ABSTRACT

Earth is a dynamic system comprising the biosphere, hydrosphere, atmosphere and the lithosphere. They are combination of interrelated, interdependent or interacting parts forming a collective whole or entity. Injury to one, is injury to all. Any change on one affects the rest of them.

The case of how gas flaring into the atmosphere from a petroleum gas flow station in Izombe, Imo State of Nigeria is affecting other subsystems (lithosphere, Biosphere and hydrosphere) in the environment reveals more evidence that earth is a system. And what affects one subsystem, directly or indirectly affects others.

This research is an investigative research involving questionnaires, and consultation of research works done by other authors in the study area.

From the research done by Nwagbara, M. O . & Onwudiwe, H. T (2020), Gas flaring in Izombe introduces pollutants like CO(Carbon monoxide), H_2S(Hydrogen Sulphide), SO_2(Sulphur Dioxide), NO_2(Nitrogen Dioxide), VOCs(Volatile Organic Compounds), SPM(Suspended Particulate Matter) in the atmosphere in the quantity above acceptable limits. And through processes and cycles, which, over time, intermittently store, transform and/or transfer matter and energy throughout the whole Earth system in ways that are governed by the laws of conservation of matter and energy, these pollutants manifest adversely (directly and indirectly) on the other subsystems in Izombe by causing; acid rain, infrastructural decay, pollution of the water system, death of fishes, land pollution, malfunctioning and death of plants, health challenges and death of animals (including humans) in the area. Research done by Ezeigbo, O.R, et al (2013) also determined the extent of land pollution caused by the flare. The report showed that the flare caused increase in acidity of the land, increase in temperature, decrease in moisture content, decrease in organic matter, increase in hydrocarbon content and decrease in Total Viable Microbial Counts of Soil Samples of the Study Area. From the above report, it could be determined the cause of infertility and morbidity of plants in the study area.

The protocol used is earth as a system. The research proved that earth is a system by showing that changes in the atmosphere also caused changes in other subsystems.

EARTH AS A SYSTEM: A CASE STUDY OF IZOMBE PETROLEUM GAS FLARING IN IMO STATE, NIGERIA.

A

RESEARCH WORK DONE

BY THE

GLOBE TEAM (STUDENTS)

OF

CHOSEN INTERNATIONAL SECONDARY SCHOOL

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INTRODUCTION

Earth is a dynamic and integrated system. A system is a complex whole, with smaller connected parts working together. It is a combination of interrelated, interdependent or interacting parts forming a collective whole or entity. On a macro level, the Earth system maintains its existence and functions as a whole through the interactions of its parts, called components. At a lower level or micro level, it is helpful to think of the Earth system in terms of four central components known as the subsystems – the hydrosphere, geosphere, atmosphere and biosphere (GLOBE (2023), Earth as a System Protocol). Hydrosphere includes the oceans, seas, rivers, streams, groundwater, water vapors, ice-sheets etc.; the geosphere or lithosphere are the soil and rocks components of the earth; The atmosphere is the air, which is made up of different gasses. The atmosphere (air) is a protective blanket which nurtures life on the earth surface and protects it from the hostile environment of outer space. It is composed of 78.1% Nitrogen, 20.8% Oxygen and a number of other gases such as Argon, Carbon dioxide, Methane and water vapour that total about 1%. Most of the air is held close to the earth surface by the gravitational force (Enger and Smith, 2004). while the biosphere includes all living things on earth.

These subsystems are interconnected by processes and cycles, which, over time, intermittently store, transform and/or transfer matter and energy throughout the whole Earth system in ways that are governed by the laws of conservation of matter and energy. The energy that drives these processes comes mainly from the Sun and sometimes from energy sources within the Earth. These processes include evaporation, erosion, convection currents, transpiration, photosynthesis or weathering. They can occur at different rates and in different places over time.

