The Environmental Impacts of Generated Air Pollution in Omdurman Industrial and Residential Area, Khartoum State, Sudan.

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Abstract

Industrial pollution is considered as one of the most important sources of environmental pollutants, which may have negative impacts on the human health and environment. This study is conducted with the aim of identifying environmental impacts resulting from air pollutants in Omdurman industrial and residential areas in Khartoum state. The study adopted a scientific method including, environmental measurement of air pollutants (carbon monoxide, sulfur dioxide, nitrogen dioxide, volatile organic compounds and particulate matter). These pollutants were measured in nine different sites during the winter and summer seasons of 2012 including two samples per season. The study revealed the following results: the carbon monoxide (CO) concentration average range was 0 to 7.9 ppm, which fits the allowed locally limits (22.6 ppm) and internationally (35 ppm). Regarding SO_2 and NO_2, their average concentration ranged between 0 to 0.4 and 0 to 0.27 respectively, and it is also classified within the locally allowed limits(11.8 and 26.6ppm) and internationally (2 and 20 ppm) during the entire year. The average concentration of volatile organic carbon(VOCs) in different locations were between 449 to 2526 ppb which exceeded the limits of permited value (750 ppb). The average values of the particulate matter were from 1.11 to 27.78 ppm which exceeds the international limits of 9 ppm.

Keywords: *Industrial pollution, Environment, Sudan, Urban air quality, VOCs*

1. Introduction

Various chemicals are emitted into the air from both natural and man-made (anthropogenic) sources[1–3]. The quantities may range from hundreds to millions of tons annually. Urban air quality is an issue of major concern owing to recent upward trends in population growth and urbanization and industrialization around the world[4–7]. Consequently, there is an increasing need to understand the detailed dynamics governing emission and transport of particulate matter in the atmosphere[8]. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet[9]. Exposure to air pollution is part of urban living throughout the world[10–12]. Over the past 20 years, there has been a shift in the type of air pollution affecting developed countries, such as the traditional pollutants from stationary sources (such as SO_2 and suspended particulate matter [SPM]) have been effectively controlled by the implementation and enforcement of legislation in many developed countries. In addition, a change from domestic coal burning to electricity and natural gas for heating and cooking purposes has led to a lower level of emissions of SO_2 and SPM with a concomitant improvement in air quality. However, further economic development (and increasing personal wealth) has resulted in increase in industrial emissions, and especially in motor vehicle traffic. This in turn, has led to increases in pollutants associated with motor vehicle transport[13].

2. Problem statement

Air pollution is essentially a problem occurring in the wake of large-scale industrialization in the world. The problem, which initially started in the western countries notably in Great Britain and U.S.A has now started in developed eastern countries as well alarming proportions to many countries mostly in large cities where vehicular traffic predominates. In addition to power station, there are more than 100 million tons of carbon monoxide being released into the air every year. Other air pollutants: hydrocarbons, sulphur oxides, nitrogen oxides and others amount to millions of tons each by year. The impact of air pollution on human beeings is broad. In humans, the pulmonary deposition and absorption of inhaled chemicals can have direct consequences for health. Nevertheless, public health can also be indirectly affected by deposition of air pollutants in environmental media and uptake by plants and animals, resulting in chemicals entering the food chain or being present in drinking water and thereby constituting additional sources of human exposure. Furthermore, the direct effects of air pollutants on plants, animals and soil can influence the structure and function of ecosystems, including their self-regulation ability, thereby affecting the quality of life[14]. In addition, pollutants can be transported over long distances from their sources, causing impacts hundreds or even thousands of kilometers downwind. Atmospheric chemistry influences human health, climate, food production, and through its impact on visibility, our view of the world. Chemicals in the air affect us with each breath we take[15]. In a recent estimate of the global burden of disease (GBD), outdoor air pollution was estimated to account for approximately 1.4% of total mortality; 0.4 of all disability-adjusted life years (DALYs), and 2% of all cardiopulmonary disease[16]. Ambient (outdoor air pollution) in both cities and rural areas was estimated to cause 3.7 million premature death worldwide per year in 2012, this mortality is due to exposure to small particulate matter (PM10) which cause cardiovascular and respiratory disease, and cancers[17]. The early stages of industrialization in the Sudan started during the past century when expansion in cotton production induced the establishment of ginning factories and other industries. The Sudan Government has been very much involved in industrial development, so there are many petro-chemical industries. Since the Sudan joined to oil producing counties, oil refineries were constructed and as the result of the new emerged businessman. Transport companies and many industries activities were established, in addition to new high ways were constructed. All of these activities contributing to air pollution problem, because some pollutants may exceed the ordinary rates and there are few studies that have been done in this field in Sudan[18]. The main objective of this research was to assess the environmental impacts of generated air pollution in Omdurman industrial and residential areas Khartoum State.

