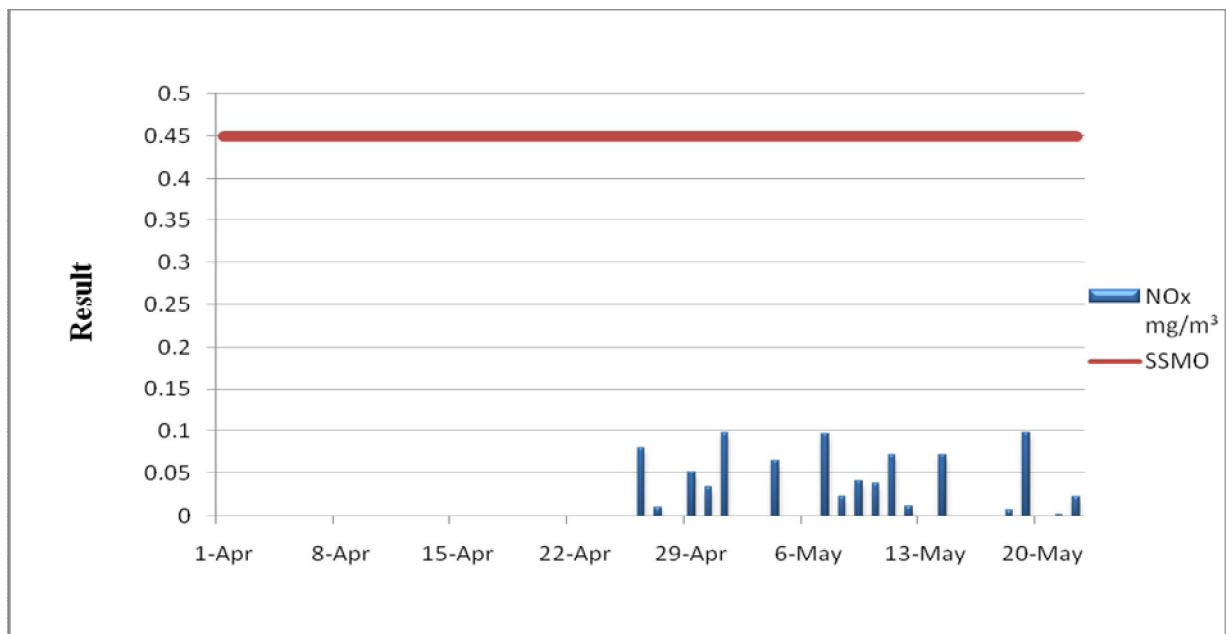

Fig 4-10: Variation of NOx with Time (April- May, 2018)

Fig 4-10: indicated that detected of NO₂ for a period of sixty days were all fall below the standard (SSMO).
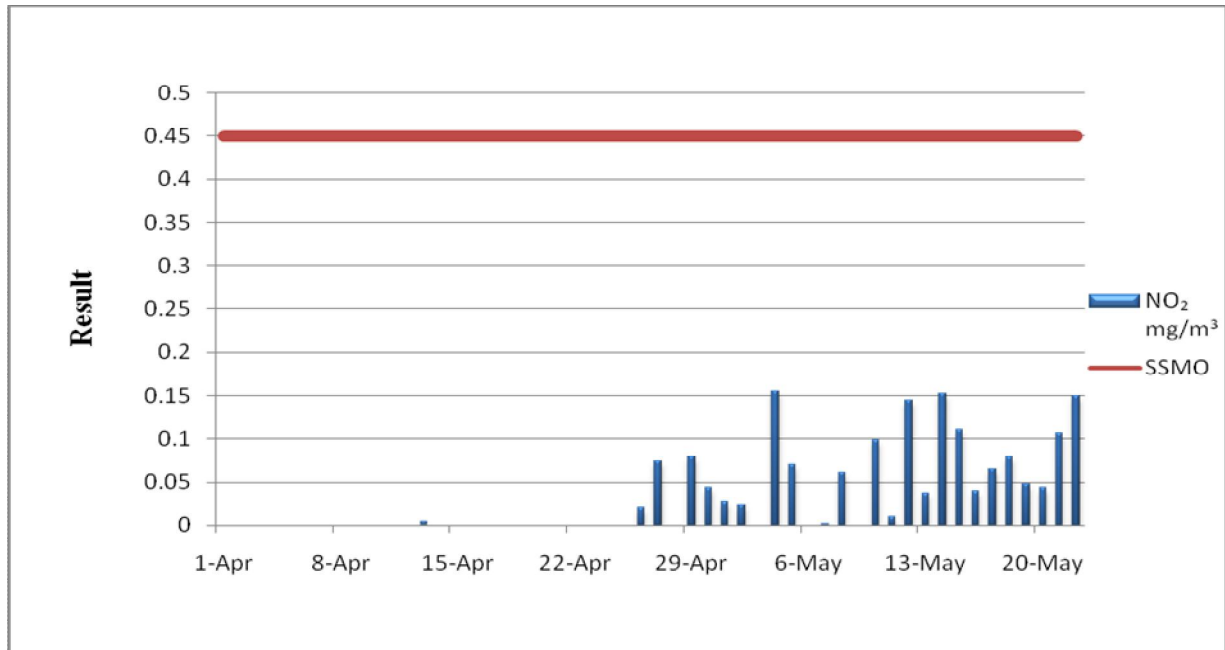

