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Monitoring and Adaptation to Air Pollution: The Case of Oil Producing Communities in the Niger Delta Region

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Abstract: Air pollution is a very complex problem in the oil-bearing region of Niger Delta and poses multiple challenges in management and mitigation. This study is aimed at providing air quality monitoring plan and adaptation strategies for the residents of three oil bearing communities. Air quality data of the area was collected from NASA after a field study to determine the coordinates of the study area. After downloading the data, the latitude, longitude, and concentration data had to be extracted from the set of data using a computer high level language called python. The data formats gotten in this research were netcdf4, he5, and hdf. The techniques of analysis used were descriptive in the form of tables and trend analysis. Furthermore, geospatial analysis was carried out to note the spatio-temporal hot and cold spots in the area. The hot spot analysis tool calculates the Getis-Ord statistic for each geo-referenced household. This tool identified those households with either high or low attribute values that cluster spatially. In conclusion, wind and human activities greatly influence the pollutants distribution in the study area. Across these communities, Mgbede community is the cold spot region in both seasons while Ebocha is a hot spot region during the dry season and Okwuzi a hot spot region during the rainy season. Again, the concentration of HCHO increases across the three communities during the wet season, while that of $PM_{2.5}$ decreases in the three communities during the wet season. In a related development, the concentration of SO_2 across the three communities decreases during the dry season. Thus, this study proposed monitoring and adaptation plan to atmospheric pollution in the study area by the residents.

Keywords: Air Pollution, Hot Spot, Cold Spot, Mitigation, Adaptation

1. Introduction

The relevance of air to the sustenance of life in the planet cannot be over emphasized. When this valuable resource is impaired by human activities, the quality is compromised and its availability to man becomes injurious to human health. Although, there is no time in human history when the air is devoid of extraneous material, atmospheric composition according to Wayne varies tremendously according to location, temperature and time [20].

Sources of atmospheric pollution refer to various activities, locations or factors that release pollutants into the atmosphere, they include natural and anthropogenic sources [2]. Natural sources include dusts from unvegetated lands, methane from animal husbandry, radioactive elements through decaying of naturally occurring radioactive elements, wildfires and volcanic eruption in some regions. In these oil producing communities of Rivers State, the natural emission of these pollutants is very low and within the region's carrying capacity. However, the anthropogenic sources are increasing the quantity and amount of the pollutants daily. It could result from stationary (point) or mobile (non-point) sources. Examples of stationary sources are standby generators and gas flaring stacks while mobile ones are vehicles on transit.

On the other hand, natural activities which introduce foreign substances into the atmosphere could be poisonous or safe depending on their characteristics, quantity and duration of exposure. For instance, pollen grains produced during the pollination of crops alter the atmospheric composition but still play a vital role in the agricultural production. Similarly, catastrophic processes such as volcanic eruptions emit some toxic gases into the atmosphere which can threaten the life of human beings within the vicinity in question with other environmental consequences.

In recent time, it is well documented that declining air quality and its attendant problems are as a result of increasing roles of human activities in the troposphere. Industrialization, agriculture, urbanization, transportation are vital human activities that alter the quality of the air we breathe. In the Niger Delta Region, production of Oil and gas and other activities have gone a long way to alter the quality of air and life in the region. Gas flaring, oil and gas spillages, land and water pollution, explosions of oil and gas facilities destroy the traditional economic activities and health of the people leading to massive hunger, poverty and involvement in illicit socio-economic activities such as sea piracy, oil bunkering together with attendant consequences [7]. This paper shows a study that monitored the quality of air in Ebocha, Okwuzi and Mgbede communities and stipulates measures to adapt to its associated challenges in the study area.

2. Literature Survey

The impact of air pollution on human health has been a global problem and a nightmare to global, regional and national governments. Efforts to counter its effects at these levels have continued for decades. The United Nations Conference on Environment and Development, Rio 1992 popularly known as the Rio Earth Summit took place in Rio de Janeiro, Brazil. It is the conference that is central to the general development of customary international environmental law. All the 176 States that attended the conference agreed to its principles with the emergence of the Rio Declaration, the Convention on the Biological Diversity, the Framework Convention on Climate Change, Agenda 21 (an Action Plan on development and environment) and non–legally binding authoritative statement of principles in this area. The key principles of the conference are Principle 7 - on common but differentiated responsibilities, Principle 10 - fostering public awareness and participation on environmental decision making, Principle 15 on precautionary approach, Principles 16- the pollution pays principle, Principle 17 – on Environmental Impact Assessment and Principles 18 and 19 on Risk communication.

The 1992 Framework Convention on Climate Change among other issues has its main objective stated in Article 2, which is to stabilize the emissions of greenhouse gases at a level that would not interfere with the climate system or food production but would still enhance sustainable economic development of the global community. The offshoot of the convention was the Kyoto Protocol which was adopted in 1997. The protocol sets binding emission reduction targets for Annex I countries in relation to six gases such as CO_2, NO_x, hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), methane and ground level ozone. Although the implementation of the convention seems slow, yet it is witnessing significant impact. Despite the fact that the worst global emitter of CO_2 which is USA, and other three advanced countries Australia, Monaco and Liechtenstein have not ratified it, Russia in 2004 did, and enforced it in 2005.

The 1999 Gothenburg Protocol was aimed at abating acidification, eutrophication and ground level ozone. It has twenty-five parties and entered into force in May 2005. It was set out to specifically reduce Nitrogen Oxides (No_x), Sulphur IV oxide (SO_2), volatile organic compounds (VOCs) and Ammonia (NH_3) emissions. The protocol sets emission ceilings for each pollutant to be reached by 2010 and above, limits sources of emission both mobile and stationary, aims to promote exchange of information and technology among parties. The Gothenburg protocol was further amended in 2012 to include national emission reduction commitments to be achieved in 2020 and beyond. The implementation measures include regulation through national laws, and setting standards, financial incentives (taxes, incentives and subsidies), promotion of renewable sources of energy, fuel switching and increased energy efficiency to combat air pollution and climate change.

In Nigeria, development of environmental legislation has proliferated and classified into four stages [13]. The first stage is between 1900 -1956, the second is the petroleum focused environmental protection period between 1957- early 1960s, the third stage is the rudimentary and perfunctory crisis period (1970s – pre 1987). Lastly, the contemporary period (Post 1987). The contemporary period witnessed the formation of Federal Environmental Protection Agency (FEPA) with major function of establishing national environmental guidelines, standards and criteria most especially in the area of atmospheric quality, water quality, effluent discharges and protection of ozone layer [8].

In the Niger Delta region of Nigeria, the debate on environmental pollution at various communities where oil and gas activities occur has continued to attract international condemnation and severe reactions from host communities.

In Rivers State, the UNEP Report in 2011 affirms that the Ogoni land is environmentally devastated [18]. Various other scholars have carried out studies to reveal the atmospheric condition of the state particularly and Niger Delta Region at large. Adoki [4], investigated the atmospheric concentration of some pollutants in Oyigbo, Rivers State and revealed that the levels of particulate matter, sulphur iv oxide and oxides of nitrogen are above World Health Organization (WHO) limit, hence constituting a significant public health issue in the state.

The ignoble fact remains that despite the millions of dollars generated from this region by both government and multinational companies the only general hospital (in our study area) is under lock and keys for over ten years! Access to health facilities by the residents in this oil rich region is grossly limited. Abalogu and Okolo, [1], posit that oil produced in the Niger Delta is the life blood of the Nigerian economy, but has failed to translate to regional prosperity and development in the Niger Delta. Instead, the region has been rewarded with massive environmental degradation, political and economic marginalization. This exemplifies the paradox of poverty in the midst of plenty as well as dearth in the midst of abundance.

3. Problem Definition

Air pollution problem is pervasive and remains a major public health and environmental issue both in developing and developed world [6]. The influence of exposure to air pollutants on human health and well-being has been an interesting subject and gained much volume of research over the last 50 years. Air Pollution is considered one of the major factors leading to many diseases such as cardiovascular and respiratory diseases and lung cancer [2]. It also, adversely affects the animals and deteriorates the plant environment.

In the Niger Delta region of Nigeria, agitations through various court proceedings and insurgency as a result of pollution, marginalization of the people, bad governance, inconsistent policy framework and divide and rule policy of the oil companies in various communities where oil and gas activities take place are prevalent [1]. Also, in Rivers State, the ministry of environment has taken several drastic measures at curtailing air pollution particularly soot emission in Port Harcourt. For instance, soot alert was carried out in the state in 2017 to create public awareness of the emerging problem of particulate matter pollution and measures to mitigate and control it [15]. Some companies were shut down and individuals burning tyres were arrested. However, atmospheric quality in the state continues to deteriorate and human health exposure to particulate matter pollution continues to raise some concerns in the state.

In Ebocha, Mgbede and Okwuzi, communities where this study is carried out, gas flaring and other environmentally harmful practices of the multinational oil companies have continued unabated for more than fifty years. Gas flaring involves incomplete combustion and a release of large amounts of black soot which is enriched with polyaromatic hydrocarbons and other acidic pollutants [11]. Acid deposition is already a significant problem in the region. The dominance of grasses and shrubs in some parts of the region suggests a considerable loss of natural forests [19]. Incidences of accelerated roof corrosion, soiling of surface and paints due to soot deposition, asthma, respiratory and skin infections, lung dysfunction are increasing daily. In line with the fact that the soil is a deposition environment for atmospheric pollution. A study on the effects of gas flaring on soil pH in Egbema clan which includes the study area was carried out [14]. The study revealed high levels of acid deposition (3.7 in the pH meter) on the soil.

In 2015, a sudden release of Air pollutants occurred during a hydrocarbon storage tank explosion belonging to Nigeria Agip Oil Company in the Ebocha Oil Center. See Figure 1. According to the Company Report, the incident caused a daily production drop of millions of barrels of oil which caused the company huge losses, running into millions of US dollars per day. During the period of incident, rain water turned dark, traffic congestion occurred for hours following poor atmospheric visibility, health of the people deteriorated with rising cases of cough, high blood pressure, vomiting and stooling especially among children and the elderly. Hospital admissions within this period also peaked when compared with other years.