3. Materials and methods

3.1. Study area

Khartoum State is the capital of the Sudan with a total area of about (22.000 Km^2). Omdurman city is located on the western bank of the River Nile White which represents the main industrial center of the country. Omdurman city suffers from a clear environmental problems represent in solid waste disposal, poor sanitation (liquid waste disposal and storm water drainage) addition to other natural problems (floods, dust, desert encroachment and soil carving). Industrial area is located in the west of the big market and the north of Elshaaby market in Omdurman city. Omdurman industrial area is comprises a number of light industries like food and beverages industries, textile industry, leather industry, wood industry and manufacturing industries.

4. Results and Discussions

4.1. Environmental Measurements

Over all pollutants expected from different industries, the parameters examined in this study are : Carbon monoxide (CO), Sulphur dioxide (SO_2), Volatile organic Compounds (VOC's), Nitrogen dioxide (NO_2) and particulate matter (PM). Locations as well as parameters to be examined were set by using GPS program which represent all the geographical sites around the study area. The measurements were carried out on a four different days; each day represents a certain season of the year 2013: these are 6th February, 6th March, 3rd May and 3rd June of 2013. Samples were taken by using two common categories of air-sampling equipment (Direct Sense Tox model TG-501 Toxic gas Probe) which has direct-reading instruments for gases and vapors, which provide an immediate measurement of concentration; and sample collecting devices (Apex Air Sampling (Casella)) for particulate matter, which collect a sample of air that was subsequently weighed at laboratory (**Fig**. 1). Three points at each selected location were investigated and several instantaneous concentration were recorded for carbon monoxide (CO), Sulfur dioxide (SO_2), volatile organic compounds (VOC's) and Nitrogen dioxide (NO_2) within each points and the average concentration for each parameter outcome were tabulated. The same three points were also investigated for particulate matters and their concentrations were tabulated. Findings were interpreted against local and international standards. Different mixing patterns of pollutants in air are given rise to different problems[19]. Heavy concentrations of air pollutants, which are often in the form of smog, settle over a city, creating a health hazard for its people. People produce most of the wastes that cause air pollution. Such wastes are usually in the form of gases. These substances result mainly from burning fuel for motor vehicles and heating buildings. Industrial processes and burning of garbage also contribute to air pollution.

As shown in Table 1, the average concentrations range between 0.0 to 7.9 ppm and the maximum value was at location H. In fact, the higher concentration of CO is due to the existence of this location near the intersection of streets in addition to the proximity of some industries (Soap Factory).

According to the National Institute for Occupational Safety and Health of USA (NIOSH), the recommended exposure limit for 8 hours for CO is 35 ppm[20]. As shown in the result, all the maximum readings lie within the allowable limit, these results are also lie within the allowed limits of the local standards "Sudanese Standards and Meteorological Organization" (SSMO), which set the maximum allowable limits for CO to be 26 mg/m^3 (22.6 ppm).

Fig. 1. The experimental setup for air collecting systems.

