International Scholars Journals

Advanced Journal of Environmental Science and Technology ISSN 2756-3251, Vol. 15 (11), pp. 001-009, November, 2024. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

The Impact of Air Pollution on Human Health in Rivers State, Nigeria: A Survey of Disease Prevalence

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Accepted 15 September, 2024

The effect of air pollution on diseases of the people of Rivers State, Nigeria has been studied by analyzing epidemiological data collected from the State Ministry of Health, Nigeria in relation to ambient Air Quality data of the State and National Ambient Air Quality Standard data. It was found that a total number of 30,435 disease cases were reported during 2003 to 2008, out of which 61 patients died. The diseases found to be prevalent in the study area as a result of air pollution were pertussis, pulmonary tuberculosis, cerebrospinal meningitis (CSM), pneumonia, measles, chronic bronchitis, and upper respiratory tract infection (URT). The ambient air quality observed in the state (lead = 0.1115 ppm/year, particulates = 10 ppm/year, N-oxides = 2.55 ppm/year, SO_2 = 1 ppm/year, VOC = 82.78 ppm/year) was far worse than the World Health Organization Air Quality Standard (Lead = 1×10^{-6} ppm/year, particulates = 10^5 ppm/year). This clearly indicates their unsafe levels and concomitant health risks. This study (survey on diseases) showed that air pollution has direct impact on health of the people. The intensification of environmental education, especially among rural dwellers in the state is very essential to overcoming the health as well as pollution problems.

Key words: Air pollution, air quality standard, environmental education, epidemiological data, health effects, Niger-Delta, rural dwellers, World Health Organization.

INTRODUCTION

During recent years, there has been a growing awareness about possible biological effects of deposition of various pollutants in the atmospheric environment (Abdulkareem and Odigure, 2001; Bolion, 1991). Due to this, “air pollution and population health” has become one of the most important environmental and public health issues (Bingheng and Haidong, 2008). This is because atmospheric pollution poses significant impact both to human health and the environment. Evidences from various governmental organizations and international bodies have proven that air pollution is a major risk to the environment, quality of life, and health of the population (Colbeck and Nasir, 2010; WHO, 2000a, 2004a, b, 2007). Economic development, urbanization, energy consumption, transportation/motorization and rapid population growth are major driving forces of air pollution (Colbeck and Lazaridis, 2010).

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The human health effects due to air pollutants include carcinogenicity, pulmonary tuberculosis, cerebrospinal meningitis, pneumonia, whooping cough and measles (Nwachukwu and Ugwuanyi, 2010; Ugwuanyi and Obi, 2002); while the environmental effect is global warming (Bolion, 1991). The health effects which are due to air pollution are called epidemiological diseases. These diseases are well-defined by Nwachukwu and Ugwuanyi (2010), and Ugwuanyi and Obi (2002). Epidemiological studies play an ever important role in environmental health risk assessment. This is because epidemiological information (data) contributes increasingly to policy development, public health decision-making, the establishment of environmental regulations, and research planning (WHO, 2000a). Unlike laboratory experiments, epidemiology provides evidence based on study of human populations under real world condition. The contribution of epidemiology and air pollution factors to health risk assessment has been widely discussed (WHO, 2000a, 2004, 2007); however, these studies can never be enough as the parameters involved are highly temporarily and spatially variable. Therefore, they need to

be continually studied.