***Figure 1.** Atmospheric pollution from Oil Facility Explosion in NAOC Ebocha Oil Center in 2015.*

Nevertheless, developing countries (such as Nigeria) have formidable laws to tackle atmospheric pollution, which are useless if not adequately enforced [3]. These implementation challenges among others include corruption, lack of funding for the regulatory bodies, lack of skilled personnel, conflicting roles of multiple regulatory bodies, low level of public awareness on environmental issues, and litigation cost [3]. Indeed, it is a very complex problem in the region and poses multiple challenges in management and mitigation. However, where the people are not protected by law or where the implementation of corporate social responsibilities of multinational oil corporations are ineffective, should the victims of air pollution episodes remain handicapped and suffer undue degradation in the quality of their health due to regular exposure to deadly atmosphere? Definitely no. Thus this study is aimed at providing air quality monitoring plan and adaptation strategies for the residents of the oil bearing communities.

4. Methodology

Air quality data of the area was collected from NASA after a field study to determine the coordinates of the study area. The known coordinate as in Table 1 was used to browse through the website of NASA to get to their database where the information on pollutants concentration is stored. After downloading the data, the latitude. longitude and concentration data had to be extracted from the dataset using a high level computer language known as phyton. The data format gotten in this research are he5, netcdf4 and hdf. The air quality data was arranged according to season.

Table 1. *The coordinates of the study area.*

POINTS	LATITUDE	LONGITUDE
Ebocha	05°26' 06.3" N	06° 41' 19.2" E
Mgbede	05°27' 24.5" N	06°40' 26.9" E
Okwuzi	05° 28' 22.2" N	06° 43' 47.1" E

The techniques of analysis were descriptive using tables and trend analysis. Furthermore, geospatial analysis was carried out to ascertain the spatio-temporal cold and hot spots in the area. The hot spot analysis tool calculates the Getis-Ord statistic for each geo-referenced household recognized areas those households with either high or low attribute values cluster spatially.

5. Results

5.1. Spatial Concentration of SO_2 in Dry Season

In the month of December, it was discovered that Ebocha had SO_2 level of 1.65378E-06 kg/m^2, Mgbede, 1.65136E-06 kg/m^2 and Okwuzi, 1.65136E-06 kg/m^2. This indicates that Ebocha had the maximum level of SO_2 in December. In the month of January, Ebocha, Mgbede and Okwuzi SO_2 concentrations were 1.15342E-06 kg/m^2, 1.15503E-06 kg/m^2, 1.15567E-06 kg/m^2 respectively, this shows that Okwuzi had the uppermost level of SO_2 in January. In the month of February, Ebocha, Mgbede and Okwuzi had SO_2 concentration of 9.15046E-07 kg/m^2, 9.14628E-07 kg/m^2, 9.14469E-07 kg/m^2 respectively, this equally indicated that Ebocha had the highest concentration of SO_2 in February, see Figure 2.

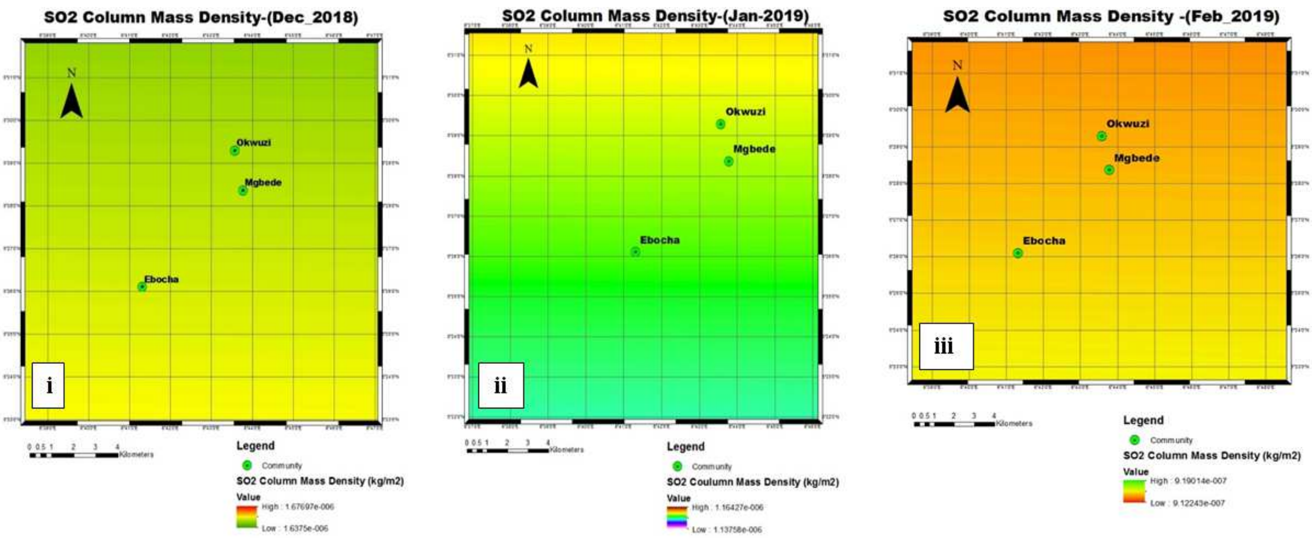

Figure 2. *Spatial distribution of SO_2 concentration within the study area in (i) December, (ii) January, and (iii) February.*

5.2. Spatial Concentration of So_2 in Wet Season

In the wet season period between June, July and August, Ebocha, Mgbede and Okwuzi had SO_2 concentration of 8.91193E-08 kg/m^2, 8.93669E-08 kg/m^2, 8.94634E-08 kg/m^2 respectively, the implication of this is that Okwuzi had the uppermost level of SO_2 in June. In the month of July, Ebocha, Mgbede and Okwuzi had SO_2 level of 8.07366E-12 kg/m^2, 8.39886E-12 kg/m^2, 8.5244E-12 kg/m^2 respectively, this shows also that Okwuzi had the uppermost level of SO_2 in July. In the month of August, Ebocha, Mgbede and

Okwuzi had SO_2 concentration of 7.79678E-08 kg/m^2, 7.80931E-08 kg/m^2, 7.81415E-08 kg/m^2 respectively, this equally indicates that Okwuzi community had the uppermost level of SO_2 in August, this is demonstrated in Figure 3.

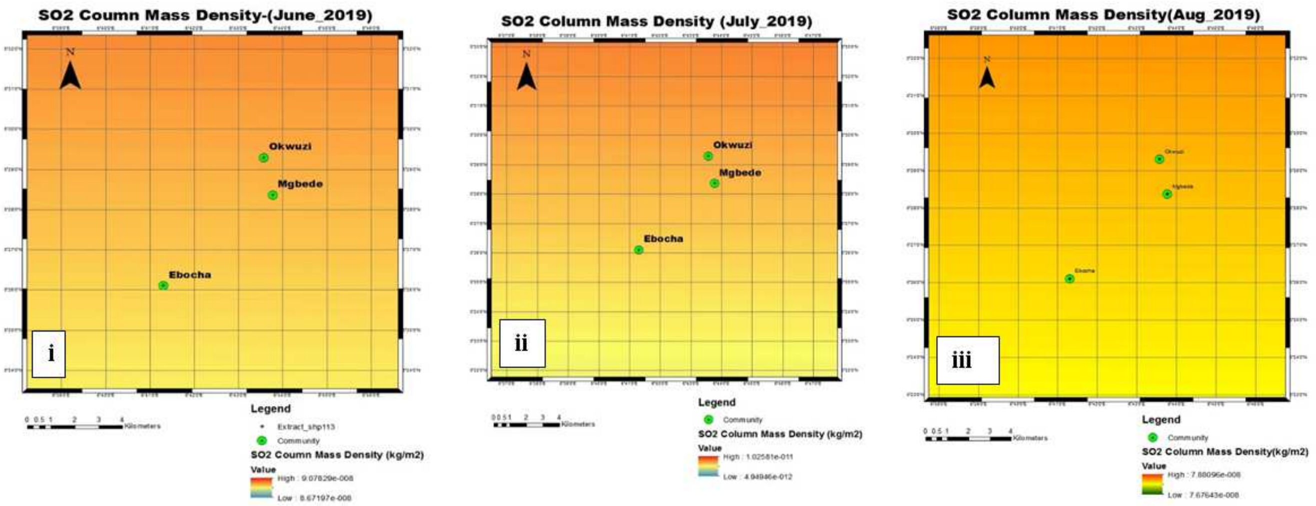

Figure 3. *Wet season distribution of SO_2 concentration within the study area: (i) June, (ii) July, (iii) August.*