Fig 4-11: Variation of NO₂ with Time (April- May, 2018)

Fig 4-12: indicated that detected values of H₂S for a period of sixty day, the recorded value is zero.
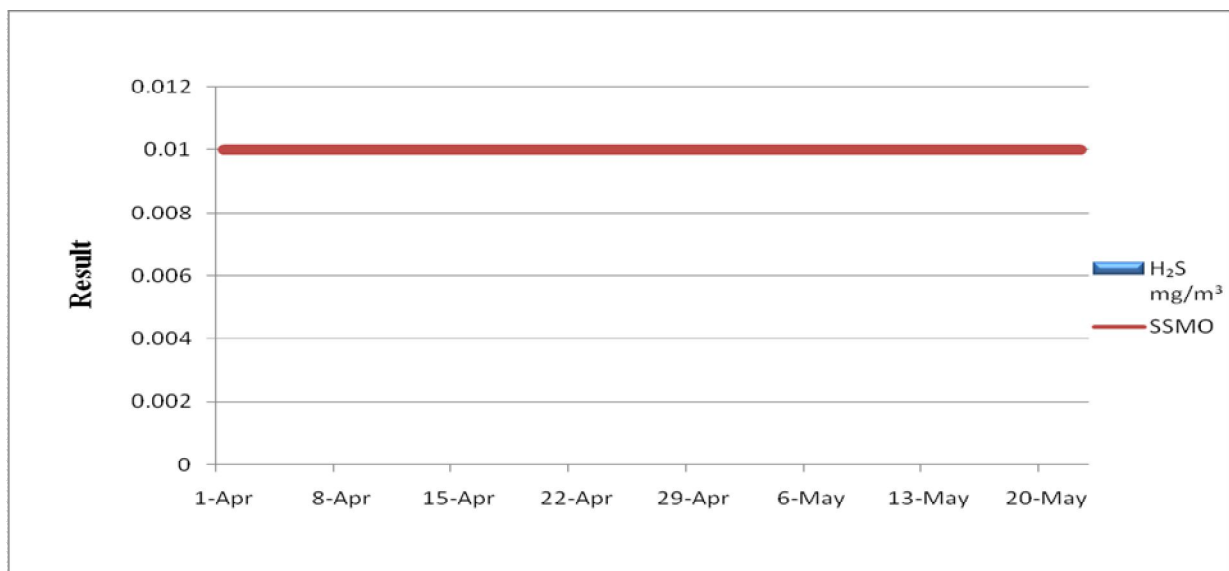

Fig 4-12: Variation of H₂S with Time (April- May, 2018)

Chapter Five

Conclusions and Recommendations

Chapter Five
Conclusions and Recommendations

5.1 Conclusion

The aim based on the results obtained the following:

1. The concentrations of gases are well below the upper limit of the SSMO. However CO values were above the limit.

2. The crude oil in Sudan has less sulfur content compared with other crude oil.

3. Gas indicators do not give a warning unless the limits are exceeded and therefore there is an impact on workers and the environment.