In recent years, several epidemiological studies have emerged showing adverse health effects associated with short-term and long-term exposure to air pollutants. Time series studies conducted in Asian cities also showed similar health effects on mortality associated with exposure to particulate matter, NO_2, SO_2, O_3 (Ali and Ather, 2010; Ali and Ather, 2008; Ghauri et al., 2007; Kumar and Joseph, 2006) to those explored in Europe and North America (William, 2012; Menezes et al., 2012; Vlatka et al., 2011; Icaga and Sabah, 2009; Rodriguez et al., 2007; Perrino et al., 2008; Zabalza et al., 2007; Dragan et al., 2008; Bingheng and Haidong, 2008). Osuji and Avwiri (2005) monitored the ambient air quality of industrial areas of Nigeria for criteria pollutants CO, NO_2, SO_2, O_3, Particulate Matter, and Pb and found all of them to be very high as compared to World Health Organization Air Quality Guideline. This means that these pollutants are already of risk to the teaming Nigerian population. Nwachukwu and Ugwuanyi (2010) studied air pollution and its possible effects on rural dwellers in Rivers State, Nigeria and found out that the lower atmosphere of the State is already affected by air pollution and that this is already affecting the health of its inhabitants.

The levels of air pollutants can vary from country to country and from continent to continent (WHO, 2004b). For example, air pollution levels in developed countries have been decreasing dramatically in recent decade, however; in developing countries, air pollution levels are still at relatively high levels (Bingheng and Haidong, 2008). This is because in developed countries, there is advanced air quality management and this is ensured by establishment of air quality laws, ambient air quality standards, continuous monitoring of air quality and development of emission control strategies (Colbeck and Lazaridis, 2010). In developing countries, these laws are not in place, and where they are in place, they are not enforced. Also, lack of technological know-how and lack of environmental education among the citizens are other major reasons many developing countries have not been able to control their air quality.

Nigeria is among the developing countries. Since Nigeria started exploration of its oil and gas, and other natural resources, it has experienced an escalation in its population growth, urbanization, and industrialization, together with great increase in motorization and energy use. As result, a substantial rise has taken place in the type and number of emission sources of various pollutants. However, due to lack of air quality management capabilities, the country is suffering from deterioration of air quality.

Before the 1970s, when industrial activities and urbanization were at low levels in Nigeria, most part of the country could have passed any safety standards as regards air pollution and its effects on man (Osuji and Avwiri, 2005). The problem of air pollution became a pact to be reckoned with in the country following the environmental side-effects of the rapid industrialization that accompanied the 1973 to 1980 oil booms in Nigeria (Nwachukwu and Ugwuanyi, 2010; Ugwuanyi and Obi, 2002).

Gas being flared into the atmosphere is one of such indiscriminate discharge and the petroleum industry operation is a major contributor (Onosode, 1996). Similarly, massive use of fuel wood for cooking by the people due to the nation's ailing economy, indiscriminate bush burning and other damaging forces have aspirated the problem contemporarily. There is, therefore, undoubtedly a high rate of atmospheric pollution in Nigeria especially in the country's industrial areas. For example, the air over Lagos, where about 38% of the manufacturing industries in the country are located, has since 1983 been credited with characteristic unpleasant odour. The Niger-Delta region of Nigeria where oil and gas are produced, and where Rivers State is located is indeed another case in point (Nwachukwu and Ugwuanyi, 2010; Osuji and Avwiri, 2005; Ugwuanyi and Obi, 2002; Oyekunle, 1999).

In the face of this development, the people of Rivers State who are at the heart of Niger-Delta geopolitical zone of Nigeria, with a good number of multi-national oil companies, cement companies, traffic congestion etc, may be the worst hit. It is now increasingly recognized that the contribution of the petroleum industry to the environmental depredation goes far beyond the immediate vicinity of the oil producing areas (Ikelegbe, 1993).

Following are listed air pollutants and the associated diseases (WHO, 2004a; Obi and Ugwuanyi, 2002):

(i) Respiratory: Irritation and decreased pulmonary function.

(ii) Particulate matter: Stress on the heart, bronchial constriction, impairment of lung elasticity and gaseous exchange efficient, silicosis (a form of pneumoconiosis caused by inhalation of dust particles), respiratory tract disease systematic toxicity, and altered immune defense.

(iii) Cement dust: Pulmonary tuberculosis, allergic asthma, pneumonia, heart disease, bronchitis influenza emphysema, and mycosis.