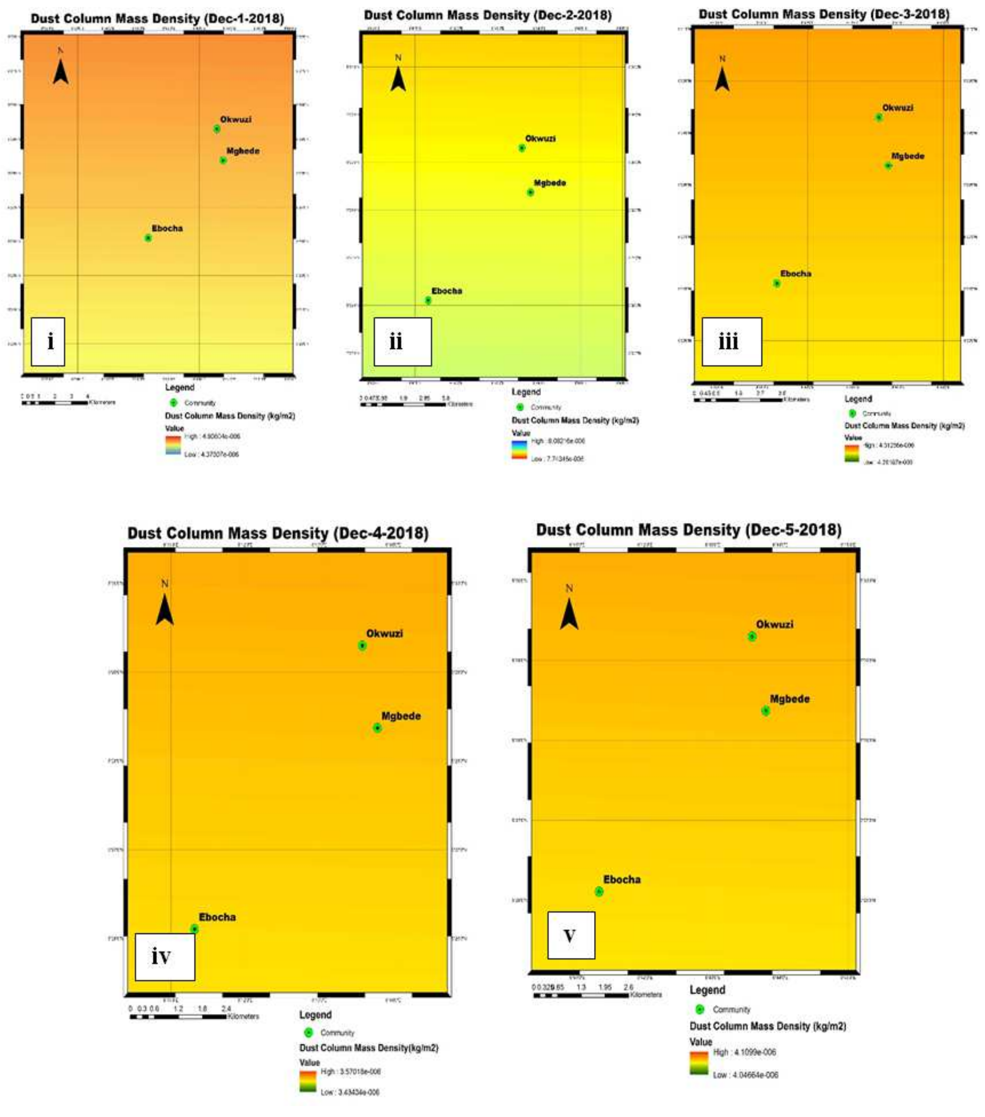

Figure 4. *Spatial distribution of Dust Column Mass Density concentration within the study area during December, Dry season (vi) Dec. 1, (vii) Dec. 2, (viii) Dec. 3, (ix) Dec. 4, and (x) Dec. 5 (2018).*

5.3. Spatial Spreading of Dust Column Mass Density $PM_{2.5}$ in the Dry Season

During the period of the dry season, from the month of December to February, using a five days monthly average, it was found that Ebocha, Mgbede and Okwuzi had Dust Column Mass Density is 2.08793E-05 kg/m^2, 2.08788E-05 kg/m^2, 2.08785E-05 kg/m^2 in December respectively, this indicates that Ebocha had the uppermost quantity of $PM_{2.5}$ in December. In the month of January, Ebocha, Mgbede and Okwuzi had Dust Column Mass Density of 2.99876E-06 kg/m^2, 3.00445E-06 kg/m^2, 3.00665E-06 kg/m^2 respectively, this shows that Okwuzi had the highest level of $PM_{2.5}$ in January. In the month of February, Ebocha, Mgbede and Okwuzi had Dust Column Mass Density of 3.62596E-06 kg/m^2, 3.62774E-06 kg/m^2, 3.6284E-06 kg/m^2 respectively, this equally revealed that Okwuzi had the uppermost amount of $PM_{2.5}$ in the month of February (Figure 4, Figure 5 and Figure 6).

5.4. Dust Column Mass Density $PM_{2.5}$ During Wet Season

In the wet season between June to August, using a five days monthly average, it was discovered that Ebocha, Mgbede and Okwuzi had Dust Column Mass Density of 1.25289E-05 kg/m^2, 1.2559E-05 kg/m^2, 1.25707E-05 kg/m^2 in June respectively, this indicates that Okwuzi community had the highest amount of Dust Column Mass Density – PM2.5 in June. In July, Ebocha, Mgbede and Okwuzi had Dust Column Mass Density -PM2.5 of 6.01017E-06 kg/m^2, 6.01339E-06 kg/m^2, 6.01465E-06 kg/m^2 respectively, this indicates that Okwuzi had the highest amount of Dust Column Mass Density -PM2.5 in July. In August, Ebocha, Mgbede and Okwuzi had Dust Column Mass Density of 2.87289E-06kg/m^2, 2.86918E-06 kg/m^2, 2.86769E-06 kg/m^2 respectively, this indicated that Ebocha had the highest amount of Dust Column Mass Density-PM2.5 in August, See Figure 7, Figure 8 and Figure 9).

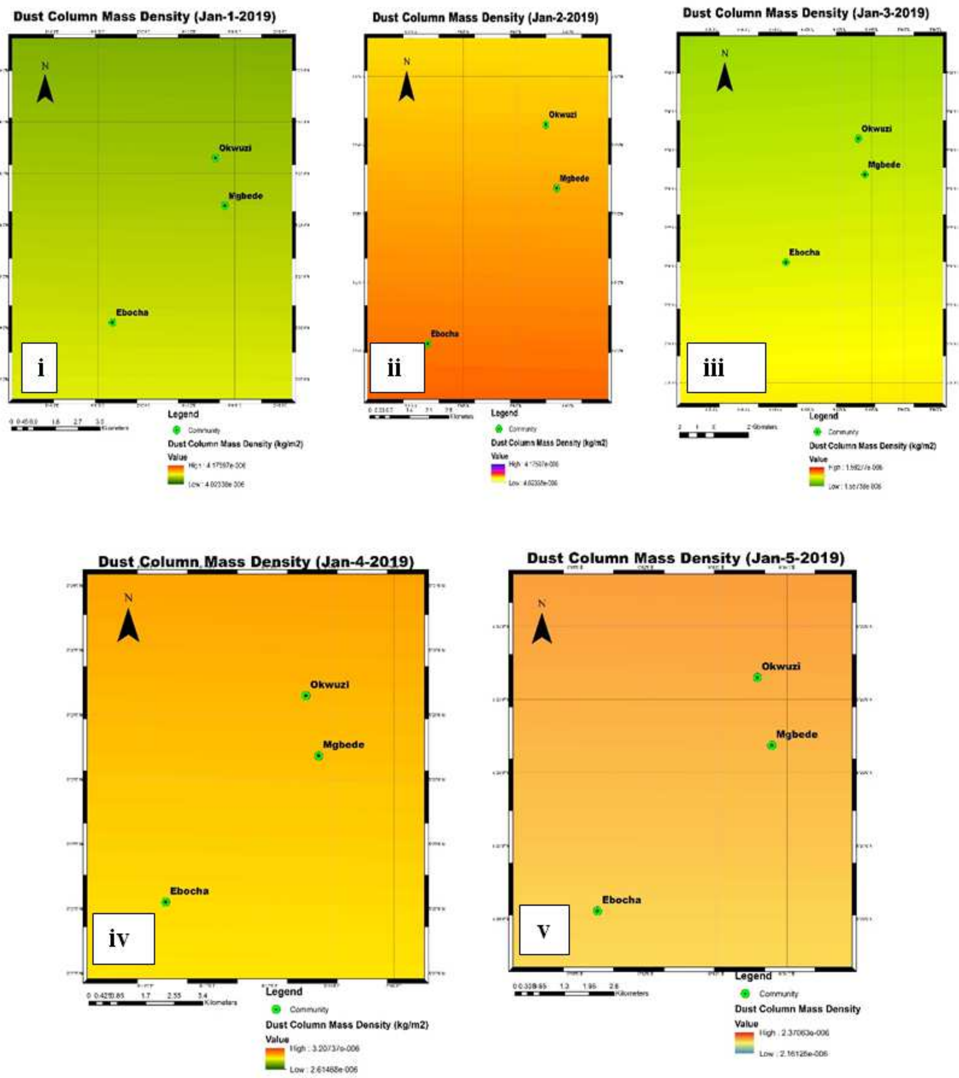

Figure 5. *Spatial map distribution of Dust Column Mass Density concentration within the study area during January, Dry season (vi) Jan 1, (vii) Jan 2, (viii) Jan 3, (ix) Jan 4, and (x) Jan 5 (2019).*