4. The study points out that the emitted gases there is no serious harmful.

5.2 Recommendations

1. The study recommends sustaining the concentration levels that were monitored in the refinery and considering following an awareness strategy in case an extension in oil refinery operations takes place within the same industry (KRC).

2. Install modification filters for carbon monoxide (CO) before its release in the air.

3. The importance of a gas analyzer or treatment in large units (RFCC, power station and DCU).

4. Stronger Health Protection system is required.

5. Studies on the effect and factors are urgently needed to improve the air quality.

6. Continuous environmental monitoring of the local environment.

7. Cleaner production strategies are needed to be applied in the refinery.

References

- Barabza Jacqueline, (1999): Petroleum Engineering – Environmental Impact of the Oil Industry, Brazil

- Brady MJ & Associates, (2005): Best Available Technology for Air pollution Control Manchester, UK.

- Cheremisinoff N. P, (1989): Air Pollution Control (Encyclopedia of Environmental Control Technology, Volume 2) Gulf Publishing Company, Houston, USA.

- EPA's 2008 Report on the Environment

- G.St Cholakov Pollution Control Technologies volume 3- Control of Pollution in Petroleum Industry

- Gary W. V. & Stephen J., (2000): Environmental Chemistry A global prespective Oxford University Press Inc, New York

- Han Dawei, (2012): Concise Environmental Engineering, PhD

- Hassan, S. N.M. 1981. Traffic air and noise pollution in central Khartoum city area, M.Sc., Environmental Studies, University of Khartoum ,Sudan

- Moneim Hind Abdel, 2005: The Environmental Impact of Gaseous By-Products and Pollutants In Waste Water at Khartoum Refinery Institute of Environmental Studies, University of Khartoum

- Health Safety and Environment Department, Khartoum Refining Company, 2003

- International Finance Corporation World Bank Group

- Krupa V. S, (1997): Air Pollution, People and Plant APS Press (The American Phytopathological Society), USA.

- Kumar Sameer & Katoria Dhrur, (2013): Air pollution and its control measures Delhi, India

- Mahajan P. S., (1985): Pollution Control in Process Industries TATA McGraw-Hill Publishing Co. Limited, India

- Meryers A. R., (1997): Handbook of Petroleum Refining Process McGraw Hill Companies, USA.

- Ministry of Energy and Mining, 2000. Impact of Petroleum Industry on Environment. Sudanese Petroleum Corporation Report, Khartoum, Sudan, P.1-58

- Ministry of Energy and Mining, (2000): Impact of Petroleum Industry on Environment, Sudanese Petroleum Corporation Report, Khartoum, Sudan,

- Ministry of Energy and Mining, (2005): Regulations for protection of the environment in the petroleum industry .Sudanese Petroleum Corporation, Ministry of Energy and Mining, Khartoum, Sudan.

- Ministry of Energy and Mining, 2005. Regulations for protection of the environment in the petroleum industry .Sudanese Petroleum Corporation, Ministry of Energy and Mining, Khartoum, Sudan, P.1-43

- Peirce J. J., Weiner F. R. & Vesilind A. P., (1998) Environmental Pollution and Control – 4th edition Butterworth-Heinemann, USA.