A cycle is a collection of connected, on-going processes that circulates a common component throughout a system – such cycles are continuous with no beginning or end. Cycles in the Earth system include the rock cycle, the food chain, the carbon cycle, the nitrogen cycle, the water cycle and energy cycles.

Earth's subsystems are all dynamic and ranges in varying complexities. Changes in one part of a subsystem can cause effects in other parts of that subsystem and/or the other subsystems, sometimes in ways that are quite unexpected. This response occurs because the subsystem attempts to maintain its stability, so if one variable changes, other variables may be affected to varying degrees. This degree of response also describes how stable or unstable these systems are. For example, a glacier is a relatively unstable system – if the temperature in the atmosphere rises above the melting point of ice, the glacier melts and decreases in ice and the glacier retreats. In contrast, a tree is a relatively stable system that regulates environmental changes due to water shortage, for example, by reducing the size of its leaves' stomata so it can return to a relative state of equilibrium.

On a bigger scale, the rising temperature in the atmosphere in a region can bring on a cascade of environmental changes to restore equilibrium across the subsystems, such as changes in evaporation and transpiration rates, weather patterns such as winds and precipitation, salinity of water bodies like lakes and seas, and type of species and numbers of organisms. Each response to a change can trigger a string of interconnected responses, which makes the repercussions of any single change in this complex and dynamic earth system difficult to predict. In this context, we are investigating the impact of flaring petroleum gas into the atmosphere to the biosphere, lithosphere and hydrosphere of the study area (Izombe), to proof the earth as a system (a change in one subsystem causes changes in other subsytems of the environment).

RESEARCH QUESTIONS AND HYPOTHESIS

LOCATION: The research was conducted in Izombe, which is situated in Oguta local government area of Imo State, Nigeria. Its geographical co-ordinates are 5°52’00” North, 6° 52’0’’ East.

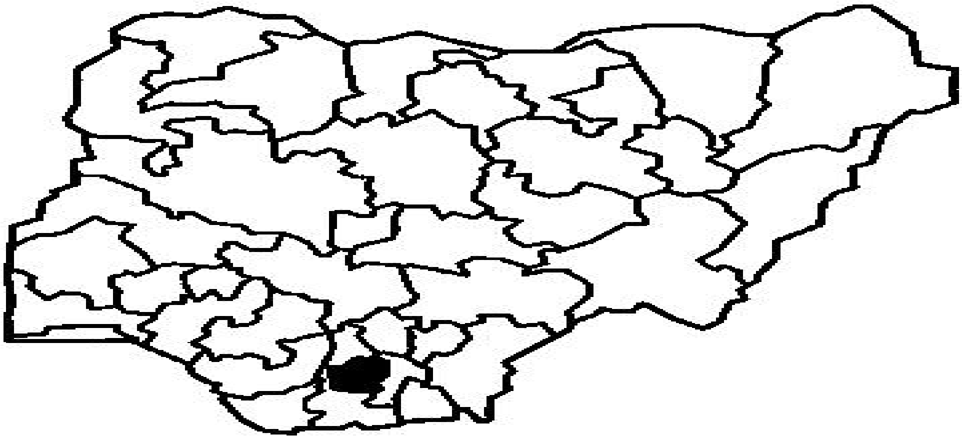

Figure 1 RESEARCH AREA

RESEARCH PROBLEM:

There has been a phenomenal damage to the quality of air, water, soil and plants in Izombe community in Oguta Local Government Area of Imo state, due to high level of petroleum gas flaring emission into the atmosphere from two flare sites.

Figure 2 GAS FLARE SITE

RESEARCH QUESTIONS:

- What is gas flaring?
- Why is gas flared?
- Which of the subsystem in environment is the gas flared to?

- And what is the impact of the gas flaring to the component of the environment?
- To proof that earth is a system, does the gas flaring affect other components of the earth?