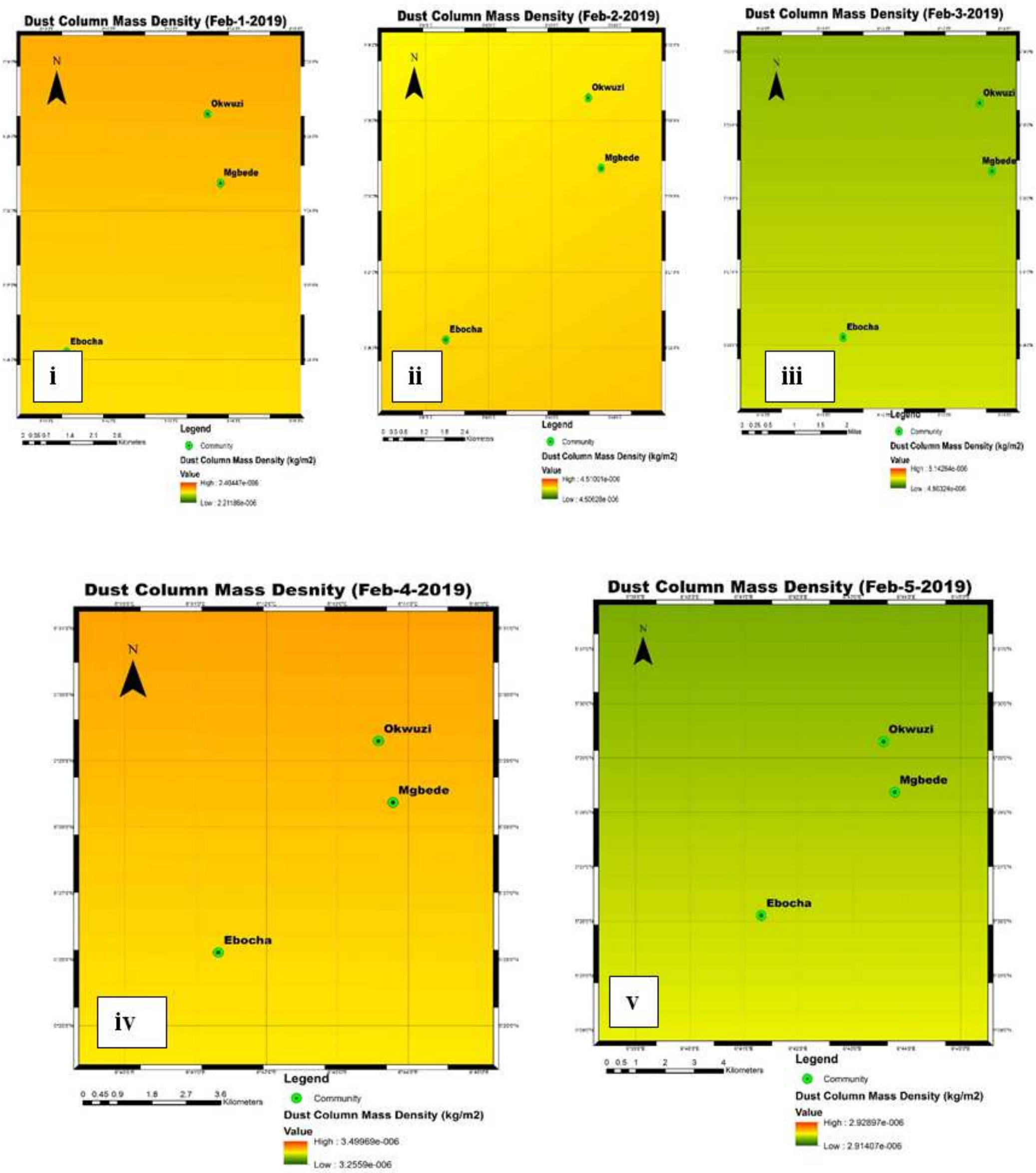

Figure 6. *Spatial map distribution of Dust Column Mass Density concentration within the study area during February, Dry Season (i) Feb 1, (ii) Feb. 2, (iii) Feb. 3, (iv) Feb 4, and (v) Feb. 5 (2019).*

5.5. Wet Season

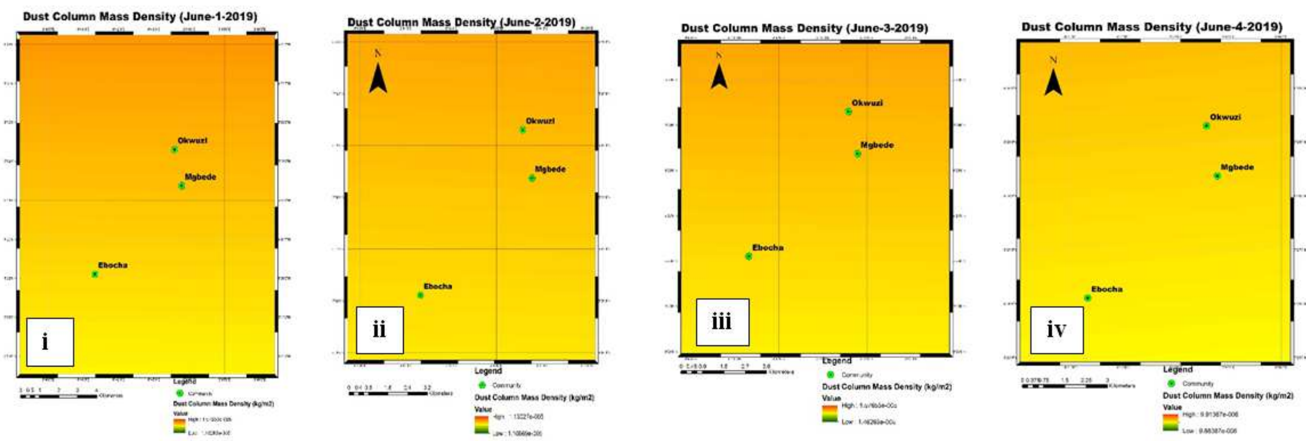

Figure 7. *Spatial map distribution of Dust Column Mass Density concentration within the study area during June Wet season (i) June 1, (ii) June 2, (iii) June 3, (iv) June 4, (2019).*

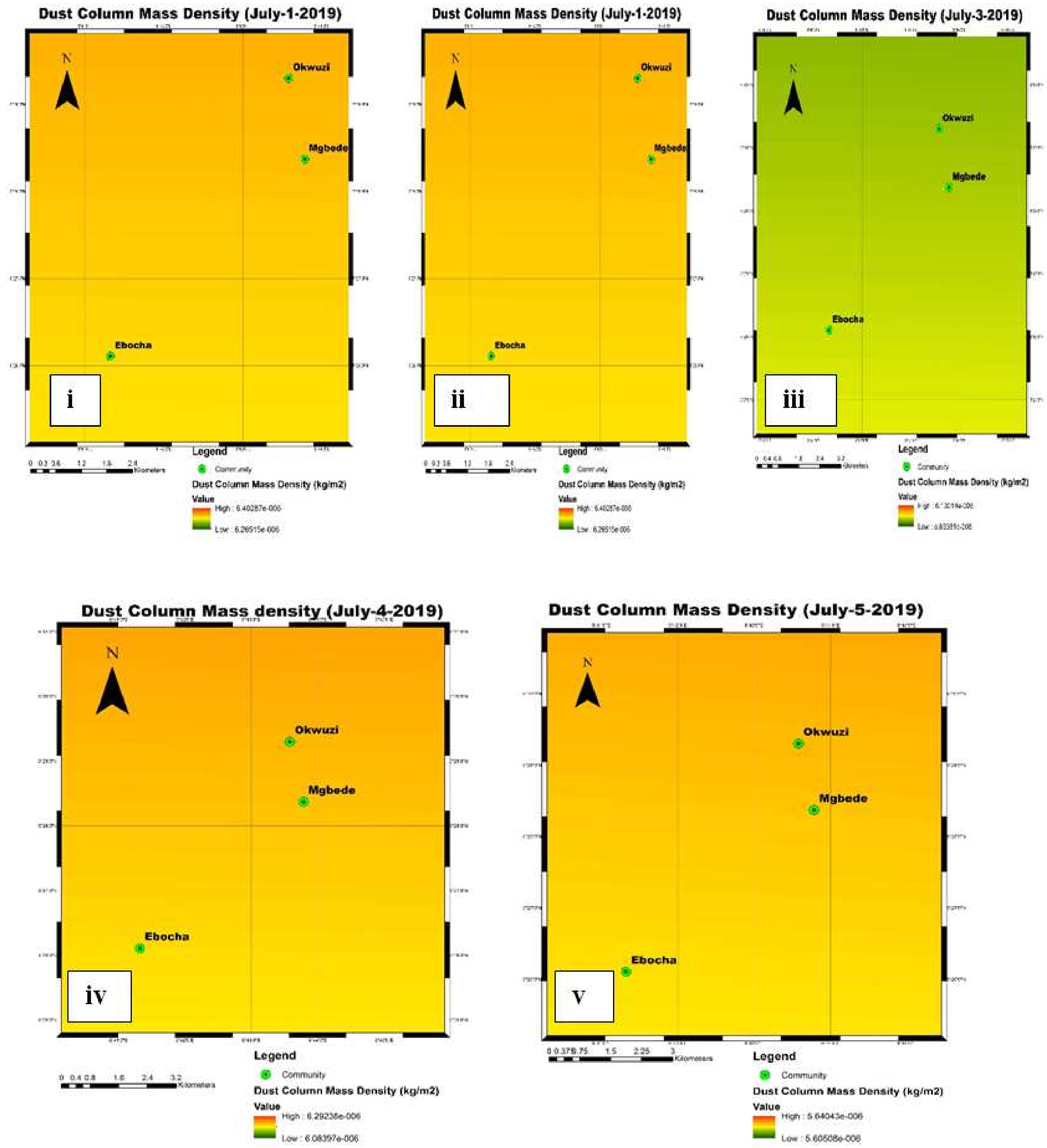

Figure 8. *Spatial map distribution of Dust Column Mass Density concentration within the study area during July, Wet season (i) July 1, (ii) July 2, (iii) July 3, (iv) July 4, and (v) July 5 (2019).*