- The World Bank annual report 1998

- The World Health Report 2005

- The World Health Report 2008

- Van Gils H.V.M. 1982. Air Pollution Control Methods and Equipment in the Oil Refining Industry. Shell International Petroleum Publication. The Netherlands, P.167-189

- Wang K. L. & Pereira C. N., (1979): Handbook of Environmental Engineering Volume 1 Air and Noise pollution Control The Humana Press, USA

- North Carolina Climate Office, Composition of the Atmosphere
  https://climate.ncsu.edu/edu/Composition

- Visionlearning , Atmosphere and Ocean

  www.visionlearning.com/en/.../Earth...Earths-Atmosphere/107

- BusinessDictionary, Air Pollutants

  http://www.businessdictionary.com/definition/air-pollutant.html

- Institute of Technology and Management, Air pollution and control

  https://bmsit.ac.in/...**materials**/.../APC-_10CV765_-Dr_RG.pdf

- The Habitable planet, Atmospheric pollution

  www.learner.org/courses/envsci/unit/pdfs/unit11.pdf

- United State Department and Labor, Occupational Safety and health
  Administration
  www.osha.gov/OshDoc/data_Hurricane_Facts/hydrogen_sulfide_fact.ht
  ml

- European Environment Agency, Air Pollution, 2017

  https://www.eea.europa.eu/themes/air/air-pollution-sources

- Queensland Government, Environmental Pollution Monitoring, Air
  pollution, 2013 Viewed, 2016
  www.qld.gov.au/environment/pollution/monitoring/air/airpollution

Appendices

(وأقيموا الوزن بالقسط ولا تخسروا الميزان)

Date : ————
Ref. : ————

التاريخ : — / أكتوبر / 2006
الرقــم : هـ س م م /1/أ/1

إجراءات اعتماد مواصفة

مواصفة الانبعاثات الغازية الناتجة

من مصافي النفط والصناعات البتروكيميائية(4044)

1-اللجنة الفنية للبيئة

استنادا إلى المادة (13) للبند (1) من قانون الهيئة السودانية للمواصفات والمقاييس قامت اللجنة المذكورة أعلاه، بوضع مشروع المواصفة المرفق لرفعه للمدير العام– الهيئة السودانية للمواصفات والمقاييس للدراسة واستكمال إجراءات الإصدار.

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2- مدير إدارة المواصفات :.......................... التاريخ ....

عليه أوصى بإجازة واعتماد هذه المواصفة

3- المدير العام: .... التاريخ ....

4- مجلس الإدارة: .... التاريخ ....

5- .... التاريخ ....

المحتويات

مواصفة الانبعاثات الغازية الناتجة
من مصافي النفط والصناعات البتروكيميائية

1- المجال (Scope)

تختص هذه المواصفة القياسية السودانية بتحديد قيم للحدود القصوي المسموح بها للانبعاثات الغازية الناتجة من مصافى النفط والصناعات البتروكيميائية .

2- التعريفات (Definitions)

2-1 المصدر :

فى هذه المواصفة يشمل مصافى النفط ومنشأت الصناعات البتروكيميائية .

2-2 الحدود القصوي المسموح بها :

هي تراكيز الحدود القصوي المسموح بها بتحديد المعايير القياسية لأحد او مجموعة من الغازات المنبعثة من مصافى النفط و الصناعات البتروكيميائية.

2-3 الانبعاثات الغازية :

الانبعاثات الغازية المبينة فى هذه المواصفة هى مركب او مركبات لغازات عضوية او غير عضوية لها اضرار على البيئة وصحة الانسان .

2-4 النفط الخام :

ويقصد به جميع المولد الهيدروكربونية او المشتقة منها بحالتها الطبيعية سواءً سائلة او غازية او صلبة بجميع درجاتها لو كثافتها .

2-5 تكرير النفط :

هي سلسلة من العمليات الفيزيائية والكيميائية التى تؤدى الى فصل النفط الخام الى منتجات نهائية تستخدم لاغراض متعددة .

2-6 صناعات بتروكيميائية :

ويقصد بها اى عمليات صناعية ينتج عنها مواد كيميائية من النفط الخام او الغاز الطبيعى .

3- المتطلبات والأشتراطات (Requirements and Conditions)

يجب أن لا تتجاوز تركيزات الانبعاثات الغازية الصادرة من مصافى النفط والصناعات البتروكيميائية الحدود القصوى المسموح بها والمبينة في الجدول رقم (1).

