USING THE WSN BASED TNGAPMS FOR AIR QUALITY INDEX (AQI) DETERMINATION IN THE NIGER DELTA AREA (NDA)

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ABSTRACT

Air Quality Index (AQI) determination; with a view to ascertaining its nexus vis-à-vis the wellbeing of the human and physical environment has been a major concern of governments and peoples of the world. Dovetailed in this respect, several air pollution monitoring devices ranging from the "data logger" to the "wireless sensor network" (WSN) have been put to use with varying success and with more of setbacks to their credit. Inclusive of the drawbacks of this conventional air pollution monitoring systems are their non-scalability and appropriation of limited data. The need for a reversal of the trend and as a corollary, the achievement of high spatiotemporal resolution of the air pollution information was thus inevitable and eventually found expression in a combination of the low-cost portable ambient sensors and the Wireless Sensor Network (WSN) into one system that predisposed The Next Generation Air Pollution Monitoring System (TNGAPMS). This study derives its impetus on the complementarity of The Next Generation Air Pollution Monitoring System's SSN, CSN, VSN and how a concurrent application of them is able to significantly obviate the setbacks outlined above. This paper is strictly an "advisory compendium" summed up after an in depth study of the perceived dynamics of both the conventional as well as the WSN Based airpollution monitoring systems; with particular reference to the application and results of the TNGAPMS in the Niger Delta Area (NDA).

Keywords: *Air pollution, Wireless Sensor Network (WSN), The Next Generation Air Pollution Monitoring System (TNGAPMS), The Niger Delta Area (NDA).*

1. INTRODUCTION

Air pollution constitutes a major environmental, health and economic constraint in the Niger Delta Area (NDA). Day in; day out, a barrage of gaseous and particulate matter are released into the atmosphere at levels that far exceed the precautionary optimum of both the national and international regulatory bodies [1].

This predicament is further compounded by the fact that air quality studies in the area is ironically and speciously bedeviled by multifaceted issues ranging from lack of equipment, inadequate expertise, lack of infrastructure and weak policy framework[2].

The fact that the Federal Government of Nigeria(FGN) was only recently setting up a committee(about sixty years after the commencement of oil exploration and gas flaring in Oloibiri) to restate commitment to zero gas flaring policy[3] puts paid the lack of political will and preponderance of policy failures that had ambushed and thwarted to astand-still efforts aimed at mitigating the problem of air pollution in the Niger Delta Area and Nigeria at large.

The Niger Delta Area(NDA) is aconglomerate of nine (9) states, comprising: Ondo, Edo, Imo, Abia, Cross River, Akwa Ibom, Rivers, Bayelsa and Delta.

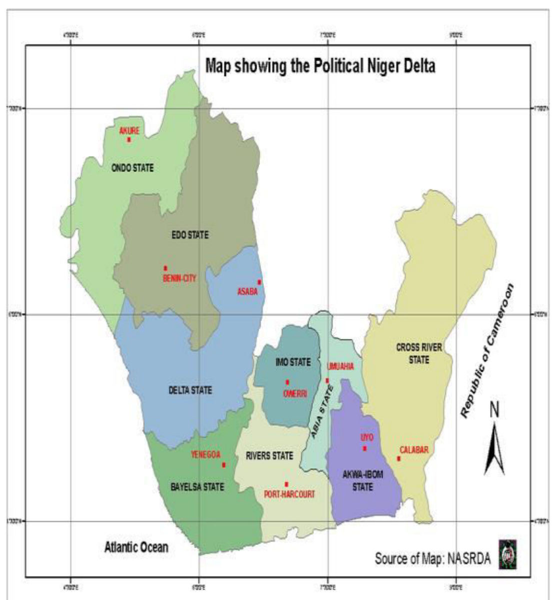

Fig 1.Political Map of the Niger Delta Area[2]

The NDA covers 20,000km^2 within wetlands of 70,000km^2 that comprises seven and a half percent (7.5%) of Nigeria's total land mass; and is home to 20 million endangered people[2].From Cross River State in the east to Ondo State in the west; and from Imo State in the North to Rivers State in the South, the environmental milieu is devoid of pollution monitoring systems. A situation which makes this study an imperative to bring about co-operative relations between researchers and policy makers vis-à-vis evolving a low-cost effective template for addressing the air pollution hazards of the Niger Delta Area (NDA).