(iv) Carbon dioxide: Reduces the quantity of O_2 transported to tissues, hence can impress extra burden on those suffering from anaemia, chronic lung conditions, heart and blood vessel diseases, brain damage, impaired perception, eye and nasal irritation, lung damage respiration tract disease.

(v) Lead/asbestos: Causes asbestosis (chronic lung cancer), and mesotheleliionia (a rare form of cancer). Kidney disease and neurological impairment, primarily affects children.

(vi) Photochemical oxidants (e.g. ozone): Long exposure to it can cause reduced eye-sight, fatigue, pneumonia, pulmonary headache, breathing difficulties, chest pain,

Table 1. Summary of the number of patients admitted in all the hospitals in Rivers State, 2003.

Disease	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Measles	114	78	83	75	63	-	-	64	35	108	63	61	712
Tuberculosis	86	71	47	65	66[1]	-	-	54	64	74	69	60	656[1]
CSM	-	-	2	-	2[1]	-	-	-	-	5	3	-	12[1]
Pertusis	54	48	23	41	24	-	-	77	3	-	17	2	289
Pneumonia	235	350	290	393	-	-	462	472	273	300	353	3470	342[1]

Superscripts indicate the number of patients that died.

Table 2. Summary of the number of patients admitted in all the hospitals in Rivers State, 2004.

Disease	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Measles	105	163	205[1]	205	185	220[1]	163[5]	108	51	37	60	78	1433[7]
Tuberculosis	62	62	69	97	75	122[1]	116	65	68	92[3]	94[2]	61[4]	983[10]
CSM	1	1[1]	1	4	1	2	3[1]	3	1	1	1	-	19[2]
Pertusis	6	-	-	3	-	11	2	3	8	10	10	5	81
Pneumonia	289[1]	287	347	306	457	667	635[2]	402	387	316	463[1]	463[1]	4760[3]

Superscripts indicate the number of patients that died.

burning sensation to throat and eye, respiratory disease, aging of lungs and respiratory tissue.

(vii) Sulfur dioxide: Respiratory irritation, shortness of breath, impaired pulmonary function, increased susceptibility to infection, illnesses to lower respiratory tracts (particularly in children), chronic lung disease, pulmonary fibrosis, increases toxicity in combination with other pollutants.

(viii) Carbon monoxide: Interferes with oxygen uptake into the blood (chronic anoxia), heart and brain damage impaired perception, asphyxiation, weakness, headache and nausea.

(ix) Nitrogen dioxide: Reduction in lung function, increase in mortality, increase in airway allergic inflammatory reaction, and increased probability of respiratory symptoms.

In the continuing search for lasting solutions to problems caused by air pollution, one approach we believe is to obtain information on the health effects of environmental pollution on the inhabitants of Rivers State (especially the rural dwellers) who, indeed, are worst hit, as they have little or no knowledge about the hazardous nature of these pollutants. It is against this background that we present our findings in this regards sequel to a study conducted in Rivers State, Nigeria.

MATERIALS AND METHODS

Study design

This research study covers five years (2003 to 2007) in Rivers State, Nigeria. Epidemiological data of all the people in the state (as indicated in routine monthly notification form supplied by World Health Organization) treated for air-borne related diseases in 1985, 2003, 2004, 2005, 2006 and 2007 were collected from the State Ministry of Health. The 1985 data was used as reference data to find out the impact of air pollution on human health (diseases) during the study period (2003 to 2007). It is important to note that the 2003 to 2007 data collected from the State Ministry of Health represent the sum of the incidences from all the hospitals within the study. The most recent Ambient Air Quality (AAQ) data of the State, the National Ambient Air Quality Standard (NAAQS) data and the summary of the Updated World Health Organization Air Quality Guideline (WHOAQG) data were equally collected for the purpose of comparison.