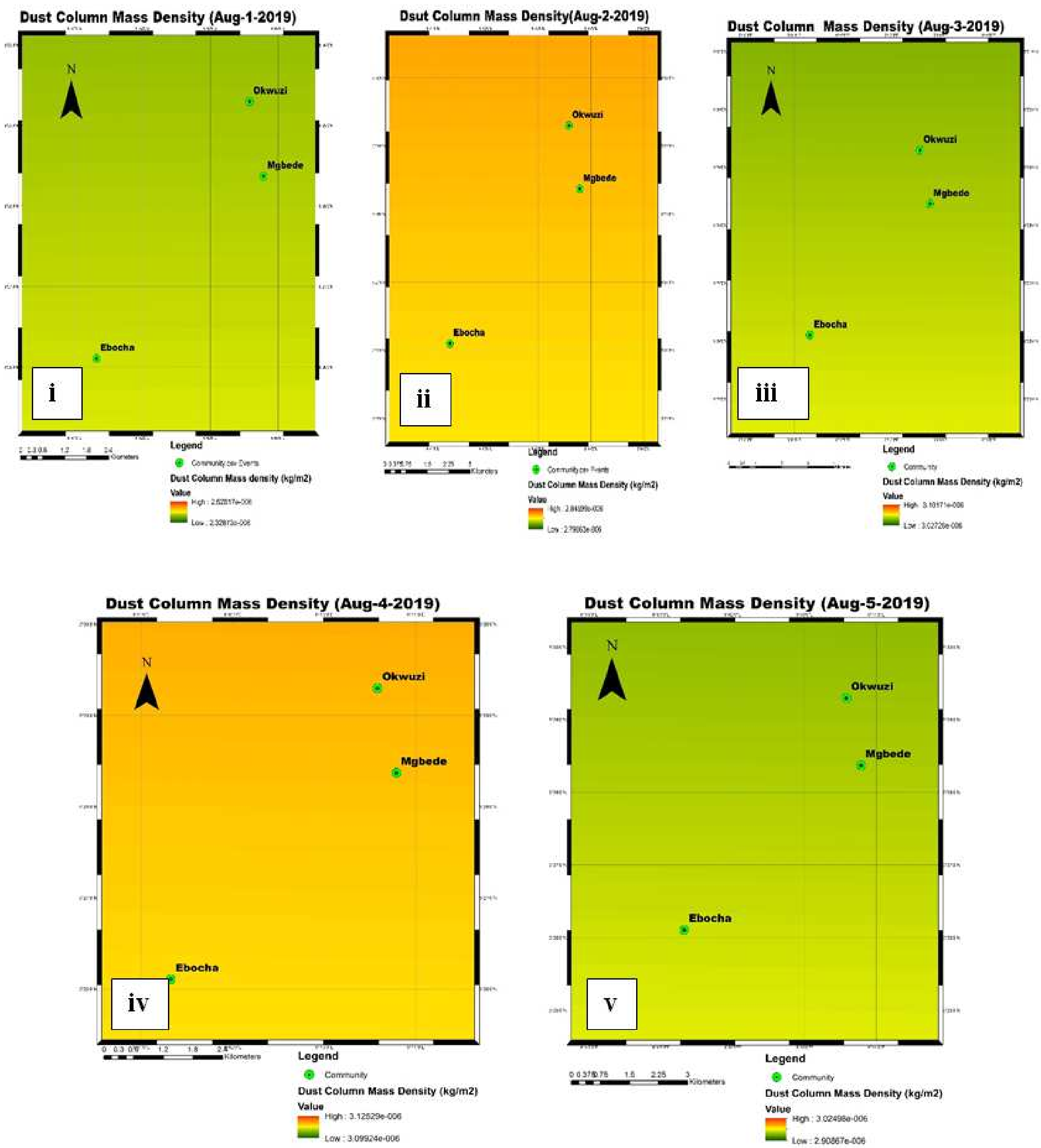

__Figure 9.__ Spatial map distribution of Dust Column Mass Density concentration within the study area during August Wet season (i) Aug 1, (ii) Aug 2, (iii) Aug 3, (iv) Aug 4, and (v) August 5 2019.

5.6. Column Amount of Formaldehyde (HCHO) During Dry Season

The compound, Formaldehyde (HCHO) is one of the most common Volatile organic compounds VOCs. It is colorless with a sharp bitter taste.

In the dry season period in the month of December 2018 and February 2019, it was discovered that Ebocha, Mgbede and Okwuzi had Column Amount of HCHO of -7.68E+17 molec/cm^2, -7.26E+17 molec/cm^2, and -7.26E+17 molec/cm^2 in December respectively, this shows that Ebocha community had the highest Column Amount of HCHO in December. In January 2019, Ebocha, Mgbede and Okwuzi had Column Amount of HCHO of -1.29E+18 molec/cm^2, -1.19E+18 molec/cm^2, and 1.18E+18 molec/cm^2 respectively, this shows that Ebocha had the highest Column Amount of HCHO. In February 2019, Ebocha, Mgbede and Okwuzi had Column Amount of HCHO of -8.58E+17 molec/cm^2, -8.26E+17 molec/cm^2, and -8.39E+17 molec/cm^2 respectively, this equally indicated that Ebocha had the highest Column Amount of HCHO in February. This entails that Ebocha had the uppermost amount of HCHO during the months of dry season (Figure 10, Figure 11 and Figure 12).

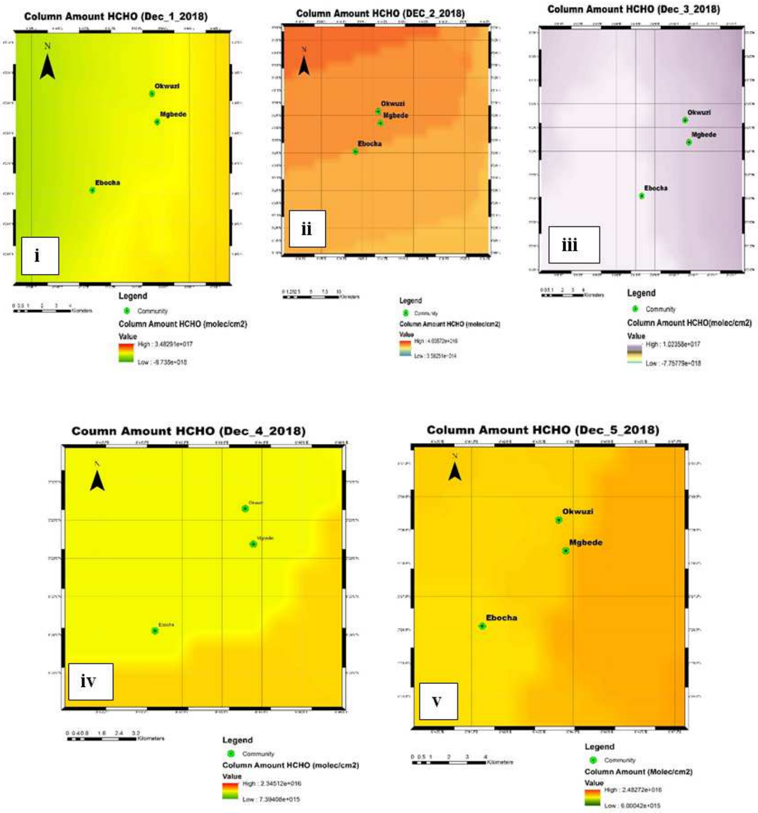

Figure 10. *Spatial map of Column Amount of Formaldehyde in Ebocha, Mgbede and Okwuzi during December, Dry Season (i) Dec 1 (ii) Dec 2, (iii) Dec 3, (iv) Dec 4, (v) Dec 5, 2018.*

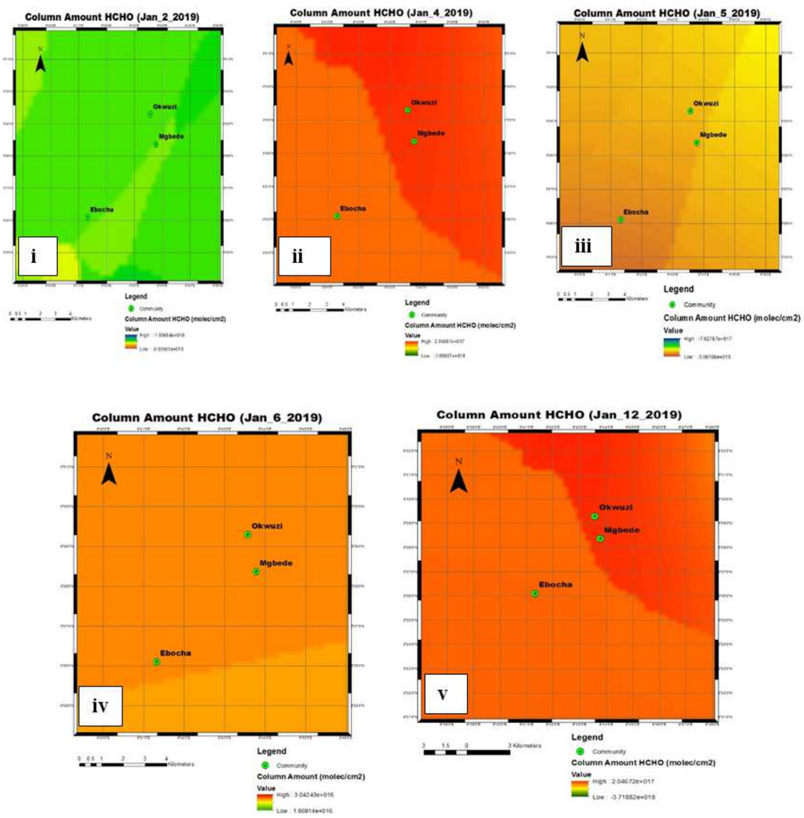

Figure 11. *Spatial map of Column Amount of Formaldehyde in Ebocha, Mgbede and Okwuzi during January, Dry Season (i) Jan 2, (ii) Jan 4, (iii) Jan 5, (v) Jan 6, (v) Jan 12, 2019.*