RESEARCH HYPOTHESIS

In local Nigerian community (Izombe) in Oguta Local Government Area of Imo state, two Petroleum flare sites exist. Petroleum associated gases have been flared for over 20 years now, which have been causing adverse effects not only to the receiving atmosphere but to the; biosphere, lithosphere and hydrosphere of the area and it's environs. Showing that the earth is a system (what affects one component (atmosphere) affects the other components of the earth system).

LITERATURE REVIEW

WHAT IS GAS FLARING?

A gas flare which can be referred to as flare stack, flare explosion, bottom flare, or flare pit is gas combustion by industrial plants such as petroleum refineries, chemical and natural gas processing plants. It is prevalent at oil or gas extraction areas containing oil wells, gas wells, offshore oil, gas rigs, and landfills. When natural gas is generated to the surface but cannot easily be used, it is "burned for removal" or "flared".

Flaring mostly occurs when gas is generated as an outcome of oil extraction and brought to the surface. It is simply burned off if there is no infrastructure to put such associated gas to productive use. Gas flaring is the explosion of associated gas produced during several industrial processes constituting oil and gas recovery, petrochemical process, landfill gas extraction, and wastewater treatment. It is the intended open-air burning of natural gas and common practice in the largest scale oil. Gas flaring is the controlled burning of waste natural gases associated with oil production. One of the main sources is the "solution gas" trapped in underground oil supplies, which is released when oil is brought to the surface. Gas flaring is used to eliminate gas when the volume is insufficient to warrant recovery or collecting it is not economical (UKOOA, 2005). Gas flaring could be described as the cheapest means of expelling excess hydrocarbon gathered in an oil/gas production flow station/site. Gas flaring is environmentally unsustainable hence; successive governments have tried to discourage its practice through policy instructions and sanctions. Gas flare in most oil fields in Nigeria are located at ground level and surrounded by thick vegetation, farmland and villages with a distance of about 20 m from the flare (Abdulkareem, 2005). In areas having limited infrastructure, this gas is burned off either at the top of a large stack or from a pit in the ground which has wrecking outcomes on local communities.

WHY IS GAS FLARED?

A conventional but contentious way of eradicating undesirable gas is by flaring. Excess gas is flared due to the lack of processing and storage facilities. Other reasons why gas is flared are;

- Pressure aid to avert the risk of combustion from simply emitting large quantities of reactive gases.
- Removal of waste products from chemical production processes
- Safe explosion of combustible organic compounds

WHICH OF THE SUBSYSTEM IN ENVIRONMENT IS THE GAS FLARED TO?

Gas is flared to the atmospheric components of the environment. (Shewechuk 2002, Akpan 2008), stated that world-wide, about 115 billion cubic meters of gas are flared or vented into the atmosphere every year. Of this quantity, Nigeria alone flares almost 23billion cubic meters every year.

IMPACT OF GAS FLARING TO THE ATMOSPHERE

Flaring emits black carbon, methane, and volatile organic compounds which are powerful climate forcers and dangerous air pollutants. The black carbon emission reduces visibility in the atmosphere. The consequences of this act of excessive flaring is of a large contribution to global warming and climate change due to the emission of large quantities of the two major greenhouse gases carbon dioxide and methane (Briggs, 2005). Another major consequence of gas flaring is sour gas (Hydrogen Sulphide) and sulphur oxides emission, the end product of these compounds when it combines with atmospheric oxygen and water is acid rain.

IMPACT OF THE ATMOSPHERIC GAS FLARING ON THE LITHOSPHERE & BIOSPHERE

Gas flaring in Nigeria also has other direct consequences on the local environment. This can easily be seen as all vegetation surrounding is damaged and some are completely destroyed for as much as 50meters and more (Efe, 2003). The increase in temperature as well as the release of sooth and other toxic gases emanating from the flare site causes immense health problems and infrastructural damage in the communities nearest to flare sites (Nwaugo et al., 2006). Flaring of associated gas releases emissions rich in carbon, nitrogen, and sulfur oxides and soot. These acid gases are carried downward as acid deposition (wet and dry depositions) onto vegetation, soil, and water bodies in communities close to the flare sites. Also, intense heat and continuous illumination are associated with gas flaring. The low height of flare stacks ensures local pollution at ground level and nearby dry deposition, as well as close heating of surrounding vegetation and soil.