Accordingly, the study seeks to meet or approximate the following objectives, viz:-

(a) To sensitize policy makers on the need to evolve affordable pollution monitoring mechanisms.

(b) To highlight the imperative of using the TNGAPMS as a viable option for addressing the air pollution problems of the Niger Delta Area (NDA).

(c) To let its findings serve as an advisory compendium for policy makers interested in the subject matter of air pollution monitoring.

1.1 AIR POLLUTION

As evinced in fig.2 below, air pollution constitutes a mixture of substances within the air called pollutants, which could be separated into toxic gases and particulate matter (PM); with the most commonly found toxic gases being: carbon dioxide(CO_2),Carbon monoxide(CO), Oxides of nitrates(NO_X), Oxides of Sulphur(SO_X), Ozone(O_3) *and etc.*

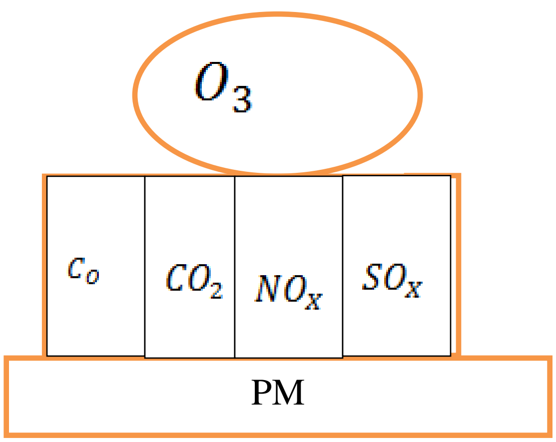

Fig 2: Air Pollutants

A pollutant as illuminated in [4] is a substance in the air that is capable of endangering humans and the environment. Likewise,[5] lends credence to what constitutes air pollution by describing it as an impact of chemicals, particulate matter or biological materials that cause harm or discomfort to the human and physical environment through seepage.

1.2 EFFECTS OF AIR POLLUTION

Air pollution goes on unmitigated in the Niger Delta Area (NDA). What this presupposes in the short or long run is quite obvious: air pollution engendered deaths shall proliferate, not just here in the Niger Delta Area or Nigeria, but the world at large. Abundance of data exists worldwide in corroboration of this assertion.

In Nigeria, for instance, the Former Senate President, Dr. Bukola Saraki reported at the 2017 Clean Cooking Forum organized by the Federal Ministry of Environment that Nigeria records Sixty-five thousand(65,000) deaths annually due to air pollution occasioned by the use of wood for cooking and was quick to pledge his support for legislation that will promote use of "clean cook stoves."[6]

In a much more alarming manner, the World Health Organization (WHO) revealed on its twitter handle in 2014 that an estimated seven million people die every year from outdoor and household air pollution. [7]

It is, thus, unequivocally true that air pollution constitute a major health constraint that predisposes death. A situation which underscores the need for monitoring devices that could ascertain the dynamics of toxic gases and particulate matters with a view to empowering Control and Mitigation Agenciesto bring about ameliorative measures.

1.3 AIR POLLUTION MONITORING In a retrospective outlook of the genesis of air pollution monitoring devices, [8] cited data loggers as one of the pioneer means for collecting data periodically and stated its performance perspective as time consuming and relatively quite expensive when placed side by side the Wireless Sensor Network(WSN). The same applies to other conventional air pollution monitoring devices such as the gas chromatograph-mass-spectrometers, which are decried on account of their being large, unwieldy and cost deficient.

Fig 3.Data Logger


Fig 4. A Gas Chromatograph-Mass Spectrometer.

Scholarly findings such as the one outlined in[9] discourage their use on account of their inability to provide air pollution data of high spatiotemporal resolution due largely to non-scalability and limited data appropriation.