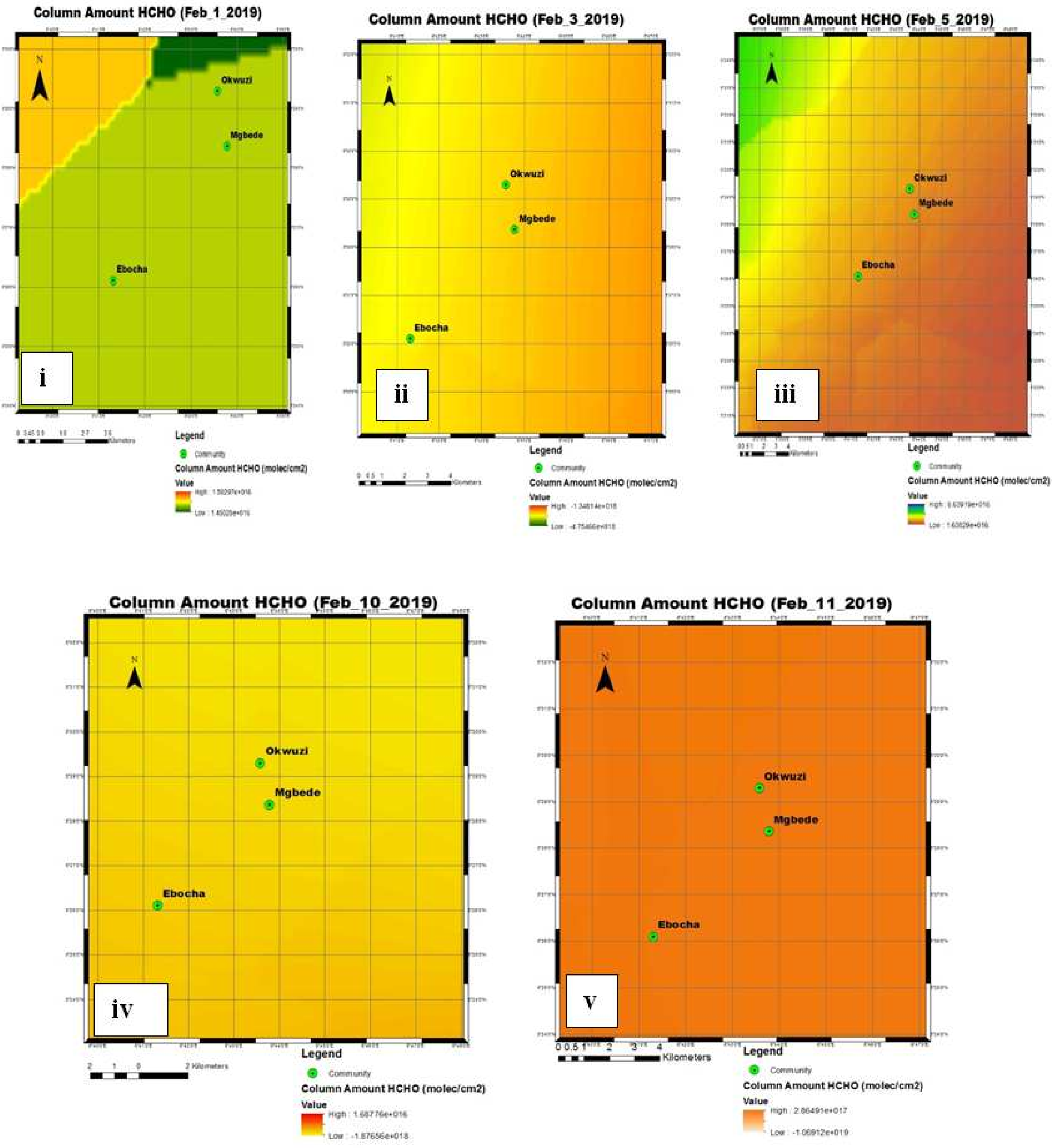

Figure 12. Spatial map of Column Amount of Formaldehyde in Ebocha, Mgbede and Okwuzi during February, Dry Season (i) Feb 1, (ii) Feb 3, (iii) Feb 5, (iv) Feb 5, (v) Feb 11, 2019.

5.7. Column Amount of Formaldehyde (HCHO) During Wet Season

In the Wet season from the month of June and July 2019, it was discovered that Ebocha, Mgbede and Okwuzi had Column Amount of HCHO of -1.87E+17 molec/cm^2, -2.67E+17 molec/cm^2, and -2.68E+17 molec/cm^2 respectively, this shows that Ebocha community had the highest Column Amount of HCHO in June. In July, Ebocha, Mgbede and Okwuzi had Column Amount of HCHO of -2.34E+17 molec/cm^2, -3.06E+17 molec/cm^2, and -3.08E+17 molec/cm^2 respectively, this indicates that Ebocha had the highest Column Amount of HCHO. In August 2019, Ebocha, Mgbede and Okwuzi had Column Amount of HCHO of -6.86E+17 molec/cm^2, -5.15E+17 molec/cm^2, and -4.92E+17 molec/cm^2 respectively, this shows that Okwuzi had the highest Column Amount of HCHO in August (Figure 13, Figure 14 and Figure 15).

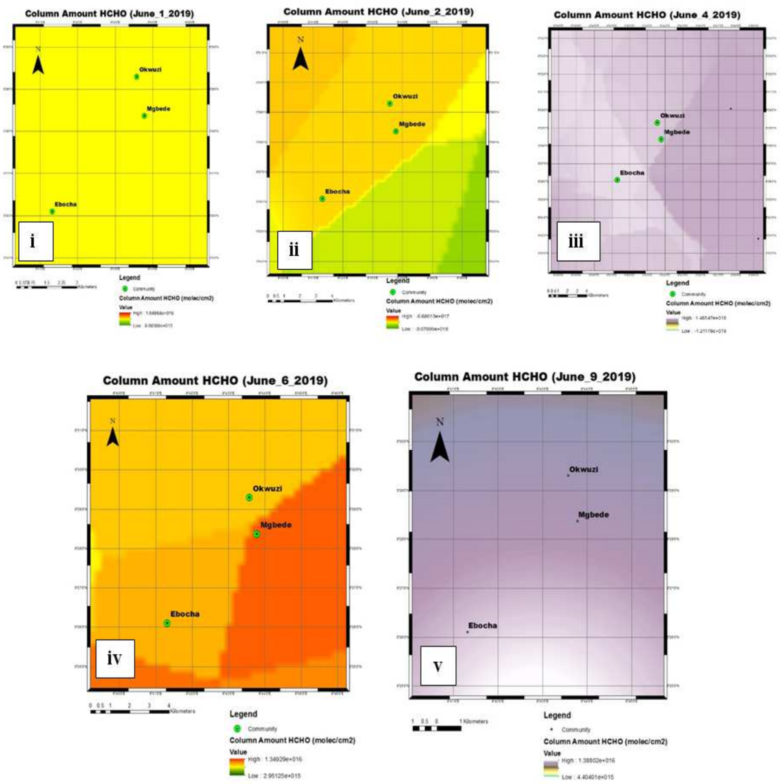

Figure 13. *Spatial map of Column Amount of Formaldehyde in Ebocha, Mgbede and Okwuzi during June, Wet Season (i) June 1, (ii) June 2, (iii) June 4, (iv) June 6, (v) June 9, 2019.*

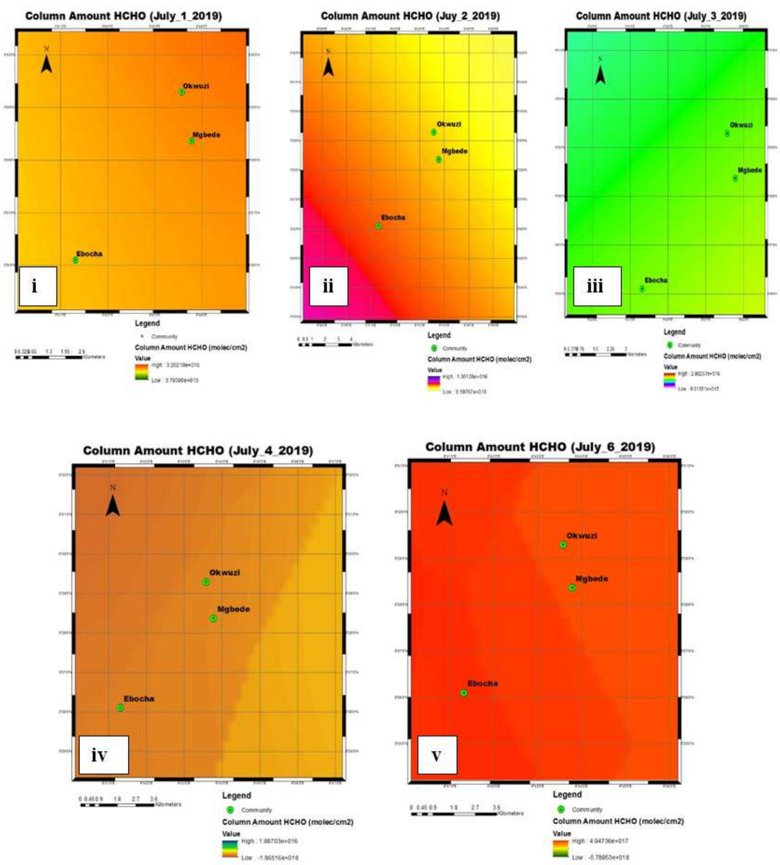

Figure 14. *Spatial map of Column Amount of Formaldehyde in Ebocha, Mgbede and Okwuzi during July, Wet Season (i) July 1, (ii) July 2, (iii) July 3, (iv) July 4, (v) July 5, 2019.*

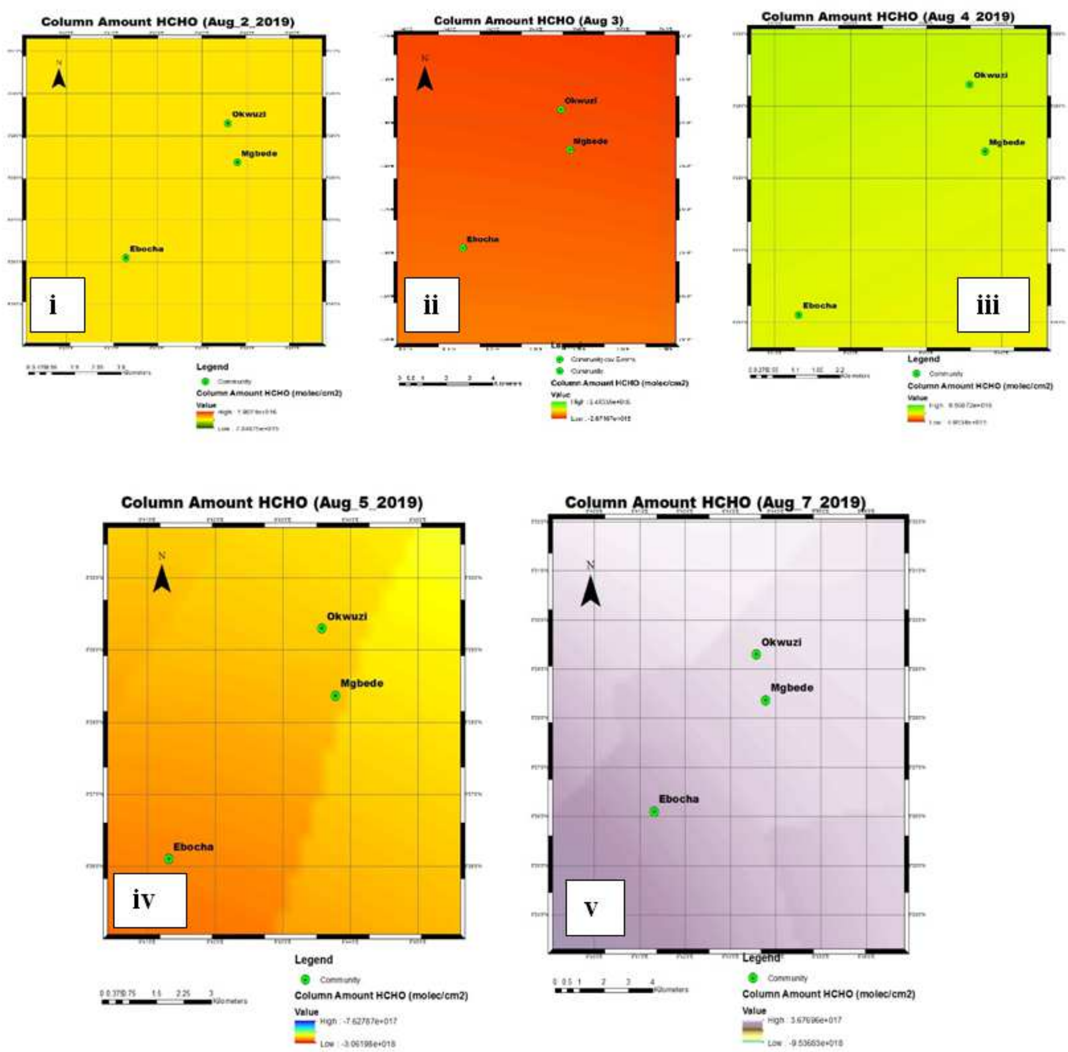

Figure 15. Spatial map of Column Amount of Formaldehyde in Ebocha, Mgbede and Okwuzi during August, Wet Season (i) Aug 2, (ii) Aug 3, (iii) Aug 4, (iv) Aug 5, (v) Aug. 7, 2019.