Likely acid deposition and intense heat from gas flares are likely to harm the fertility of the surrounding soils. The obvious signs are the poor vegetation growth and scorched soils around gas-flare locations.

Acid deposition decreases the soil pH. However, the effect of acid deposition on a particular soil ecosystem is influenced by such factors as acid sensitivity, neutralization capability, concentration and composition of acid reaction products, and the amount of acid added to the system. The basic cations (Ca^{2+}, Mg^{2+}, and K^{+}) are replaced by hydrogen ions or soluble metals and are lost through leaching. Increased acidity reduces activity of soil microorganisms sensitive to low pH, thus decreasing decomposition of plant residues and the recycling of essential plant nutrients. The concentration of trace-metal ions in soil solution increases (including aluminium, copper, iron, zinc, boron, manganese, chromium, and nickel) to levels that may be phytotoxic. Phosphorus compounds in the soil become mostly aluminum and iron phosphates, resulting in a reduced availability of plant phosphorus. Plant uptake of molybdate is reduced. Nitrification by the main autotrophic genera involved (Nitrosononas and Nitrobacter) is inhibited; thus, NH^{4+} is the main form of nitrogen taken up by plants instead of NO^{3-}. There is reduced symbiotic nitrogen fixation by legumes, except the Rhizobium strain, which is acid tolerant.

IMPACT OF THE ATMOSPHERIC GAS FLARING TO THE HYDROSPHERE

Apart from causing acid rain which finds its way to the water bodies. The rain water (while falling) mix with carbon blacks and other emitted substances, making the water unfit for household and industrial use. The polluted rain water however pollutes the aquatic water bodies killing fishes and other aquatic organisms.

MATERIALS AND METHOD

Figure 3 CORRODED BUILDING ROOF WITH ACID RAIN IN THE STUDY AREA

Figure 4 POLLUTED FISHING LAKE IN THE STUDY AREA

Air Quality Index		
AQI Category and Color	**Index Value**	**Description of Air Quality**
Good Green	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Moderate Yellow	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
[redacted] Orange	[redacted]	[redacted]
Unhealthy Red	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy Purple	201 to 300	Health alert: The risk of health effects is increased for everyone.
Hazardous Maroon	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

CHART 1 : GLOBE Air quality index.

AQI Category	AQI rating	PM10 µ g/m3	CO (ppm)	NO2 (ppm)	SO2 (ppm)	NH
Very good (0 -15)	A	0-15	0-2	0-0.002	0-0.002	0-50
Good (16 -31)	B	51 – 75	2.1-4.0	0.02-0.03	0.02-0.03	0-50
Moderate (32 – 49)	C	76-100	4.1-6.0	0.03-0.04	0.03-0.04	51-100
Poor (50 – 99)	D	101-150	6.1-9.0	0.04-0.06	0.03-0.04	201-300
Very Poor(100 or over)	E	>150	>9.0	>0.06	>0.06	301-500

Source: USEPA 2000

We did a review from the research made by Nwagbara, M. O . & Onwudiwe, H. T (2020) on the Air Quality Assessment of the study area as presented in the table below;

Distancefrom flare site (m)	**CO (ppm)**	**H2S (ppm)**	**SO2 (ppm)**	**NO2 (ppm)**	**VOCS (ppm)**	**SPM (ppm)**
100	5.29	2.32	3.49	1.39	3.00	10.71
200	3.17	1.21	2.33	1.04	2.19	8.51
300	2.68	0.43	1.27	0.92	1.22	4.69
K	0.63	0.01	0.59	0.03	0.00	2.17

Table 1 The air quality assessment of the study area;
100meter from gas flare point, 200meter from gas flare point, 300meter from gas flare point and K is the control (Far away from the gas flare point).
CO=Carbon monoxide; H_2S=Hydrogen Sulphide; SO_2=Sulphur Dioxide; NO_2=Nitrogen Dioxide; VOCs=Volatile Organic Compounds; SPM=Suspended Particulate Matter.