2. WSN BASED AIR POLLUTION MONITORING SYSTEMS.

In their taxonomy and review of WSN based air pollution monitoring systems, [9] outlined a total of eighteen(18) devices that was inclusive of their own innovation, viz:

- The Next Generation Air Pollution Monitoring System(TNGAPMS)[10]
- Urban Air Quality Monitoring System[11]
- Wireless Sensor Network for Outdoor Air pollution Monitoring[12]
- Outdoor Air Quality Monitoring System[13]
- Wireless Sensor Network for Outdoor Air Pollution Monitoring[8]
- WSN Based Indoor Air Pollution Monitoring System[14]
- Mobile Based Outdoor Pollution Monitoring System[15]
- The Participatory Sensing Technology for Monitoring Outdoor Air Pollution(P-Sense)[16]
- Low Cost and Portable Urban Air Quality Monitoring Using Vehicular Sensor Networks[17]
- Real-Time Air Quality Monitoring Through Mobile Sensing In Metropolitan Areas[18]
- Low Cost Wireless Sensor Network Based Indoor Air Quality Monitoring System[19]
- Vehicular Sensor Network Based Air Pollution Monitoring System[20]
- Wireless Sensor Network for Monitoring and Analyzing The Air Quality in Doha, Qatar[21]
- Low Cost and Portable RF Based Sensor System[22]
- Low Cost Portable Air Pollution Monitoring System by Using the Internet of Things(IOT)[23]
- Random Forest Method for Finding the Air Quality(RAQ) for Urban Areas[24]
- The Environmental Sensors Based Air Quality Monitoring Station[25]
- Real Time Pollution Monitoring Using Wireless Sensor Networks(WSN)[9]

The study states that quite unlike the conventional wired network, which constitute a more or less selective deployment, the wireless sensor systems can be placed anywhere, and are capable of self-organization. Out of the eighteen above: 8 were SSN styled, 3 VSN based, 2 CSN styled, 2 strictly WSN based andthree others that thrive on Internet of Things (IOT), RAQ and the TNGAPMS.

3. METHODOLOGY

The methodology adopted in determining the dynamics of the sensor nodes in air pollution monitoring in the NDA is “The Next Generation Air Pollution Monitoring System (TNGAPMS)”.

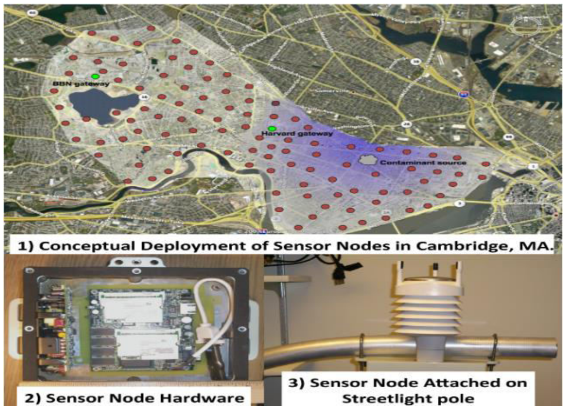

Fig 5: SSN System component of TNGAPMS[10]

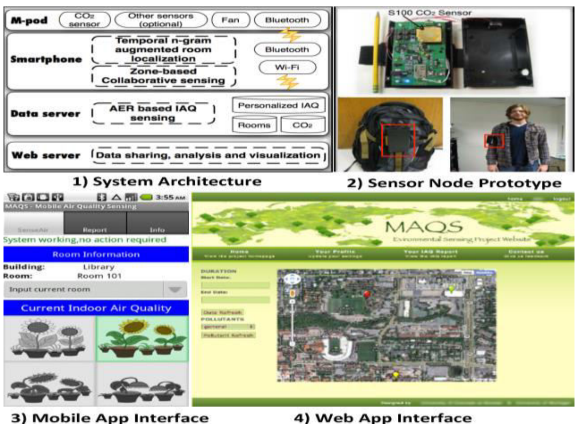

Fig 6: CSN System component of TNGAPMS[10]