The major air-borne related diseases investigated are pneumonia, pulmonary tuberculosis, measles, cerebrospinal meningitis (CSM), and whooping cough (pertusis). These disease terms are well defined in literature (Nwachukwu and Ugwuanyi, 2010; Ugwuanyi and Obi, 2002; Brooks et al., 2007; Willy et al., 2008).

RESULTS AND DISCUSSION

A total number of 30,435 incidences were recorded within the period of review (that is, 2003 to 2007), with an annual average of 6,087 incidence and a total number of 61 deaths (Tables 1 to 12; Figures 1 to 8), corresponding to an annual average of 12.2 deaths. Pneumonia emerged with the highest number of incidence both on monthly and annual basis. It equally has the highest incidences within the period of review (that is, 2003 to 2007).

Tables 1 to 5 represent the environmental impact matrices of the patients versus the diseases, while Tables 6 to 10 represent monthly incidences of measles,

Table 3. Summary of the number of patients admitted in all the hospitals in Rivers State, 2005.

Disease	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Measles	43	128[1]	65	31	21	29	33[1]	79[4]	27	73	25	66	620[6]
Tuberculosis	71[4]	66[1]	57[1]	52	92	91	101	94[2]	88[3]	61	58	66	897[14]
CSM	-	-	-	-	-	4	5	-	2	4	-	2	17
Pertusis	10	6	-	7	1	-	6	1	-	-	-	14	43
Pneumonia	291[1]	313	325[1]	285	331[3]	502[1]	452	594[1]	419[2]	3232	212	262	4309[14]

Superscripts indicate the number of patients that died.

Table 4. Summary of the number of patients admitted in all the hospitals in Rivers State, 2006.

Disease	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Measles	75	59	58	62	54	42	44	55	36	20	5	4	514
Tuberculosis	58[1]	46	51	48	69	85	42	55	60	46	44	73	677[1]
CSM	-	-	-	-	-	-	-	-	-	-	-	-	4
Pertusis	-	-	-	-	-	1	-	-	-	-	-	-	1
Pneumonia	295	288	342	376	377	354	405	339	401	325	362[1]	525	4189[1]

Superscripts indicate the number of patients that died.

Table 5. Summary of the number of patients admitted in all the hospitals In Rivers State, 2007.

Disease	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Measles	7	11	10	22	6	10	16	15	22	17	17	14	167
Tuberculosis	74	41	61	59[1]	70	62	114	43	54	43	71	65	757[1]
CSM	-	1	-	1	-	-	-	-	-	-	-	-	2
Pertusis	-	-	1	1	-	-	7	-	-	-	1	3	13
Pneumonia	319	405	332	466	476	680	460	656	704	461	443	408	581

Superscripts indicate the number of patients that died.

Table 6. Measles.

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
2003	114	78	83	75	63	-	-	64	35	108	63	61	712
2004	105	163	205	205	185	220	163	108	51	37	60	78	1433
2005	43	128	65	31	21	29	33	79	27	73	25	66	620
2006	75	59	58	62	54	42	44	55	36	20	5	4	514
2007	7	11	10	22	6	10	16	15	22	17	17	14	167

pulmonary tuberculosis, CSM, pertusis, and pneumonia respectively within the period under review. Table 11, on the other hand, illustrates the total number of occurrence per year for each disease.

Table 12 shows the annual recorded number of death incidence for each of the diseases and their total. For example, in 2003, a total number 2 death incidence occurred, 22 in 2004, 34 in 2005, 1 in 2006 and 1 in 2007. Measles has a total of 13, 27 from pulmonary tuberculosis, and 3 from CSM, none from Pertusis, and 17 from pneumonia, making it a total of 61 death incidence within the period review (2003 to 2007).

A comparison of Tables 13 and 1 to 5 shows that the studied air-borne diseases were relatively low during which only few industries were established. In 1985, only 154 patients were recorded with these diseases per annum (Table 13), about 20 years later when the state had attained peak in industrialization, an average of 6,087 patients contracted the diseases in a year. Similarly, in 1985, 26 deaths were recorded out of 154 incidences (that is, 17% of the patients treated died). In 2003, 2 patients died out of 5139 (that is, 0.4%), in 2004,

Table 7. Pulmonary tuberculosis.

