Full Length Research Paper

A survey on the effects of air pollution on diseases of the people of Rivers State, Nigeria

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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, SO₂ = 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 = 10⁵ 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).

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

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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, \( \text{NO}_2 \), \( \text{SO}_2 \), \( \text{O}_3 \) (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 \( \text{CO} \), \( \text{NO}_2 \), \( \text{SO}_2 \), \( \text{O}_3 \), Particulate Matter, and \( \text{Pb} \) 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 Ugwuanvi (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 Ugwuanvi, 2010; Ugwuanvi 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 Ugwuanvi, 2010; Osuji and Avwiri, 2005; Ugwuanvi 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 deprecation 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 Ugwuanvi, 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 \( \text{O}_2 \) 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 respiratory tract disease.
(v) Lead/asbestos: Causes asbestosis (chronic lung cancer), and mesothelellionia (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  | 2   | -   | -   | 54  | 64  | 74  | 69  | 60    |
| CSM          | -   | -   | 2   | -     | 2   | 2   | -   | -   | -   | -   | 5   | 3   | 12    |
| Pertusis     | 54  | 48  | 23  | 41    | 24  | -   | 77  | 3   | -   | 17  | 2   | 108 | 656   |
| Pneumonia    | 235 | 350 | 290 | 393   | -   | -   | 462 | 472 | 273 | 300 | 353 | 3470|       |

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 | 185   | 220 | 163 | 108 | 51  | 37  | 60  | 78  | 1433|       |
| Tuberculosis | 62  | 62  | 69  | 97    | 75  | 122 | 116 | 65  | 68  | 92  | 94  | 61  | 912   |
| CSM          | 1   | 1   | 1   | 4     | 1   | 2   | 3   | 3   | 1   | 1   | 1   | -   | 19    |
| Pertusis     | 6   | -   | -   | 3     | -   | 11  | 2   | 3   | 8   | 10  | 10  | 5   | 81    |
| Pneumonia    | 289 | 287 | 347 | 306   | 457 | 667 | 635 | 402 | 387 | 316 | 463 | 463 | 4760  |

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 | 65  | 31    | 21  | 29  | 33  | 79  | 27  | 73  | 25  | 66  | 620  |
| Tuberculosis  | 71  | 66  | 57  | 52    | 92  | 91  | 101 | 94  | 88  | 61  | 58  | 66  | 897  |
| CSM           |     | -   | -   | -     | -   | 4   | 5   | -   | 2   | 4   | -   | 2   | 17   |
| Pertusis      | 10  | 6   | -   | 7     | 1   | 6   | 1   | -   | -   | -   | -   | 14  | 43   |
| Pneumonia     | 291 | 313 | 325 | 285   | 331 | 325 | 331 | 325 | 362 | 325 | 362 | 525 | 4189 |

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  | 46  | 51  | 48    | 69  | 85  | 42  | 55  | 60  | 46  | 44  | 73  | 677   |
| CSM           |     | -   | -   | -     | -   | -   | -   | -   | -   | -   | -   | -   | 4     |
| Pertusis      | -   | -   | -   | -     | -   | -   | -   | -   | -   | -   | -   | -   | 1     |
| Pneumonia     | 295 | 288 | 342 | 376   | 377 | 354 | 405 | 339 | 401 | 325 | 362 | 525 | 4189 |

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    | 70  | 62  | 114 | 43  | 54  | 43  | 71  | 65  | 757   |
| 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   |

Measles, 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  | 12   |
| 2004 | 1   | 1   | 1   | 4     | 1   | 2    | 3    | 3   | 1    | 1   | -   | 19  | 19   |
| 2005 | -   | -   | -   | -     | 4   | 5    | 2    | 4   | 2    | -   | 2   | 17  | 17   |
| 2006 | -   | -   | -   | -     | -   | -    | -    | 4   | -    | -   | -   | 4   | 4    |
| 2007 | -   | 1   | -   | 1     | -   | -    | -    | -   | -    | -   | -   | 2   | 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  | 81    |
| 2005 | 10  | 6   | -   | 7     | 1   | 6    | 1    | -   | -    | -   | 14  | 43  | 43    |
| 2006 | -   | -   | -   | 1     | -   | -    | -    | -   | -    | -   | -   | 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| 5139  |
| 2004 | 289 | 287 | 347 | 306   | 451 | 667  | 635  | 402 | 387  | 504 | 316 | 463 | 4760  |
| 2005 | 291 | 313 | 325 | 285   | 331 | 502  | 452  | 594 | 419  | 323 | 212 | 4309| 5385  |
| 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 km², with a population of over 7 million.