Table 1. The results of the average concentrations of carbon monoxide (CO) in the selected locations during the study period

Location	Monthhs			
	February	March	May	June
	Average (ppm)	Average (ppm)	Average (ppm)	Average (ppm)
A	0.0	0.0	4.5	1.3
B	0.0	0.0	0.0	0.0
C	0.1	0.1	2.8	0.0
D	0.0	0.0	0.0	0.0
E	0.7	0.0	2.3	3.0
F	0.0	0.0	3.4	0.0
G	0.0	0.0	0.0	0.0
H	0.3	0.0	7.9	0.0
I	0.0	0.0	0.0	0.0

As shown in Table 2, the average concentrations of Sulphur Dioxide ranged between 0.0 to 0.3 ppm and the maximum values were at locations G & H. The highest concentration in these two locations is due to the emissions from cars and factories (location G located between two intersections of streets in the direction of the south and the north where, the wind plays an important role in the drifting of generated emissions). According to National Institute for Occupational Safety and Health (NIOSH), the recommended exposure limit for 8 hours for SO_2 is 2 ppm,[20], as shown in the result, the maximum reading was 0.4 ppm is lower than the allowable limit, and it may cause negative health effects for people who live near high traffic roads. Nevertheless, these results are also lie within the allowable limits of the local Sudanese Standards and

Meteorological Organization (SSMO), which set the maximum allowable limits for SO_2 to be 0.031 mg/m^3 (11.8 ppm) for annual exposure time.

Table 2. The results of average concentrations of Sulphur Dioxide (SO_2) in the selected locations during the study period

Location	Monthhs			
	February	March	May	June
	Average (ppm)	Average (ppm)	Average (ppm)	Average (ppm)
A	0.1	0.03	0.3	0.0
B	0.1	0.13	0.1	0.2
C	0.1	0.1	0.0	0.7
D	0.1	0.07	0.03	0.03
E	0.1	0.0	0.07	0.0
F	0.0	0.0	0.0	0.0
G	0.3	0.2	0.0	0.0
H	0.3	0.17	0.0	0.0
I	0.1	0.23	0.0 7	0.03

Table 3. The results of average concentrations of Nitrogen Dioxide (NO2) in the selected locations during the study period

Location	Monthhs			
	February	March	May	June
	Average (ppm)	Average (ppm)	Average (ppm)	Average (ppm)
A	0.04	0.07	0.07	0.12
B	0.12	0.21	0.12	0.0
C	0.04	0.03	0.07	0.03
D	0.04	0.06	0.07	0.01
E	0.08	0.08	0.08	0.01
F	0.05	0.04	0.11	0.01
G	0.03	0.04	0.11	0.0
H	0.05	0.06	0.18	0.0
I	0.07	0.10	0.15	0.0

From Table. 3, the average concentrations of NO_2 ranged between 0.0 to 0.21 ppm and the maximum values is at location H. The higher concentration of NO_2 is due to the same reason mentioned in (table 1).
According to National Institute for Occupational Safety and Health (NIOSH), the recommended exposure limit of NO2 is up to 20 ppm[20]. As shown in obtained results, the maximum concentration is 0.27 ppm which is lower than the allowable limit. Nevertheless, these results are also coincide with the allowable limits of the local Sudanese Standards and Meteorological Organization (SSMO), which set the maximum allowable limits for Nitrogen oxides to be 0.05 g/m^3 (26.6 ppm) for annual exposure time.

Table 4. The average concentrations of Volatile Organic Compounds (VOC's) in some selected locations during the study period

Location	Monthhs			
	February	March	May	June
	Average (ppm)	Average (ppm)	Average (ppm)	Average (ppm)
A	1698	756	1194	1162
B	1426	650	525	2526
C	1115	1102	709	1069
D	568	609	489	1001
E	634	1078	734	1392
F	478	1037	784	1271
G	474	1149	574	1575
H	795	1130	990	1525
I	449	1415	498	1863

