

seminars as this encourages and motivates the students in the learning process, promote learning by doing, allows the students to discover fact for themselves and aid achievement in Biology.

2. Biology students should always be encouraged to work together and learn from each other, whether male or female to promote understanding and as well as to reduce gender gap during Biology lesson.

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## **VOLATILE ORGANIC COMPOUNDS EMISSION FROM CRUDE OIL SPILLS IN NIGER DELTA OIL AND GAS FACILITIES**

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### **ABSTRACT**

*Being a major hub for oil and gas activities in Nigeria, the Niger Delta region is exposed to numerous crude oil spill incidents with inventory from both upstream and downstream activities. The research work is primarily aimed at quantifying the crude oil spill incidents from the oil and gas facilities within the Niger Delta region between years 2000 – 2020 and calculating the volatile organic compound (VOC) resulting from these spills. Gas chromatography was used to carry out detailed hydrocarbon analysis on a typical Niger Delta crude oil sample from which the volatile fraction was estimated. With that, the VOC from the recorded spills were calculated. The study revealed that a total of 7975 spill incidents occurred between 2000 and 2929 resulting to the release of 863950 barrels of crude oil out of which 132924 barrels (15%) was recovered. Approximately 232194 Metric tonnes CO<sub>2e</sub> of VOC were released into the atmosphere as a result of the spill incidents. There is urgent need to greatly reduce/control oil spill incidents within the Niger Delta region considering the its significant impact on atmospheric greenhouse gas emissions.*

***Keywords:*** *Niger Delta crude oil spills, Greenhouse gas emissions, Environmental impact, Volatile Organic Compound*

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### **INTRODUCTION**

Survival on earth is largely influenced by state of the environment and the and the outcome of human activities therein. One of the global events that arise from man-environment relationship is climate change. Climate change is a huge

threat and is considered the most serious ecological threat to the survival and sustainable development of humanity (IPCC, 2007). The primary cause of climate change is the burning of fossil fuels, such as oil and coal, which emits greenhouse gases (GHG) into the atmosphere - primarily carbon dioxide. Other human activities, such as agriculture and deforestation, also contribute to the proliferation of greenhouse gases that cause climate change. According to Keeling (1997), greenhouse gases, mainly carbon dioxide but including others such as methane, nitrous oxide, and halocarbons, enter the air mainly as byproducts of the combustion of coal, natural gas, and petroleum, and to a lesser degree through other industrial and agricultural activities; their rates of emission into the air are roughly proportional to the global rate of energy consumption arising from human activity.

Niger Delta is the major hub of oil and gas activities in Nigeria. Niger delta has a long history of oil spills which is as a result of the oil and gas activities. The growth of the country's oil industry, combined with a population explosion and a lack of enforcement of environmental regulations has led to substantial damage to Nigeria's environment, especially in the Niger Delta region

The major cause of climate change is the release of greenhouse gases into the atmosphere. These gases are released as a result of anthropogenic activities. These gases include carbons (CO<sub>2</sub>, CO), sulphur, methane, nitrous oxide, chloroflouro-carbons (CFCs) etc. According to Yousif *et al.* (2018), methane in addition to some VOCs emitted from crude oil such as ethane, propane, butane, pentane, and hexane, can also interact with NO<sub>x</sub> in the air forming ground-level ozone known as the tropospheric ozone. This therefore makes VOC an ozone precursor and a global warming agent (Bolaji and Huan,2013). According to Johnson T. (2011), many VOCs found in crude oil, such as benzene, toluene, and xylene, are known human toxicants and exposure to them can result in a wide variety of adverse health effects, from irritated eyes and respiratory pathways to cancer and birth defects. VOC has been shown to have very adverse effect on both the human health and the environment.

## **AREA OF STUDY**

The study area is the Niger Delta region of Nigeria. The Niger Delta is located in the Atlantic coast of Southern Nigeria and is the world's second largest delta with a coastline of about 450km which ends at Imo River entrance (Awosika,

1995). The Niger Delta covers an area of 70,000 Km<sup>2</sup> (27,000 sq mi) of marshland, creeks, tributaries and lagoons that drain the Niger River into the Atlantic at the Bight of Bonny.

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## METHODOLOGY

The study involved the collation of spill data for the period year 2000-2020.

Estimation of Volatile Organic Carbon (VOC) from spilled crude oil.

Crude samples were obtained from 3 oil and gas facilities within the Niger Delta. The samples were collected from the separator vessels which is the initial crude oil recipient vessel straight from the well head. This is aimed at ensuring that the crude oil light ends are still intact as at the time of sampling.