6. Discussion

It exposes that Okwuzi and Ebocha communities are severely contaminated in the area while Mgbede community revealed a minimum amount of contaminants. Usually, Ebocha is known as the hot spot of pollution in the study area in the dry season and Okwuzi the hot Spot during the rainy season, while Mgbede is categorized as the cold spot of pollution in dry and wet seasons. Therefore the result of pollution distribution between the seasons is not unconnected with the directions of the seasonal winds that blow across the study areas. In this area of study, there are two main seasonal winds popularly called the SE trade wind and the NE Trade wind blowing across the area. This affirms the work of Kim., Kwon, Lee, Seo and Choi, [9] which opines that seasonal wind patterns is vital in the spread of contaminants in the city of Korea. In the same vain, it was affirmed in a study in China that seasonal differences of $PM_{2.5}$, SO_2, NO_2 and CO concentrations in six locations were connected with wind direction [5].

In addition, human activities are another factor influencing the spread of atmospheric pollutants in each of the communities. For example, gas flaring is the main source of formaldehyde in the area of study area. Formaldehyde is formed in the troposphere during the oxidation of hydrocarbons [17]. Formaldehyde records the uppermost amount (-7.68E+17 molec/cm^2, -1.29E+18 molec/cm^2, -8.58E+17 molec/cm^2) in Ebocha community. Also, the spreading of $PM_{2.5}$ is linked to trash burning by farmers during the farming season in the place which occurs in the dry season specifically from January towards February. This is in line with the works of Pozzer, Tsimpidi, Karydis., Meil and Lelieveld, [16] that the activities of human beings, particularly agriculture, are the bases of atmospheric pollutants in the environment making it a primary element of level of pollutant concentration in the area of study.

7. Conclusion

Following the results of the various analyses undertaken in this research, the following conclusions are drawn:

Human activities and wind significantly influence the spreading of pollutants in the area of study.

Amongst these three communities, Mgbede is the least polluted and called the cold spot area in both seasons while Ebocha is a hot spot region during the dry season and Okwuzi a hot spot region during the rainy season.

It was also learnt that the level of HCHO increases in the three communities in the wet period. The level of $PM_{2.5}$ decreases in the three communities during the wet season. While, the concentration of SO_2 across the three communities declines in the dry season.

8. Implications of the Findings

The present study provides the scientific foundation and technical basis for the control of $PM_{2.5}$, SO_2, and formaldyde (HCHO) in the study area. This goes a long way in terms of reducing emissions of these atmospheric pollutants substantially and improving human health in the area. In view of this, there is need to install a technical infrastructure which could reliably, repeatedly and precisely measure atmospheric contaminants. The basis of understanding atmospheric pollutants is measurement and the emissions of air pollutants from sources bring about operational air pollution strategies and control [10].

It is relatively expensive to have continuous measuring locations across the area considering the large land mass of the study area. Thus, judicious choice of location for the installation of the monitoring devices is very essential [12]. In this design, the guiding principle in the choice of air pollution monitoring stations should be the concentration of pollutants in each area, population density of the area, as well as transportation corridors. For instance, Ebocha and Okwuzi communities were identified as pollution hotpots, and should have three monitoring stations each, while Mgbede Community identified in the study as the cold spot should have two monitoring stations. The proposed monitoring plan is shown in Figure 16 and Figure 17 and adaptation plan displayed in Figure 18.

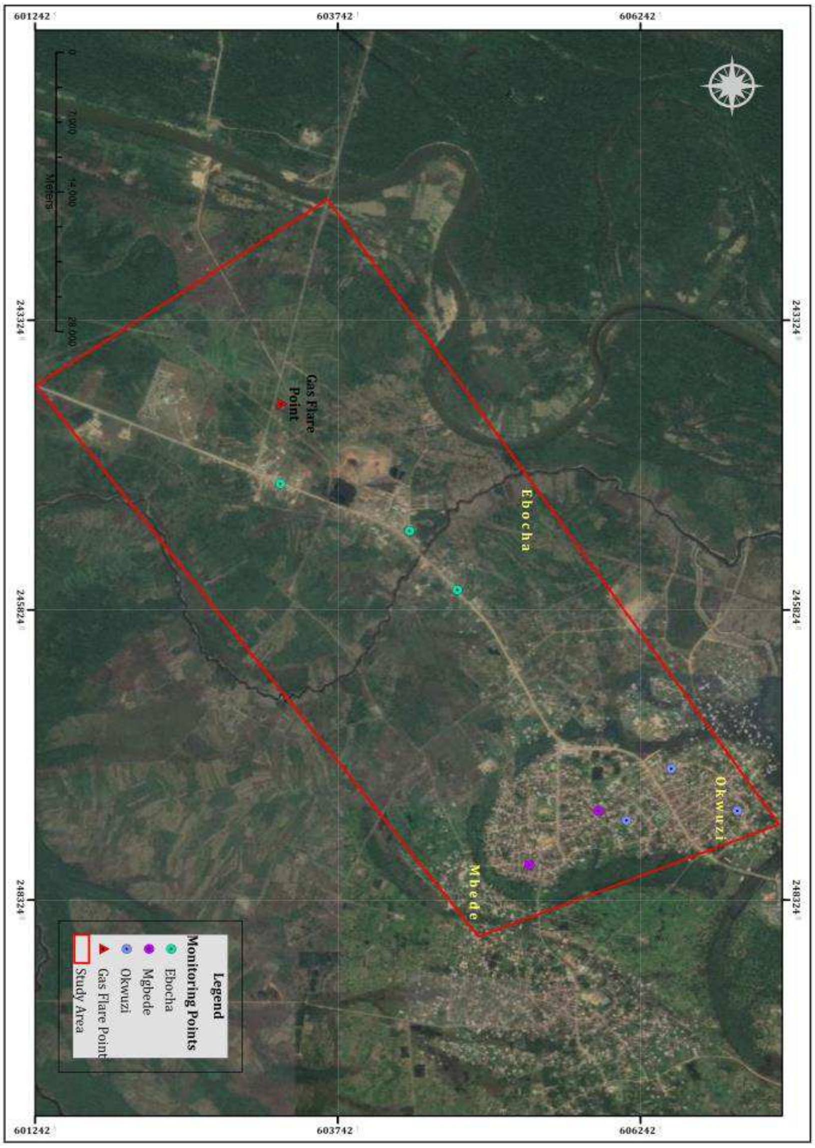

Figure 16. *The proposed monitoring station in the study area.*

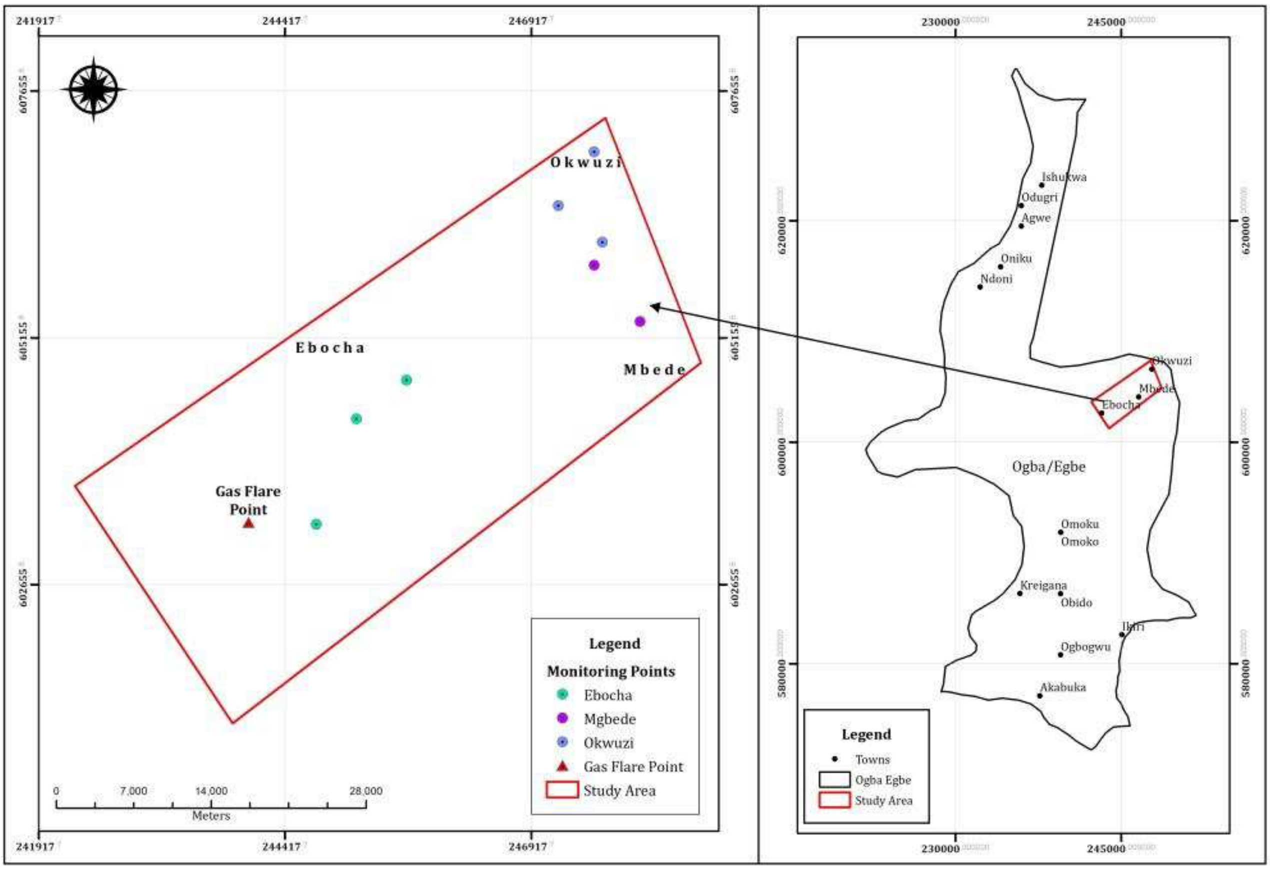

Figure 17. The proposed monitoring stations in the study area.