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
2003	86	71	47	65	66	-	-	54	64	74	69	60	656
2004	62	62	69	97	75	122	116	65	68	92	94	61	983
2005	71	66	57	52	92	91	101	94	88	61	58	66	879
2006	58	46	51	48	69	85	42	55	60	46	44	73	677
2007	74	41	61	59	70	62	114	43	54	43	71	65	757

Table 8. Cerebrospinal meningitis (CSM).

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
2003	-	-	2	-	2	-	-	-	-	5	3	-	12
2004	1	1	1	4	1	2	3	3	1	1	1	-	19
2005	-	-	-	-	-	4	5	-	2	4	-	2	17
2006	-	-	-	-	-	-	-	-	4	-	-	-	4
2007	-	1	-	1	-	-	-	-	-	-	-	-	2

Table 9. Whooping cough (pertusis).

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
2003	54	48	23	41	24	-	-	77	3	-	17	2	289
2004	6	-	-	3	-	11	2	3	8	33	10	5	81
2005	10	6	-	7	1	-	6	1	-	-	-	14	43
2006	-	-	-	-	1	-	-	-	-	-	-	-	1
2007	-	-	1	1	-	-	7	-	-	-	1	3	13

Table 10. Pneumonia.

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
2003	235	350	290	393	342	-	-	462	472	273	300	353	3470
2004	289	287	347	306	457	667	635	402	387	504	316	463	4760
2005	291	313	325	285	331	502	452	594	419	323	212	26	4309
2006	295	288	342	376	377	354	405	339	401	325	362	525	4189
2007	319	405	332	466	476	680	460	656	704	461	443	408	5810

Table 11. Total number of occurrence per year for each disease.

Year	Measles	Pulmonary tuberculosis	CSM	Pertusis	Pneumonia	Total
2003	712	656	12	289	3470	5139
2004	1433	983	19	81	4760	7276
2005	620	897	17	43	4309	5886
2006	514	677	4	1	4189	5385
2007	167	757	2	13	5810	6749

22 deaths occurred out of 7,276 incidence (that is, 0.3%), in 2005, 34 deaths were recorded out of 5,886 (that is, 6%). In 2006, 1 incidence was recorded out of a total of 5,385 incidences (that is, 0.02%), and in 2007, 1 patient died out of 6,749 (0.015%) patients who received treatment. The number of patients who died per year during the period under study was very small compared to the ones who died before the advent of industrialization (example, 1985). However, this could be due to more accessibility to health care by patients contemporarily than before industrialization when they had to travel to major cities before they can receive any

Table 12. Total number of death incidences per year for each disease.

Year	Measles	Pulmonary tuberculosis	CSM	Pertusis	Pneumonia	Total
2003	-	1	1	-	-	02
2004	7	10	2	-	3	22
2005	6	14	-	-	14	34
2006	-	1	-	-	-	01
2007	-	1	-	-	-	01

Table 13. Summary of incidence of airborne disease in Rivers State (1985).

Disease	Frequency	No. of death
Measles	54	11
Meningitis	16	9
Pneumonia	36	2
Pertusis	1	-
Upper respiratory tract infection (URTI)	4	-
Chronic bronchitis	22	1
Pulmonary tuberculosis	19	5

Total no. of incidence = 154; total no. of deaths = 26.

Table 14. Air quality data at selected locations in the Niger Delta. The delta covers an estimated landmass of 700,000 km^2, with a population of over 7 million.