Flashing of the crude oil was carried to establish the percentage of VOC to be expected from a typical crude oil spilled in the environment. The method used for the analysis is the ASTM D6730 using the GC FID 7890A Agilent. This is used for detailed hydrocarbon analysis (DHA) of the crude oil. samples from which the average volatile fraction was estimated. The volatile fraction considered in this study is carbon chains C1-C7. With that, the VOC from the recorded spills were calculated

**Calculating the CO<sub>2</sub> equivalent emissions from the direct VOC release to the atmosphere** The global warming potential (GWP) of VOC of hydrocarbon origin is applied to the following equation 1.0 to calculate the CO<sub>2</sub>e (carbon dioxide equivalent) of the emitted VOC.

$$\text{CO}_2 \text{ equivalent} = \text{GWP}_{\text{voc}} \times m_{\text{voc}} \quad (1.0)$$

Where  $\text{GWP}_{\text{voc}}$  is the global warming potential due to indirect effect of VOC of hydrocarbon origin (default value of 10 assumed) and  $m_{\text{voc}}$  is the number of tonnes of the VOC emitted (Murrells and Derwent, 2007)

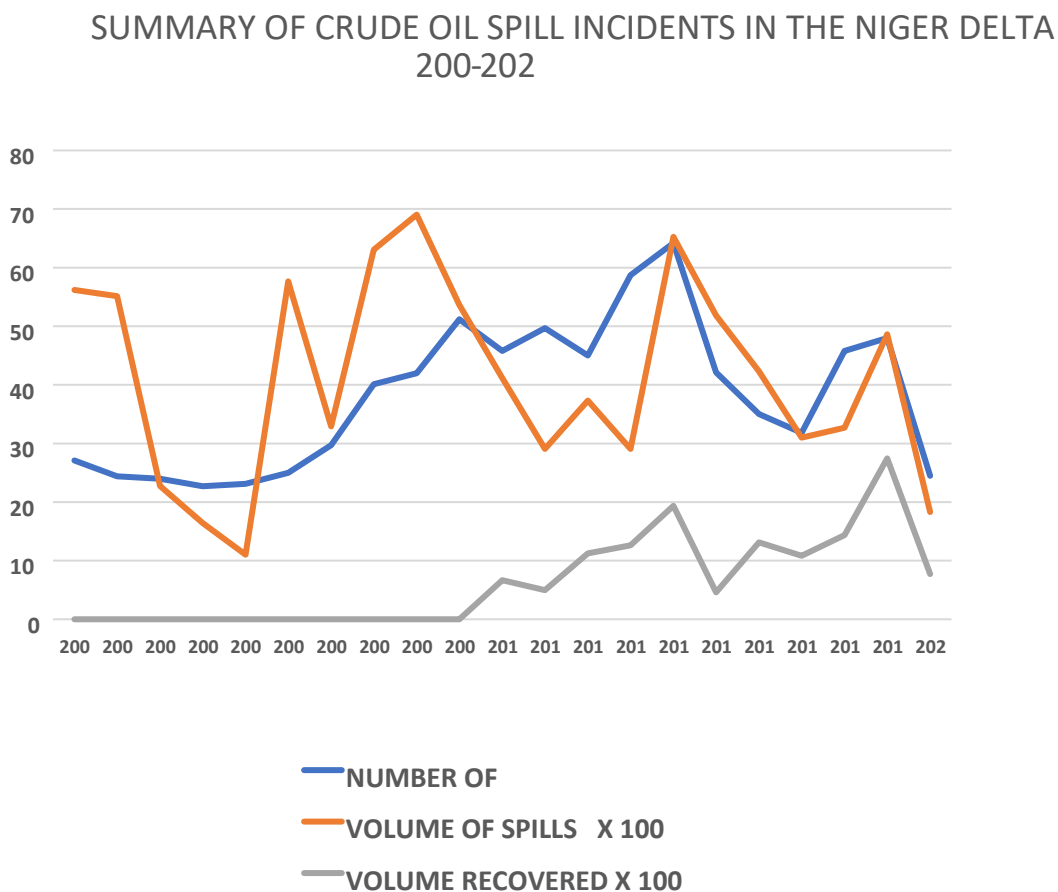
## RESULTS

The summary of the spill incidents within the Niger Delta region between year 2000 and 2020 is as shown in table 1 and fig 1 below:

Table 1: Summary of crude oil spills between year 200 and 2020

s/n	YEAR	NUMBER OF SPILLS	VOLUME OF SPILLS (BBLS)	VOLUME RECOVERED (BBLS)
<b>1</b>	2000	271	56176	n/a
<b>2</b>	2001	244	55136	n/a
<b>3</b>	2002	240	22754	n/a
<b>4</b>	2003	227	16417	n/a
<b>5</b>	2004	231	11021	n/a
<b>6</b>	2005	250	57646	n/a
<b>7</b>	2006	278	32816	n/a
<b>8</b>	2007	397	63070	n/a
<b>9</b>	2008	420	69043	n/a
<b>10</b>	2009	512	53644	n/a
<b>11</b>	2010	457	41145	6670
<b>12</b>	2011	497	29074	4958
<b>13</b>	2012	450	37294	11232
<b>14</b>	2013	587	29060	12626
<b>15</b>	2014	642	65239	19347
<b>16</b>	2015	421	51820	4616
<b>17</b>	2016	350	42295	13138
<b>18</b>	2017	318	31005	10848
<b>19</b>	2018	458	32671	14347
<b>20</b>	2019	480	48617	27446
<b>21</b>	2020	245	18302	7695
<b>TOTAL</b>		<b>7975</b>	<b>863950</b>	<b>132924</b>

Fig 1: Niger Delta crude oil spills between yr 2000-2020



### Volatile organic carbon estimation from spilled crude oil

The result of the detailed hydrocarbon analysis of the representative crude samples by gas chromatography (GC) are as follows:

Table 2: Compositional analysis of crude oil (flashed oil)

	SAMPLE A	SAMPLE B	SAMPLE C
COMPONENT	MOL %	MOL %	MOL %
N <sub>2</sub>	0	0	0
CO <sub>2</sub>	0	0	0
H <sub>2</sub> S	0	0	0
C <sub>1</sub>	0	0	0

<b>C<sub>2</sub></b>	0.23	0.22	0.06
<b>C<sub>3</sub></b>	0.61	0.58	0.52
<b>i-C<sub>4</sub></b>	0.54	0.53	0.42
<b>n-C<sub>4</sub></b>	0.88	0.85	1.28
<b>i-C<sub>5</sub></b>	1.26	1.25	1.4
<b>n-C<sub>5</sub></b>	1.1	1.11	1.59
<b>C<sub>6</sub></b>	4.13	4.22	5.78
<b>C<sub>7</sub></b>	8.98	9.48	12.04
<b>C<sub>8</sub></b>	14.63	15.11	8.09
<b>C<sub>9</sub></b>	10.3	10.4	5.98
<b>C10</b>	8.4	8.41	8.71
<b>C11</b>	6.3	6.23	5.87
<b>C12</b>	5.48	5.4	4.92
<b>C13</b>	4.56	4.47	4.76
<b>C14</b>	4.59	4.52	4.55
<b>C15</b>	4.78	4.68	4.35
<b>C16</b>	3.34	3.27	4.21
<b>C17</b>	2.65	2.59	3.71
<b>C18</b>	2.59	2.54	2.93
<b>C19</b>	2.11	1.98	2.26
<b>C20</b>	1.8	1.81	1.91
<b>C21</b>	1.67	1.52	1.69
<b>C22</b>	1.38	1.36	1.53
<b>C23</b>	1.31	1.26	1.46
<b>C24</b>	1.13	1.12	1.36
<b>C25</b>	1.05	1.07	1.27
<b>C26</b>	1.04	0.97	1.13
<b>C27</b>	0.96	0.9	1.31
<b>C28</b>	0.87	0.86	0.99
<b>C29</b>	0.7	0.68	0.91
<b>C30+</b>	0.63	0.61	3.01
<b>TOTAL</b>	100	100	100
<b>% C<sub>1</sub>-C<sub>7</sub></b>	17.73	18.24	23.09



$$\begin{aligned}
 \text{Average \% C1-C7} &= \frac{A + B + C}{3} \\
 &= \frac{17.3 + 18.24 + 23.09}{3} \\
 &= \frac{59.06}{3} \\
 &= 19.7 \%
 \end{aligned}$$

Therefore, the estimated volume of VOC from the spilled crude is 19.7% of the spilled volume.