We also reviewed the physical properties and Total Viable Microbial Counts of Soil Samples of the study area from the research done by Ezeigbo, O. R., Okike-Osisiogu, F. U., Ihemanma, C. N. and Agomoh, N. G. (2013)

Distance from the Flare (m)	pH	Temperature (oC)	Moisture Content (%)	Organic matter (%)	Hydrocarbon Content (%)
10	4.0	48.0	16.84	5.32	4.8
50	4.3	45.0	22.66	5.24	2.2
100	5.2	42.4	29.32	6.12	1.4
Control	6.8	32.0	43.50	8.62	0.2

Table 2 Physical Properties of Soil Samples

Distance from the Flare(m)	Total Bacterial Count (cfu/g)	Total Fungal Count (cfu/g)	Total Coliform Count (cfu/g)
10	3.0×10^1	2.3×10^1	2.0×10^1
50	5.0×10^2	5.0×10^2	5.0×10^3
100	1.9×10^5	6.3×10^2	5.7×10^4
Control	2.9×10^5	7.7×10^2	6.0×10^4

Table 3 Total Viable Microbial Counts of Soil Samples of the Study Area

DATA SUMMARY

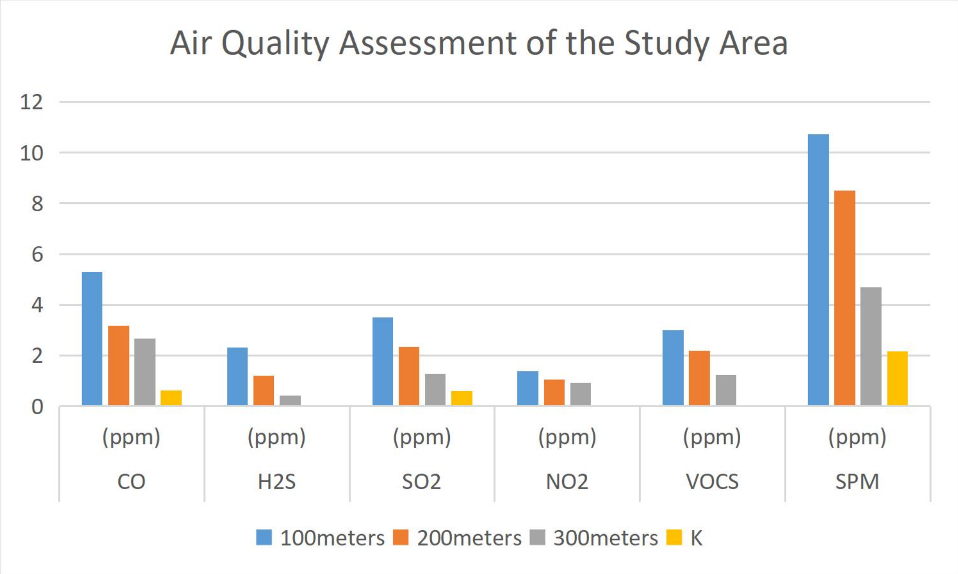

Figure 5

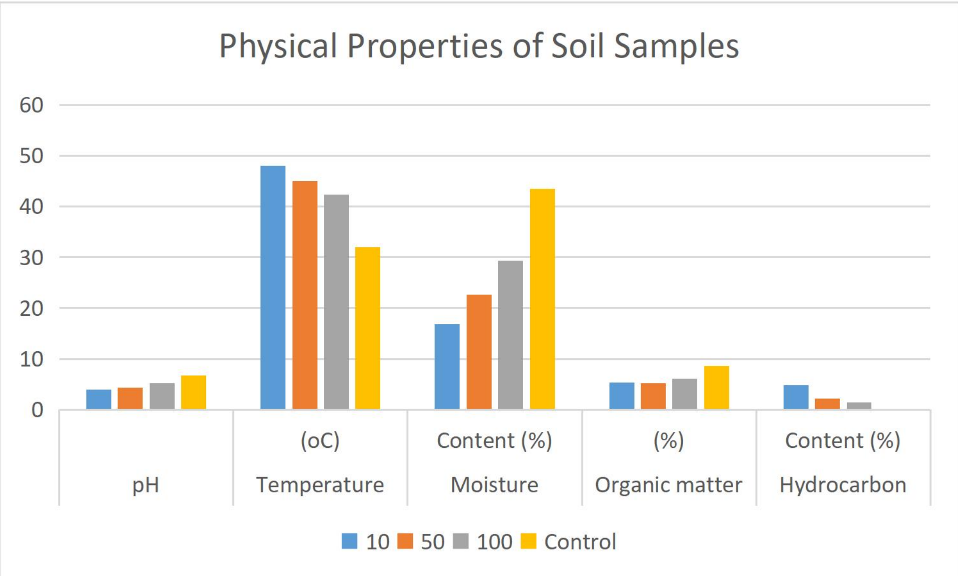

Figure 6

ANALYSIS AND RESULTS

Twenty villagers of the age range 20 to 80 years were interviewed concerning the impact of the petroleum gas flaring in the area respectively. They believe that the gas flaring in the area have affected adversely the land, air, and water conditions of the environment. That the oil particles and carbons from gas flares and power plants are not conducive for humans, fishes and other sea/river creatures. Therefore, their fishing business has been rendered useless and their farm land has also been badly polluted that it is no longer suitable for agriculture(as seen in figure 4). The indigenous also complained that gas flaring has contributed to acid rain which are corroding their building roofs(as seen in Figure 3). They don't drink from the rain water during rainy season anymore because