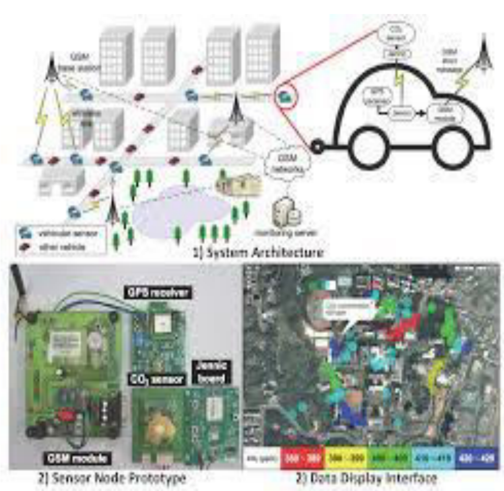

Fig 7: VSN System component of TNGAPMS[10]

This study resorted to it on account of its low-cost-cum-energy-efficient and high spatiotemporal resolution; and wholly adopts its three category functional perspective, comprising: the SSN, CSN and VSN.3.1 **RATIONALE FOR THE USE OF TNGAPMS FOR AIR POLLUTION MONITORING IN THE NDA**

Related work vis-à-vis the dynamics of the wireless sensor nodes; such as that presented by [8] sees the sensor system as consisting of a vast number of sensor nodes which are either deployed inside or in close proximity with the sensed phenomenon. The study also recognized and tabulated the six standard pollutants, comprising: Carbon monoxide (C0), Nitrogen dioxide (NO_2), Ozone (O_3), Sulphur dioxide (SO_2), Particulate matter ($PM_{2.5}$ and PM_{10}), Lead(Pb) and their health effects. This is just as [9] outlines four types of hazard gases: Carbon monoxide(C0), Nitrogen dioxide (NO_2), Ozone (O_3), Sulphur dioxide and particulate matter ($PM_{2.5}$, PM_5 and PM_{10}) as subject to be monitored in the TNGAPMS scenario.

With the exception of Lead (Pb), all the gases and particulate matter outlined in the two related studies constitute the bane of the Niger Delta Area (NDA) vis-à-vis the menace of standard pollutants, for which both studies have come with the good news of proven detection by the TNGAPMS.

Fig.8 shows the workings of a typical Wireless Sensor Network with a rapid deployment characteristic from “the sensor nodes” to “the base station” from where it is simultaneously made available to “a computer”, “the internet” as well as “a mobile phone.”

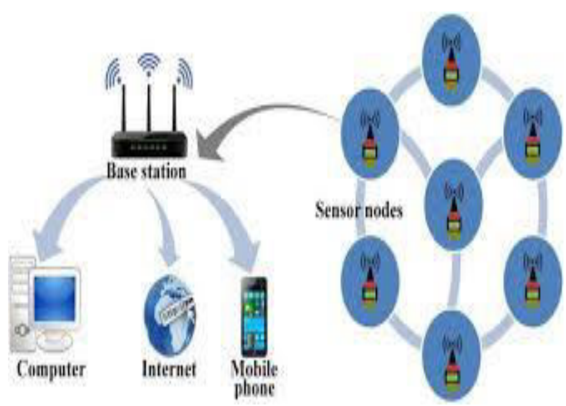

Fig. 8: Wireless Sensor Network [9]

3.2 IMPACT OF THE SENSOR NODES VIS-À-VIS THE THREE CATEGORY FUNCTIONAL PERSPECTIVE OF THE TNGAPMS SCENARIO IN THE NDA.

Concurrent application of the three categories of TNGAPMS(SSN,CSN and VSN) is advisable in the three identifiable sectoral delineation(the enclave sector, the urban sector and the rural sector) of the Niger Delta Area(NDA). Given the swift flow of air pollutants from one sectoral delineation of the NDA to the other, the same characterization of pollutants, albeit, in varying quantities are found in the enclave, the urban as well as the rural sector in the area.

Table 1 shows a proposed enclave-urban-rural sectoral deployment of TNGAPMS in the Niger Delta Area(NDA). It highlights the composition of gaseous pollutants and particulate pollutants that are subject to be determined as well as the category of TNGAPMS advanced for their determination.