Location	State[a]	Year	Zone[b]	SPM [µg/m^3][c]	SO_X [µg/m^3]	NO_2 [µg/m^3]	H_2S [µg/m^3]	NO_X [µg/m^3][d]	H/Cs [ppm]	CO [µg/m^3]	CO_2 [ppm]	NH_3 [µg/m^3][d]
Nembe creek	R/S	1991	Ms	5.9 - 1295.7	<25	7.3 - 14.3	-	-	-	1-2	-	5.6
Belema	R/S	1993	Ms	1.1 - 430.9	25 - 39.8	2.3 - 10.4	-	-	-	1-2	-	9.5
Souk	R/S	1994	Ms	0.9 - 67.3	n.d.[e]	6.0 - 12.5	-	-	-	1	-	5.1-12.4
Cawthorne	R/S	1994	Ms	9120 - 48180	-	-	3.2 - 780	45.5 - 79.0	0.1 - 20	0.1 - 32	-	100-50 ppm
Channel III												
Awoba	R/S	1994	Ms	1.4 - 13.2	31 - 89.1	2.8 - 9.5	-	-	-	1.2	-	8.33.9
Agbada I	R/S	1994	Up	11.4 - 148.9	28.8 - 96.9	2.8 - 9.5	-	-	0.01 - 21	1.3 - 1.8	-	4.2 - 5.1
Obigbo North (I)	R/S	1994	Up	17.3- 43	n.d.	2.8 - 13.0	-	-	54.78	1	-	-
Alakiri	R/S	1994	Ms	35.4 - 43.8	n.d.	2 - 12.5	-	-	n.d.	n.d.	446	-
Obigbo North (2)	R/S	1994	Up	11.0 - 33.9	n.d.	9.4 - 30.6	-	-	-	1.7 - 3.5	-	-
Bonny	R/S	1993	Sw	18.7 - 66.9	n.d.	-	n.d.	n.d.	0.6-54 µg/m^3	0.002 - 0.19	-	-

Table 14. Continued.

Bonny Terminal	R/S	1994	Ms	4-373	7-612	4.7 - 27.2	-	-	<0.16	-	<<5000	-
Iko Town	A1	1994	Ms	100 - 5193	-	-	-	23 - 2019	<0.16	-	<<5000	-
Opobo South	R/S	1994	Ms	917 - 11334	-	-	-	<<0.2 pm	-	-	-	-
Opobo North	R/S	1994	Ms	250 - 3200	-	-	-	<<0.2 pm	-	-	-	-
Ewang	A1	1994	Up	2800	-	-	-	-	-	-	-	-
Remuekpe	R/S	1994	Up	267 - 6888	-	-	-	-	-	-	-	-
Agbada II	R/S	1994	Up	100 - 2353	-	-	-	-	-	-	-	-
Awara	R/S	1994	Sw	100 - 7387	-	-	-	<<0.2 ppm	<0.16	-	<<5000	-

[a)] R/S, Rivers State; A1, Akwa Ibom. [b)] Ms, mangrove swamp; Sw, swamp: UP, upland. [c)] Suspended particulate matter after 24 h. [d)] Selected values in ppm. [e)] Not determined. (Source: Osuji and Avwiri, 2005).

Table 15. Estimates of air emission in Rivers State, Nigeria.

Source	Lead		Particulates		N-Oxides		SO_2		VOC	
	[t.yr^{-1}]	[kg^{-}yr^{-1}.km^{-2}]	[t-yr^{-1}]	[t^{-}yr^{-1}.km^{-2}]	[t-yr^{-1}]	[t-yr^{-1}.km^{-2}]	[t-yr^{-1}]	[t-yr-^{1}.km^{-2}]	[t-yr^{-1}]	[t-yr-^{1}.km^{-2}]
Medium and large industries. Pt.Har.[c)]	-	-	10496	38.6	779	2.9	-	-	292	1.1
Small indust. And households. Pt. Har*		-	-	-	-	-	-	-	3750	13.8
Vehicles. Pt. Har.	54	199	304	1.1	345	1.2	-	-	3726	4.9
Vehicles, Rivers State	253	14	1461	<0.1	1656	<0.1	-	-	6260	0.3
Gas flaring. Rivers State	-	-	2590	<0.1	103562	6	19624	1	259×10^6	315

T: Tons, Yr: Year; No energy production emissions have been included for households or industries .[B)] VOC = Volatile Organic Compounds; Pt. Har.: Port Harcourt LGA = 272 km^2 and Rivers State area is 18.754 km^2. Port Harcourt has a population of 406.738 and Rivers State has a population of ca. 3.4 million people (Source: Osuji and Avwiri, 2005).

form of treatment as a result of under-development.