when fetched the rain water are covered with black soots and layers of oil . The particles from the flare fill the air, covering everything (even plants and infrastructures) with fine layer of soot. People that are resident around the study area also complain about the intense heat from the flares sites. They believed that most cases of respiratory problems they are facing (such as asthma and bronchitis), lung disease, heart attack, miscarriage, and skin disease are as a result of drinking contaminated water, and exposure to heat from gas flaring activities. Over the past fifty years, gas flaring and venting associated with petroleum exploration and production in the region have continued to generate complex consequences in terms of energy, human health, natural environment, socio–economic environment and sustainable development (Ite *et al*., 2013). Indeed, widespread gas flaring has inflicted untold hardship and damage to human, plant and animal life in the area.

Table 1 and Figure 5 above shows the extent at which toxic gasses like carbon monoxide, Hydrogen Sulphide, Sulphur dioxide, Nitrogen Dioxide, Volatile Organic Compounds and Suspended Particulate Matters are released to the atmospheric environment from the gas flaring station. And these gases are known to cause acid rain and other environmental adverse effects. Greater concentrations of the toxic gases are found within the gas flaring area which shows proof of the acid rain and other environmental pollution problems as alleged by the villagers, Showing that change on the atmospheric subsystem of the area also caused changes on the Biosphere, hydrosphere and lithosphere. Indicating earth as a system. What affects one sphere affects the others.