S/N	Operational Sectors of the NDA	Gaseous Pollutants to be determined	Particulate Pollutants to be determined	TNGAPMS Category Advanced for their Determination
(i)	Enclave Sector	CO, NO_2, O_3 and SO_2.	$PM_{2.5}$, PM_5, and PM_{10}	SSN,CSN and VSN
(ii)	Urban Sector	CO, NO_2, O_3 and SO_2	$PM_{2.5}$, PM_5, and PM_{10}	SSN,CSN and VSN
(iii)	Rural Sector	CO, NO_2, O_3 and SO_2	$PM_{2.5}$, PM_5, and PM_{10}	SSN,CSN and VSN

Table 1: Showing Enclave-Urban- Rural Sectoral Deployment of TNGAPMS in the Niger Delta Area(NDA).

3.3 THE THREE CATEGORY FUNCTIONAL DEPLOYMENT OF THE TNGAPMS (THE SSN, CSN AND VSN) IN THE THREE SECTORS (ENCLAVE SECTOR, URBAN SECTOR AND RURAL SECTOR) OF THE NDA

Fig. 9 shows a proposed Wireless Sensor Nodes Deployment in the enclave sector of the NDA. It has its SSN Sensor nodes mounted on oil rigs, gas plants, major buildings and other strategic locations. Its CSN sensor nodes are carried by volunteer workers in the oil rigs, gas plants and other operational areas. Its VSN sensor nodes are carried on their Buses and House-boat transportation systems.

The resultant authorized air pollution information emanating from the SSN,CSN and VSN is made available to the public through webpages, and web apps.

Fig.9: Wireless Sensor Nodes Deployment in the Enclave Sector of the Niger Delta Area (NDA).

Fig. 10 shows a proposed Wireless Sensor Nodes Deployment in the Urban Sector of the NDA. The sector has its SSN sensor nodes mounted on street lights, traffic light poles and other selected locations. Its CSN sensor nodes are carried by volunteer members of the public. Its VSN sensor nodes are mounted on buses, cars, trains and other public transportation systems.

The resultant authorized air pollution information is made available to the public through web pages, and web apps.

Fig. 10: Wireless Sensor Nodes Deployment in the Urban Sector of the Niger Delta Area (NDA).

Fig. 11 shows a proposed wireless sensor nodes deployment in the rural sector of the NDA. While it could have its SSN sensor nodes mounted on church buildings, oil mill buildings and solar energy light poles along the main roads and alleys, those of the CSN sensor nodes could be carried by volunteer farmers and fishermen. This is just as its VSN could be mounted on buses, boats and other transportation system.

The resultant authorized air pollution information is made available to the public through web pages, and web apps.

Fig. 11: Wireless Sensor Nodes Deployment in the Rural Sector of the Niger Delta Area(NDA)

4. COMPLEMENTARITY OCCASIONED BY OBSERVED EFFICIENCIES AND DEFICIENCIES IN THE COMBINED APPLICATION OF THE TNGAPMS (SSN, CSN AND VSN)

A localized as well as an eclectic sensing scenario that smacks of complementarity is evinced in the workings of the SSN, CSN and VSN combined regime of The New Generation Air Pollution Monitoring System (TNGAPMS). While the localized carrier of the SSN engages in sensing the phenomenon or phenomena in a specific location or area, those of the eclectic CSN and VSN are by virtue of their being mobile able to sense phenomena in a relatively wider coverage area.

The implications of this; with all things (including power supply) being equal, their (SSN, CSN,VSN) combined functional perspective shall without doubt predispose a high spatiotemporal resolution; and as a corollary bring about effective data collection, which is the primary motive of the monitoring process.

Just like the VSN, the SSN is characterized as capable of predisposing accurate and reliable data. The same is, however, not the case with the CSN which suffers low data accuracy and reliability. But with an on the whole computation of the three combined functional perspective (SSN, CSN, VSN), the deficiencies observed in the CSN are more or less cancelled out.

4.1 OBSERVABLE RANKINGS OF THE SSN, CSN AND VSN

Whenassessed respectively and not collectively in terms of its output, the TNGAPMS(SSN, CSN, VSN) reflects a ranking which sees the SSN as least in mobility/geographic coverage; the CSN as least in temporal resolution; the SSN as least in cost efficiency; the VSN as least in endurance; the CSN as least in maintenance and data quality.