Table 4 shows the results of Volatile Organic (carbons) (VOC's) values obtained. The average concentrations range between (449 to 2526 ppb) with a maximum value at location (B), most locations lie near the intersections of the streets crowded by cars. From the Table, it is clear that, the higher concentrations of VOCs are in all selected locations during the summer season especially in June with concentrations ranges between (1001 to 2526 ppb). This is may be due to the effect of temperature that increases the concentration of Volatile Organic compounds. In fact, there are no standards been set for VOCs but the OSHA (Occupational Safety and Health Administration) regulates formaldehyde, a specific VOC, as a carcinogen. OSHA also has adopted a Permissible Exposure Level (PEL) of 0.75 ppm (750 ppb), and an action level of 0.5 ppm (500 ppb). The results obtained are exceeding this value by many times so, this will be very harmful to those resides in these areas and it needs a quick action and decision from the authorized sector. Also on national level, Sudanese Standards and Meteorological Organization (SSMO), does not set the allowable limits for VOC's.

Table 5. The average concentrations of Particulate Matter (PM) in some selected locations during the study period

Location	Monthhs			
	February	March	May	June
	Average (ppm)	Average (ppm)	Average (ppm)	Average (ppm)
A	17.41	2.22	5.19	4.45
B	6.67	1.85	4.82	5.55
C	2.22	*	2.22	1.48
D	8.89	2.59	2.22	3.33
E	4.81	8.52	2.22	2.22
F	4.44	4.44	1.11	4.81
G	7.03	4.81	4.45	2.59
H	4.81	10.37	1.74	7.04
I	14.44	1.11	2.59	2.59

The results show that, the average concentrations of PM range between (1.11 to 17.41 ppm with a maximum level at location A. These results showed the impact of ambient air pollution of higher traffic, complex industry activities and commercial operations in the study areas. According to the Occupational Safety and Health Administration (United States of America) OSHA set their allowable levels for particulate matter as: 9 ppm (10 mg/m^3) for 8-hour exposure time and 35 ppm (40 mg/m^3) for 1-hour. It is obvious that, some of the obtained results exceeded the concentration of the 8-hour and this may affect negatively on the citizen living around the area for long time such as traffic police men and those living near or in the affected areas, In addition, the results represent particulates (quantitatively), but the greatest health hazard is constituted by trace element particulates (qualitatively) such as lead, cadmium, and mercury. From the study in Khartoum State was conducted to determine lead concentrations in traffic ambient air, to determine lead levels in blood of traffic policemen, during January 2009. It found that the degree of environmental lead pollution in traffic ambient air was above the permissible level [21]. New studies also suggested that, small particles may be more likely to affect human health than larger particles to directly translocate from the lung to the blood and other parts of the body, giving them possible particular relevance for cardiovascular outcomes. Numerous epidemiological studies have demonstrated a consistent link between particulate air pollution, especially fine particulate matter with aerodynamic diameter < 2.5μ m (PM 2.5), and increased cardiopulmonary morbidity and mortality[22]. Nevertheless, these results also exceeded the allowable limits recommended by the Sudanese Standards and Meteorological Organization (SSMO), which set the maximum allowable limits for $PM_{2.5}$ (10 mg/ m^3) for annual exposure time. As shown in the result the unsuspected area contains less concentration of pollutants compared with the other locations in the study area which is due to relatively to the distant from the pollution sources.

5. Conclusion

According to the results obtained, it is concluded that:

- The average concentrations of CO, SO_2 and NO_2 in all locations in the study area are within the locally and internationally permitted limits. The average concentrations of PM and VOCs in all locations exceeded the locally and internationally permitted limits.
- In conclusion of this investigation on air pollution in Omdurman city , one could mention that, the major reasons for the concentrations of the pollutants in any area in the Omdurman city is due to following :
- Absence of mountains and hills and absence of trees, vegetation and windbreaks and the wind speed is quite enough to carry the pollution from the city atmosphere.
- Because of the existence of many industries and huge amount of transport in Omdurman.
- This study analyses provide evidence that, the current air pollution level has an adverse health effect and strengthen the rationale for further limiting air pollution levels in Omdurman area.

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