Plugging it back into the yearly spilled volume, estimated yearly VOC emissions from spilled oil in the Niger delta is as shown in table 3 below:

Table 3: Estimated yearly VOC from spilled crude in Niger Delta

s/n	YEAR	NUMBER OF SPILLS	VOLUME OF SPILLS (BBLs)	OF VOC
1	2000	271	56176	11067
2	2001	244	55136	10862
3	2002	240	22654	4463
4	2003	227	16417	3234
5	2004	231	11021	2171
6	2005	250	57646	11356
7	2006	278	32816	6465
8	2007	397	63070	12425
9	2008	420	69043	13601
10	2009	512	53644	10568
11	2010	457	40953	8068
12	2011	497	29074	5728
13	2012	450	37294	7347
14	2013	587	29060	5725
15	2014	642	65239	12852
16	2015	421	51820	10209
17	2016	350	42295	8332
18	2017	318	31005	6108
19	2018	458	32671	6436
20	2019	480	48617	9578
21	2020	245	18302	3605

<b>TOTAL</b>	7975	863950	170198
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### Calculating the CO<sub>2</sub> equivalent of the emitted VOC

Using equation 1.0

$$\text{CO}_2 \text{ equivalent} = \text{GWP}_{\text{voc}} \times m_{\text{voc}}$$

$\text{GWP}_{\text{voc}} = 10$  (default value)

Applying equation 1.0 to all the years being studied, the CO<sub>2e</sub> for the VOC emitted are as shown in table 4 below:

Table 4 : Carbon dioxide equivalent (CO<sub>2e</sub>) of emitted VOC

s/n	YEAR	NUMBER OF SPILLS	VOLUME OF SPILLS (BBLs)	VOC IN BARRELS	VOC IN METRIC TONNES	CO <sub>2e</sub> OF EMITTED VOC (METRIC TONNES)
1	2000	271	56176	11067	1509.8	15098
2	2001	244	55136	10862	1481.8	14818
3	2002	240	22654	4463	608.8	6088
4	2003	227	16417	3234	441.2	4412
5	2004	231	11021	2171	296.2	2962
6	2005	250	57646	11356	1549.3	15493
7	2006	278	32816	6465	882.0	8820
8	2007	397	63070	12425	1695.1	16951
9	2008	420	69043	13601	1855.6	18556
10	2009	512	53644	10568	1441.7	14417
11	2010	457	40953	8068	1100.6	11006
12	2011	497	29074	5728	781.4	7814
13	2012	450	37294	7347	1002.3	10023
14	2013	587	29060	5725	781.0	7810
15	2014	642	65239	12852	1753.4	17534
16	2015	421	51820	10209	1392.7	13927
17	2016	350	42295	8332	1136.7	11367
18	2017	318	31005	6108	833.3	8333
19	2018	458	32671	6436	878.1	8781
20	2019	480	48617	9578	1306.6	13066
21	2020	245	18302	3605	491.9	4919

TOTAL	7975	863950	170198	23219.4	232194
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## DISCUSSION

### Summary of Spill incidents for the study period

Between the year 2000 and 2020, there were 7975 reported oil spills (table 1). These spills resulted in a total of 863950 barrels of being released into the environment; out of which only 132699 barrels were recovered. The highest number of spills (642) was recorded in 2014 while the highest cumulative volume of 69043 barrels was spilled in 2008.

The compositional analysis of the three crude samples by gas chromatography yielded the results on table 2. The mean percentage of the volatile component (C<sub>1</sub>-C<sub>7</sub>) for the three samples was calculated as 19.7%. Therefore, for the volume of crude oil spilled approximately 19.7% escapes directly into the atmosphere as VOC.

Table 3 shows the estimated yearly VOC emission from crude oil spills in the Niger Delta within the study period. From the 7975 crude oil spill incidents recorded, 863950 bbl crude oil was released into the environment; out of which approximately 170198 bbl of VOC was emitted into the atmosphere.

For us to be able to compare VOC emission with other GHG emissions, the carbon dioxide equivalent (CO<sub>2e</sub>) has to be determined. Carbon dioxide equivalent is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential. The CO<sub>2e</sub> from the yearly VOC emissions are shown on table 4. A total of 232194 CO<sub>2e</sub> of VOC were emitted within the period under review as a result of crude oil spill in the Niger Delta. This is a significant quantity which will further aggravate the problem of GHG and global warming in our environment. This is because VOC is an ozone precursor and a global warming agent.

## CONCLUSION

Apart from the obvious environmental degradation and socio-economic effects of oil spill incidents in the Niger Delta, there is yet a hitherto relatively unexplored effect of crude oil spill.

This is the link between crude oil spill and climate change.

This study has highlighted the significant contribution of crude oil spill to atmospheric greenhouse gases in the environment. The volume of volatile

organic compounds resulting from recorded crude oil spill within the study period was quantified and presented in their carbon dioxide equivalent for ease of standardized comparison.

This revelation underscores the immediate need for effective mitigative steps to be taken against crude oil spill within the Niger Delta region.

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