Although, the incidence of the disease appears to increase in the rainy season (March to September), (Figures 1 to 5), it is possible that some of the patients contracted them in the dry season (October to February), when the particles are likely to be move around the environment by the south–westerly winds. Over 74% of all patients suffered from pneumonia attacks (Table 11). Upper respiratory tract infection (URTI), chronic bronchitis, and cerebrospinal meningitis (CSM) were relatively low over the studied period; the reason for this is yet unknown and therefore subject to further research. The air quality data at selected locations in Niger-Delta (Table 14) and estimates of air emission in Rivers State (Table 15) are well above the national (Table 16) and international (Table 17) air quality standards. These findings show strongly that air pollution is one of the major causes of health impairment in

Table 16. National ambient air quality standards (NAAQS).

Pollutants	Averaging time	Limits
Particulates	Daily averages of daily values	250 µg/m^3
	1 h	600 µg/m^3
Sulfur dioxide (SO_2)	Daily mean of hourly values.	0.01 ppm (26 µg/m^3)
	1 h	0.1 ppm (260 µg/m^3)
Nitrogen dioxide (NO_2)	Daily mean of hourly values.	0.04 – 0.06 ppm
	1 h	(75.0 - 113 µg/m^3)
Carbon monoxide (CO)	Daily mean of hourly values.	10 ppm (11.4 µg/m^3)
	8 hourly mean.	20 ppm (22.8 µg/m^3)
Non-methane hydrocarbons	Daily mean of 3 hourly values.	160 µg/m^3
Photochemical oxidants	Hourly values	0.06 ppm

Source: Rivers state Environmental Protection Agency (RSEPA, 2007).

Table 17. Summary of the updated air quality guideline (AQG) levels (2005).

Pollutants	Averaging time	AQG value (µg/m^3)
Particulate matter		
$PM_{2.5}$	1 year	10
	24 h (99th percentile)	25
PM_{10}	1 year	20
	24 h (99th percentile)	50
Ozone (O_3)	8 h, daily maximum	100
Nitrogen dioxide (NO_2)	1 year	40
	1 h	200
Sulfur dioxide (SO_2)	24 h	20
	10 min	500
Carbon monoxide (CO)	15 min	100
	30 min	60
	1 h	30
	8 h	10
Vanadium	1 year	1.5
Cadmium	24 h	1.0
Hydrogen Sulfide, H_2S	24 h	150

Sources: Krzyzanowski and Cohen (2008), and WHO (2006a, b).

the state.

Conclusions

The results of this study show that the lower atmosphere of rivers state is polluted by gases and particulates, and that it is already affecting the quality of life and productivity of the people. This confirms the earlier results of Nwachukwu and Ugwuanyi (2010).

Given the fact that a greater percentage of the land mass is covered by water than by land, the population

densities of Rivers State (181 persons/km^2); the settlement characteristics of the people (compact traditional mud house with little or no ventilation), and the overall poverty level in the country, the number of people who have suffered and died due to these disease is likely to be more than officially reported and recorded. There is no record about the people's smoking habit. The AAQ in the state (Tables 14 and 15) exceeds both the national and international standards (Tables 16 and 17); and incidences of the diseases during the advent of industrialization are low relative to the contemporary cases (Tables 1 to 5, and 13). We therefore conclude that the diseases are largely due to air pollution.

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