4- الحدود القصوى المسموح بها (Maximum Allowable Levels)

جدول رقم (1) الحدود القصوى المسموح بها للانبعاثات الغازية الناتجة من مصافى النفط والصناعات البتروكيميائية

الحد الإقصى المسموح به(ملجرام/متر^3)		الرمز	الملوث
صناعة بتروكيميائية	مصافى النفط		
20	20	VOC	المركبات العضوية الطيارة
500	500	SO_x	اكاسيد الكبريت
300	450	NO_x	اكاسيد النيتروجين
10	10	H_2S	كبريتيد الهيدروجين
15	15	NH_3	النشادر
500	500	CO	اول اكسيد الكربون
20	50	PM	الجسيمات العالقة
-	20	CHO	الالدهيدات
5	-	C_6H_6	البنزين
10	-	HCl	كلوريد الهيدروجين
5	-	C_2H_3Cl	كلوريد الفينايل
5	-	$C_2H_4Cl_2$	2.1 - ثنائى كلوريد الايثان

5- طرق ووسائل القياس (Methods Of Measurements)

المؤشر (Parameter)	طريقة الاختبار (Method of Test)	
	ASTM	EPA
المركبات العضوية الطيارة Volatile Organic) (Compounds	D 5466	EPA FM. 04
اكسيد الكبريت (Sulphur Oxides)	D2914	EPA 0006
اكسيد النيتروجين (Nitrogen Oxides)	D3608	EPA 0007
كبريتيدا لهيدروجين (Hydrogen Sulphide)	D4323-84 R03	EPA 0015
النشادر (Amonia)		EPA 03501
اول اكسيد الكربون (Carbon Monoxide)	D3162	EPA 0010b
الجسيمات العالقة (Particulate Matters)	D4096	EPA 0005
الآلدهيدات (Aldehydes)	D5197	EPA 0011
البنزين (Benzene)		EPA 1671
كلوريد الهيدروجين (Hydrogen Chloride)		EPA 0026
كلوريد الفينيل (Vinyl Chloride)	D4766	EPA 0106
2.1 – ثانى كلوريد الايثان (1,2-Di chloro ethane)		EPA 1671

يمكن استخدام اى طرق قياس اخرى معتمدة تفى بالغرض .

ASTM : American Society for Testing Materials.
EPAUSA : Environmental Protection Agency,USA

6- المصطلحات الفنية (Technical Terms)

English	عربي
Crude petroleum	النفط الخام
Gaseous emissions	انبعاثات غازية
Inorganic compounds	المركبات غير العضوية
Organic compounds	المركبات العضوية
Petroleum refining	تكرير النفط
Petrochemical industries	الصناعات البتروكيميائية
Pollutants	الملوثات
Concentration of pollutants	تركيز الملوثات
Source	المصدر
Leakage	تسرب
Environmental pollution	تلوث بيئي
Particulate matters	الجسيمات العالقة
Standard test methods	طرق الاختبار القياسية

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7- المراجع (References)

- المؤسسة السودانية للنفط - لائحة حماية البيئة فى الصناعة النفطية الخرطوم ســبتمبر 2000م

- جمهورية مصر العربية - وزارة الصناعة والثروة المعدنية - القانون رقم (4) لسنة 1994 بشأن البيئة ولائحتها التنفيذية.

- المنظمه العربيه للتنميه الصناعيه والتعدين وبرنامج الامم المتحــده للبيئــه (2001) الدليل الاسترشادي العام بالحدود القصوي للملوثات الناتجه عن الصناعه فـى الـوطن العربي مايو 2001م - القاهره .

-WHO (2000) Guidelines for Air Quality -   WHO Geneva .2000

-The World Bank Group in Collaboration with the United Nations Environment programmed and the United Nations Industrial Development Organization (1998), Pollution Prevention and Abatement handbook, the World Bank group, Washington, DC, 1999.

- دولة الإمارات العربية المتحدة – القانون الإتحادي رقم (24) لسنة 1999 بشأن حماية البيئة وتنميتها ، أبوظبي –ديسمبر 2001

-American society for testing and Materials, Annual book of ASTM standard, Vol. 11.03, Westconshohcken, 2004

Http: // www.epa.gov/ ttn /cmc

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