The results of this study (Table 2, Table 3and Figure 6) showed that gas flaring has adverse effects on the soil physical and microbiological properties of the soil. The pH of the soil samples from izombe Flow-Station revealed a high level of acidity (4.0 - 5.2) when compared with the control value (6.8). This agrees with the findings of some authors like Nwaugo *et al* (2006), Nwaogu and Onyeze (2010) and Ubani and Onyejekwe (2013) that gas flaring increases the acidity of the soil. The acidity of the soil samples in Izombe could be attributed to the flaring which produces acidic oxides of nitrogen, carbon, sulphur, which dissolves in rain water to form acid rain. High soil acidity creates chemical and biological conditions which may be harmful to plants and soil microorganisms

(Nwaogu and Onyeze, 2010). One of such conditions is the reduction in the capacity of plants to absorb cations. The soil temperatures increased as distance approaches the flare. This excessive and continuous heating, not only reduces the soil moisture (Botkin and Keller, 1998) but also affects the photoperiodicity required for plant flowering and fruiting. The percentage soil moisture content obtained from this study ranged from 16.84 - 22.66% from 10m to 50m distance while the control sample has 43.5% moisture content.

The results also revealed that the organic matter around the Flow-Station was lower when compared with the control. Organic matter from the soil is derived from residual plant and animal materials synthesized by microorganisms and decomposed under the influence of temperature, moisture and optimum soil conditions. These prevailing conditions in the study deprive the soil of the necessary fertility for effective agriculture. A decrease in total microbial counts was obtained as distance increased towards the flare. The total bacterial counts was low (3.0×10^1 cfu/g) compared to 2.9×10^5 cfu/g obtain for the control sample. The fungal counts was 2.3×10^1 cfu/g at 10m distance compared to 7.7×10^2 cfu/g for the control sample. The coliform counts were also adversely affected with 2.0×10^1 obtained at 10m distance compared to 6.4×10^4 cfu/g obtained for the control. The bacterial isolated within 10m distance from the flare were species of *Pseudomonas and Bacillus,* which were hydrocarbon degraders while fungal isolates at this distance were *Fusarium* and *Penicillium.*

SUMMARY AND CONCLUSION

Earth is a dynamic and integrated system made up of the atmosphere, biosphere, hydrosphere and the lithosphere.

In any given environment like Izombe, there is always proof of interconnection among the subsystems of the earth. Due to processes and cycles peculiar to the earth system, when pollutant is introduced to any of the subsystems, it directly or indirectly affects the other subsystems.

Within the context of this research, petroleum gas flaring into the atmosphere of Izombe is investigated. Since Izombe is part of the earth with all the subsystems (Atmosphere, Hydrosphere, lithosphere and Biosphere) inclusive. To prove that earth is a system, any change or shift in one of the subsystems causes a change/shift in the others.

From the research done by Nwagbara, M. O . & Onwudiwe, H. T (2020), Gas flaring in Izombe introduces pollutants like CO(Carbon monoxide), H_2S(Hydrogen Sulphide), SO_2(Sulphur Dioxide), NO_2(Nitrogen Dioxide), VOCs(Volatile Organic Compounds), SPM(Suspended Particulate Matter) in the atmosphere in the quantity above acceptable limits. And through processes and cycles, which, over time, intermittently store, transform and/or transfer matter and energy throughout the whole Earth system in ways that are governed by the laws of conservation of matter and energy, these pollutants manifest adversely (directly and indirectly) on the other subsystems in Izombe by causing; acid rain, infrastructural decay, pollution of the water system, death of fishes, land pollution, malfunctioning and death of plants, health challenges and death of animals (including humans) in the area. Research done by Ezeigbo, O.R, et al (2013) also determined the extent of land pollution caused by the flare. The report showed the flare caused increase in acidity of pH, increase in temperature, decrease in moisture content, decrease in organic matter, increase in hydrocarbon content and decrease in Total Viable Microbial Counts of Soil Samples of the Study Area. From the above report, it could be determined the cause of infertility and morbidity of plants in the study area.

In conclusion, pollution of the Izombe(earth) atmosphere caused pollution of the hydrosphere, biosphere and lithosphere of the area and beyond. Proving that Izombe environment is a system and as a whole the earth is a system.

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