In a related development, an adaptation plan to air pollution in the study area by the residents is proposed in Figure 18.

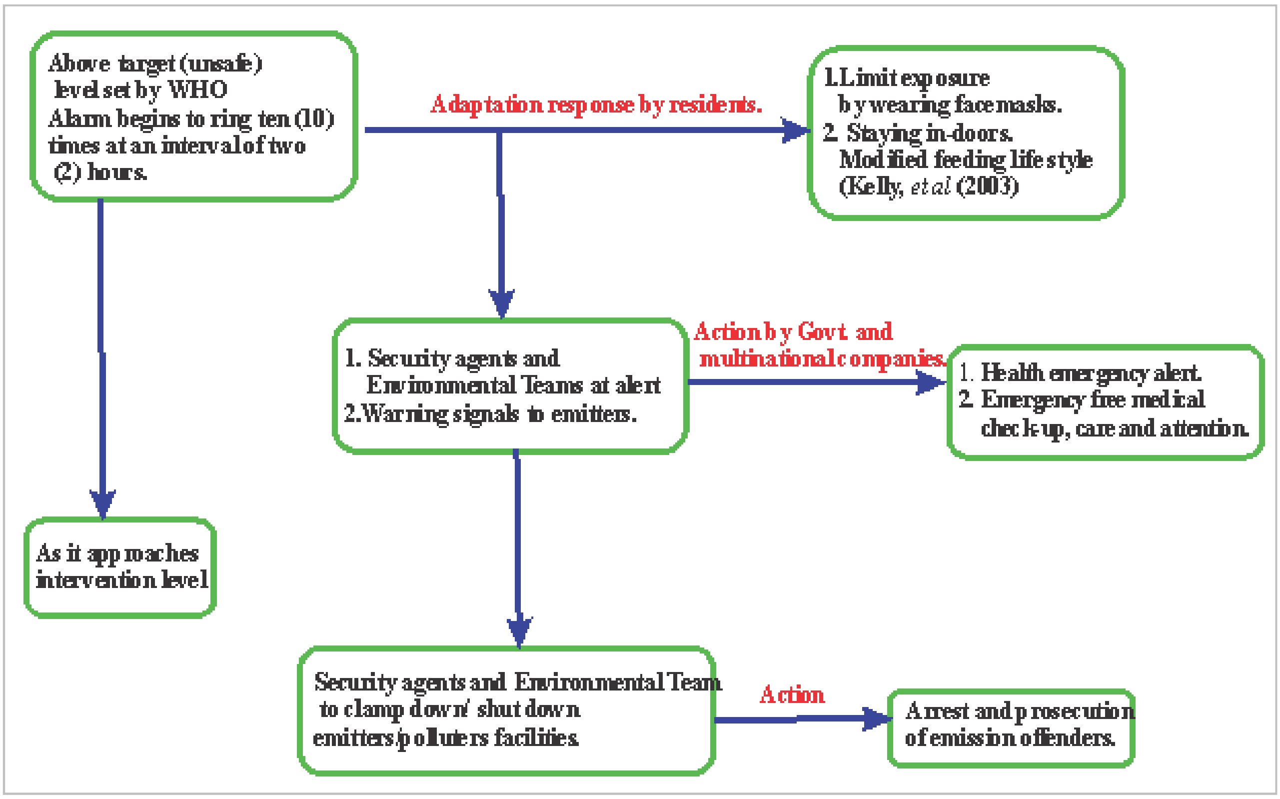

Figure 18. Air pollution adaptation plan to air pollution in the study area.

Finally, this study has presented the air pollution situation in the study area as well as the spatio-temporal dynamics and the factors that drive the phenomenon. We strongly believe that if the technical issues raised in this paper are critically addressed, air pollution will be relatively contained and managed in the study area.

References

[1] Abalogu, D. M. and Okolo, E. A. (2020). An application of non-violent approach to insurgency in Niger Delta Region, Nigeria. *An African Journal of Arts and Humanities Vol. (6) (4) pp. 2504-9038.*

[2] Abou-Rafee, S. A., Martins, L. D., Kawashima, A. B., Almeida, D. S., Morais, M. V. B., Souza, R. V. A., Oliveira, M. B. L., Souza, R. A. F., Medeiros, A. S. S., Urbina, V., Freitas, E. D., Martin, S. T., and Martins, J. A.: (2017) 'Contributions of mobile, stationary and biogenic sources to air pollution in the Amazon rainforest: a numerical study with the WRF-Chem odel,' *Atmos. Chem. Phys., 17, 7977–7995, https://doi.org/10.5194/acp-17-7977-2017, 2017.*

[3] Adesina, O. S., Mohammed, I. and Otokiti, K. V. (2020) 'The Place of Environmental Laws in Checking Oil Spillage in the Niger Delta Region of Nigeria' *International Journal of Environmental Planning and Management Vol. 6, No. 1, 2020, pp. 6-12.*

[4] Adoki, A. (2012). Air Quality survey of some locations in the Niger Delta, Area. *Journal of Appl. Sci. & Environ. Management, Vol. 16 (1) 125-134.*

[5] Chen, P., Kang, S., Yang, J., Pu, T., Li, C., Guo, J. and Tripathee, L. (2019). Spatial and Temporal Variations of Gaseous and Particulate Pollutants in Six Sites in Tibet, China, during 2016– 2017. *Aerosol Air Qual. Res. 19: 516-527 https://doi.org/10.4209/aaqr.2018.10.0360*

[6] Deguen, S., S´ egala, C., Ga¨ elle P´edrono, and Mesbah, M. (2012) A New Air Quality Perception Scale for Global Assessment of Air Pollution Health Effects. *Risk Analysis, (32) (12) 14-27.*

[7] Ebitare, B. S and Okodudu,. S. (2021) 'Forced Migration in the Niger Delta Region of Nigeria: Interrogating the role of oil induced Environmental Degradation' *International Journal of Innovative Psychology & Social Development 9 (3) pp 30-42.*

[8] Federal Govt. of Nigeria (FGN (1988). Federal Environmental Protection Agency Decree 58, 1988. *Federal Ministry of Information and Culture, Lagos, Nigeria.*

[9] Kim, S., Kwon, H., Lee,. M, Seo, Y. and Choi, S (2019) 'Spatial and temporal variations of volatile organic compounds using passive air samplers in the multi-industrial city of Ulsan, Korea' *Environmental Science and Pollution Research,* Vol. 26 page 5831-5841.

[10] Miller, C. A. (2021) "Fifty years of EPA Science for Air quality management and control" *Environmental Management 67 page 1017-1028.*

[11] Nriagu, J., Udofia, E. A., Ekong, I., and Ebuk, G. (2016). Health Risks Associated with Oil Pollution in the Niger Delta, Nigeria. *International Journal of Environmental Research and Public Health*, *13* (3), 346.

[12] Nychka,. D. and Saltzman,. N. (1998) "Design of Air quality Monitoring Networks". In: Nychaka, D., Piegorsch, W. W., Cox, L. H (eds) Case Studies in Environmental Statistics. *Lecture notes in Statistics Vol. 132 Springer, New York.*

[13] Ogunba, A. (2016). An appraisal of the evolution of environmental legislation in Nigeria. *Vermont Law Review (*40) pp. 674-693.

[14] Okoro, G. (2004) "The impact of gas flaring in soil pH". Unpublished. B.Sc. Thesis submitted to Department of Geography & Envi. Mgt., University of Port Harcourt, Nigeria.

[15] Pius, U. E (2017, February 14) Strange Black Soot Causes Anxiety in Port Harcourt. Online: ttps://guardian.ng/news/strange-black-soot-causes-anxiety-in-port-harcourt/ Accessed 2/09/2021.

[16] Pozzer, A., Tsimpidi, A. P., Karydis, V. A., Meil, A. and Lelieveld, J. (2017). 'Impact of agricultural emission reductions on fine-particulate matter and public health'*Atmos. Chem. Phys., 17, 12813–12826.*

[17] Subesi, N. T. (2020) 'Formaldehyde Advantages and Disadvantages: Usage Areas and Harmful Effects on Human Beings'. DOI: 10.5772/intechopen.89299 Available online *https://www.intechopen.com/online-first/formaldehyde-advantages-and-disadvantages- usage-areas-and-harmful-effects-on-human-beings. Accessed 20 June, 2020.*

[18] UNEP (2011). Environmental Impact Assessment of Ogoniland. *Available Online: http://postconflict.unep.ch/publications/OEA/UNEP OEA.pdf. Accessed 2/8/2021.*

[19] Uyigue; E. and Agho, M. (2001) Coping with climate change and Environmental Degradation in the Niger Delta of Southern Nigeria. *Community Research and Development Centre Nigeria pages 1-31.*

[20] Wayne, R. P. (1991). *Chemistry of the Atmosphere.* Oxford: Clarendon Press.