- In terms of mobility/geographic coverage, the Static Sensor Network (SSN) is observably the least in ranking; the Community Sensor Network (CSN) comes second, while the Vehicle Sensor Network (VSN) is the first.

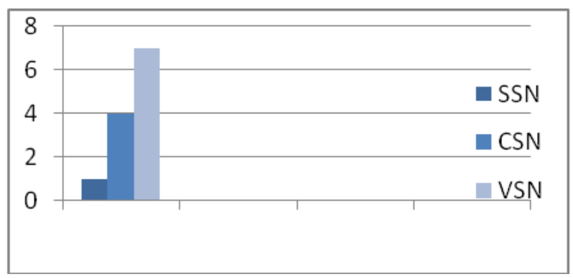

Fig. 12: Bar Chart showing the Performance Ranking of the SSN, CSN and VSN as per Mobility/Geographic Coverage**.**

- In terms of temporalresolution, the Static Sensor Network (SSN) comes first; with the Community Sensor Network (CSN) coming third, while the VSN takes the second position.

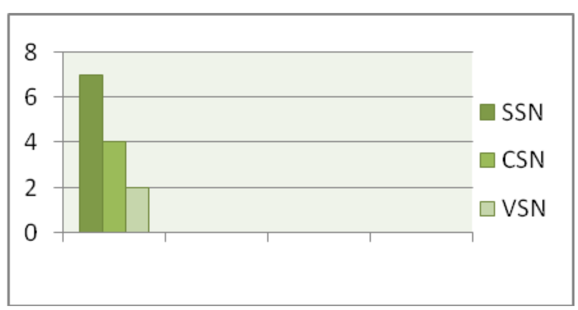

Fig. 13: Bar Chart showing the Performance Ranking of the SSN, CSN and VSN as per Temporal Resolution.

- In terms of cost efficiency, the SSN comes third, while the CSN and VSN come first and second respectively.

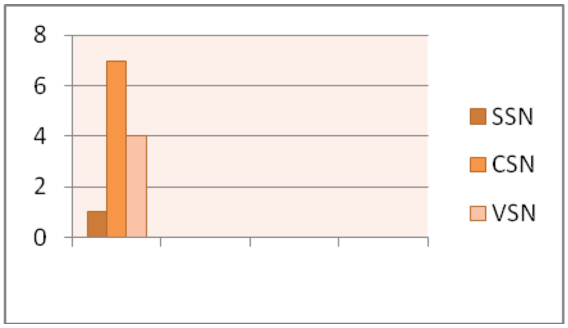

Fig. 14: Bar Chart Showing the Performance Ranking of the SSN, CSN and VSN as per Cost Efficiency.

- In terms of endurance, the SSN comes first, while the CSN and VSN come last and second respectively.

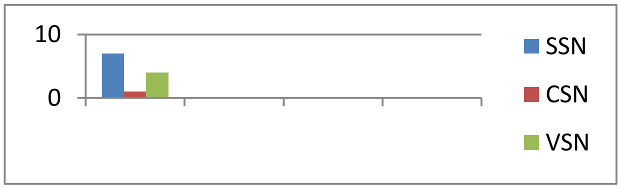

Fig. 15: Bar Chart Showing the Performance Ranking of the SSN, CSN and VSN as per Endurance.

- In terms of maintenance, the SSN comes second, while the CSN and VSN come third and first respectively.

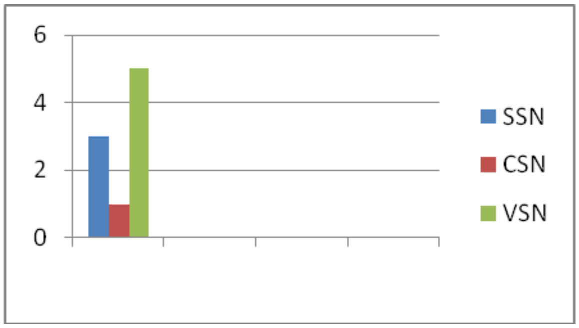

Fig. 16: Bar chart showing the performance ranking of the SSN, CSN and VSN as per maintenance.