| Location             | State² | Year | Zoneᵇ | SPM [µg/m³]ᶜ | SOₓ [µg/m³] | NO₂ [µg/m³] | H₂S [µg/m³] | NOₓ [µg/m³]ᵈ | H/Cs [ppm] | CO [µg/m³] | CO₂ [ppm] | NH₃ [µg/m³]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.⁹       | 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

| Location             | State² | Year | Zoneᵇ | SPM [µg/m³]ᶜ | SOₓ [µg/m³] | NO₂ [µg/m³] | H₂S [µg/m³] | NOₓ [µg/m³]ᵈ | H/Cs [ppm] | CO [µg/m³] | CO₂ [ppm] | NH₃ [µg/m³]ᵈ |
|----------------------|--------|------|--------|--------------|-------------|-------------|-------------|--------------|-------------|------------|----------|-------------|
| 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/m³ | 0.002 - 0.19 | -          | -           |
Table 14. Continued.

| Source                | R/S | Year | Type  | TSP | PM10 | PM2.5 | NOx | SO2 | CO | O3 | VOC |
|-----------------------|-----|------|-------|-----|------|-------|-----|-----|----|----|-----|
| 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 | - | - | - | - |
| Ewag                 | 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              | SO2                  | 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.²) | -                     | 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 × 10⁶ [315]     |

T: Tons, Yr: Year; No energy production emissions have been included for households or industries. VOC = Volatile Organic Compounds; Pt. Har.: Port Harcourt LGA = 272 km² and Rivers State area is 18,754 km². 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/m³                       |
|                              | 1 h                                 | 600 µg/m³                       |
| Sulfur dioxide (SO₂)         | Daily mean of hourly values.        | 0.01 ppm (26 µg/m³)             |
|                              | 1 h                                 | 0.1 ppm (260 µg/m³)             |
| Nitrogen dioxide (NO₂)       | Daily mean of hourly values.        | 0.04 – 0.06 ppm (75.0 - 113 µg/m³) |
|                              | 1 h                                 |                                 |
| Carbon monoxide (CO)         | Daily mean of hourly values.        | 10 ppm (11.4 µg/m³)             |
|                              | 8 hourly mean.                      | 20 ppm (22.8 µg/m³)             |
| Non-methane hydrocarbons     | Daily mean of 3 hourly values.      | 160 µg/m³                       |
| Photochemical oxidants       | Hourly values                       | 0.06 ppm                        |

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

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

| Pollutants                  | Averaging time                          | AQG value (µg/m³) |
|-----------------------------|-----------------------------------------|-------------------|
| Particulate matter          |                                        |                   |
| PM₂.₅                       | 1 year                                  | 10                |
|                             | 24 h (99th percentile)                  | 25                |
| PM₁₀                        | 1 year                                  | 20                |
|                             | 24 h (99th percentile)                  | 50                |
| Ozone (O₃)                  | 8 h, daily maximum                      | 100               |
| Nitrogen dioxide (NO₂)      | 1 year                                  | 40                |
|                             | 1 h                                     | 200               |
| Sulfur dioxide (SO₂)        | 24 h                                    | 20                |
|                             | 10 min                                   | 500               |
|                             | 15 min                                   | 100               |
|                             | 30 min                                   | 60                |
|                             | 8 h                                      | 30                |
|                             |                                         | 10                |
| Carbon monoxide (CO)        | 1 h                                      |                   |
|                             |                                         |                   |
| Vanadium                    | 1 year                                  | 1.5               |
| Cadmium                     | 24 h                                     | 1.0               |
| Hydrogen Sulfide, H₂S       | 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/km²); 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 this 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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