- In terms of data quality, the SSN comes first, while the CSN and VSN come third and second respectively.

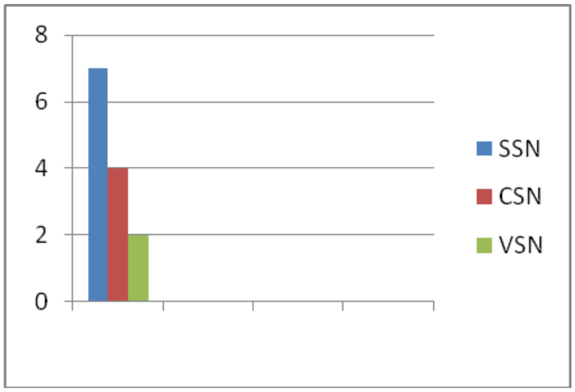

Fig. 17: Bar Chart showing the Performance Ranking of the SSN, CSN and VSN as per Data Quality.

4.2 SUITABLE SENSORS OF THE SENSED GAS AND PARTICULATE PHENOMENA

This study observably sees the solid state and electrochemical sensors as the most suitable types of sensors to monitor the gas (Carbon Monoxide, Nitrogen Dioxide, Ozone and Sulphur Dioxide) in the Niger Delta Area (NDA). And that while CO, NO_2, O_3 and SO_2) can be well detected by solid-state and electrochemical sensors, there could be need to mitigate the interference of O_3 and NO_2 in the detection of NO_2 and O_3 respectively. This study also affirms the Light Scatting and the Light Obscuration (Nephelometer) to be the most widely used particulate matter($PM_{2.5}, PM_5, PM_{10}$) sensors in the TNGAPMS scenario. This is due largely to their small size, light weight, low-cost and simultaneously measuring ability. The study equally affirms metal oxide gas sensors for developing the low-cost air quality monitoring systems. More so, as they have high sensitivity and fast response time.

5. RECOMMENDATION

The analytical framework of "The Next Generation Air Pollution Monitoring System" (TNGAPMS) is consistent with the concept of "efficient quality data appropriation", which thrives on an existing complementarity between the SSN, CSN and VSN. This no doubt obviates the low scalability and limited data collection problems evinced in the conventional air pollution monitoring systems. An advantage which can only by sustained through taking certain precautions: for which this study recommends the following imperatives:

- There must be an existing national policy on the design and operations of The Next Generation Air Pollution Monitoring System (TNGAPMS). This would make for a controversy free functional milieu within and between the nine states of the Niger Delta Area (NDA).
- Connoisseurs of the TNGAPMS project should as a matter of priority be assured a lobby of policy makers as well as administrators/technocrats to ensure compliance vis-à-vis the espoused yardsticks for the design and implementation of the TNGAPMS.
- Connoisseurs of the TNGAPMS project should ensure a proper mapping of the Niger Delta Area; with proper delineations made on traffic sites, industrial sites, farming sites, waste disposal sites and other natural sites. And as a corollary decide on which of the three categories of sensing systems (SSN, CSN and VSN) could be deployed to the sites enumerated while also ensuring guaranteed power supply and maintenance of the sensing systems.
- Connoisseurs of the TNGAPMS project should above all ensure unity of time and space in the system configuration of the TNGAPMS.

6. CONCLUSIONS

The result of these analysis show that there is an element of complementarity evinced in the concurrent usage of the SSN, CSN and VSN (which comprises TNGAPMS), and as a corollary, scalability and enhanced data appropriation. Especially indicative of this is the fact that despite the highest ranking performance in quality data appropriation accorded the SSN over and above the CSN and VSN, the SSN might not exclusively predispose scalability and enhanced data collection due largely to its static disposition, but could have this lacuna obviated in complementarity with the CSN and VSN, which have respectively been accorded higher and highest ranking performance over the SSN in mobility/geographic coverage. Hence, The Next Generation Air Pollution Monitoring System (TNGAPMS) is reminiscent of high spatiotemporal resolution. A situation which sees it as filling the gap often found missing in the conventional air pollution monitoring systems.

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