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Presence and Levels of Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Carbon Monoxide (CO) and Hydrogen Sulphide (H_2S) Gases Generated from Unmanned Dumpsites within Tarkwa - Nsuaem Municipality, Ghana

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Abstract: *The study assessed the presence, concentrations and potential health implications of selected toxic gases NO_2, SO_2, H_2S and CO) and their overall contribution to the quality of air surrounding unmanned dumpsites and the nearest residences within Tarkwa-Nsuaem Municipality using Crowcon Multi-gas detector. The results showed presence of the selected gases at varying concentrations at various locations. The highest NO_2 (0.575 ppm) was observed at Effuanta-Tamso road followed by Nzemaline (0.2 ppm), UMaT (0.2 ppm) and Ahwiteaso (0.15 ppm) dumpsites. The SO_2 concentrations was highest (1.0 ppm) at Effuanta-Tamso road followed by Nzemaline (0.8 ppm), Ahwiteaso (0.8 ppm) and UMaT (0.2 ppm) dumpsites. For H_2S, the highest was at Nzemaline (22.0 ppm) followed by Ahwiteaso (14.0 ppm), Effuanta-Tamso road (10.38 ppm) and UMaT (3.0 ppm) dumpsites. The CO concentrations were negligible, 4, 22 and 27 ppm for UMaT, Ahwiteaso, Efuanta-Tamso road and Nzemaline, respectively. Moreover, at the closest residence, CO, SO_2 and H_2S were absent except at Efuanta-Tamso that recorded SO_2 concentration of 0.1 ppm. The NO_2 gas was also recorded at the various residences close to the dumpsites except that close to UMaT dumpsite. The quality of air around the nearest residences were generally good which makes them acceptable to the public. Conversely, the air quality around the dumpsites, generally ranged between "Good" and "unhealthy for sensitive groups" categories, indicating satisfactory air quality at some dumpsites and others with poor air quality. Overall, the study has shown that the unmanned dumpsites within Tarkwa-Nsuaem generate toxic gases that may create health challenges with prolong human exposure.*

Keywords: *unmanned dumpsites, toxic gases, Air Quality Index*

1. Introduction

Globally, the volume of waste (either in solid, liquid and gaseous state) generated across the countries is increasing due to population growth, economic growth, urbanisation, and industrialisation [1]. Evidently, it is estimated that an average of 1.9 billion tons of solid waste is generated yearly in most towns/cities across the world [2]. In the case of Sub-Saharan Africa, the annual waste generated is estimated to be about 62 million tonnes [3]. Interestingly, municipal solid waste (MSW) accounts for majority of the waste generated globally. MSW typically comprises degradable (paper, textiles, food waste, straw and yard waste), partially degradable (wood, disposable napkins and sludge) and non-degradable materials (leather, plastics, rubbers, metals, glass, ash from fuel burning like coal, briquettes or woods, dust and electronic waste) [4, 5]. Practically, the increasing level of waste generated annually presents both opportunities and challenges.

One of the main challenges that underpins almost all associated health and environmental issues with waste generated globally is management. Effective waste management plays a major role in combatting the health and environmental concerns that cities, towns and villages suffer from, especially in sub-Saharan Africa (SSA) [1, 6, 7]. Thus, effective and efficient management of solid waste is one of the biggest challenges local government authorities face especially in urban areas [8, 9]. This is typical in developing countries like Ghana, where inadequate infrastructure coupled with increased population growth or urbanisation have resulted in generation of higher volumes of MSW, outstripping local authorities' ability to manage and dispose of solid waste in an environmentally-friendly and sustainable manner [10, 11, 12]. Evidently, studies have shown that low- and middle-income countries such as Ghana collect between 50 – 80% of waste generated although these countries spend about 30 to 50% of their operational budgets on solid waste management [13, 14]

In developing countries like Ghana, the large volumes of waste generated are managed by collection from streets and disposal at unmanned dumpsites or unengineered landfills. It is worth noting that these unmanned dumpsites or unengineered landfills are the most common and oldest method of municipal solid waste disposal in Ghana and most developing nations [15, 16]. Unmanned solid waste dumpsites are known to contribute to several environmental challenges including odour, leachates and toxic gas emissions [17]. The generation of dumpsite gases such as NOx, SOx, H_2S, CH_4 and several other greenhouse gases seems to be significant due to the decomposition of waste which are usually rich in organic components [18, 19, 20]. The level, type and percentage of gases produced differs spatially due to waste composition, age, quantity, moisture content and ratio of hydrogen/oxygen availability at the time of decomposition (e.g. fat, hemicellulose, etc.) [18, 19, 20, 21]. It is worth mentioning that the gases often generated are reported to have both short-and long-term health effects (such as nausea, eye and skin irritations, mood swings, slurred speech, vision issues, memory loss, headaches, respiratory and cardiovascular disorders among many others) on public health [17, 20].

Tarkwa-Nsuaem municipality is one of the mining districts in Ghana that boast of several gold and manganese mining operations. The estimated waste generation within the municipality is ~ 0.92 kg per capita per day translating to an average daily generation average rate of 3.93 kg per household per day with an average household size of 4.27 persons [22]. The most common disposal method within the municipality is the unmanned dumpsite method (which is very common in most parts of the country, Ghana). Although, this method has been used several years within the municipality but there are no existing literature or study highlighting the presence and health impact of potential toxic gases generated from the various dumpsites within the municipality. Therefore, a study to examine the presence, concentrations and potential health implications of selected toxic gases such as NO_2, SO_2, H_2S and CO and their overall contribution to the quality of air around the dumpsites and the nearest residences is warranted.

2. MATERIALS AND METHODS

2.1. Study Area

Tarkwa-Nsuaem Municipality is located within the Western Region of Ghana. The Municipality lies between latitudes 400'N and 500 40'N and longitudes 10 45'W and 20 10'W. The municipality covers a total land area of 2354 km^2 of territory [23]. The Tarkwa-Nsuaem Municipality doubles as the hub of the Ghanaian extractive industry and the single district with highest number of mines on the African continent [23]. It lies within the tropical rainforest belt of Ghana as well as the South-Western Equatorial Climatic Zone. The area records one of the highest rainfalls in the country with annual mean, max and min values of 1874, 2608 and 1449 mm, respectively [23, 24]. Notably, the study was conducted at selected dumpsites within four sub-areas within Tarkwa Township, namely; Ahwiteaso, Effuanta – Tamso Road, Nzemaline and UMaT as shown in Fig. 1.

2.2. In-situ Monitoring of Toxic Gases

Measurement of the toxic gases at the dumpsites and the nearby residences were carried out at the various sites using Crowcon gas detectors and the Dragger hand pump coupled with gas detector tubes as shown Fig. 2a and b, respectively. Notably, the position of the monitoring was selected after the personnel had carried the gas detectors around for determination of suitable areas where the presence of the gases were detected as shown in Fig. 3. At each selected monitoring sites, four selected gases [Carbon monoxide (CO), Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2) and Hydrogen Sulphide (H_2S)] were measured for a period of one hour. Typically, the distances from the dumpsites to the nearest residences ranged between 8 – 15 m for all the locations.

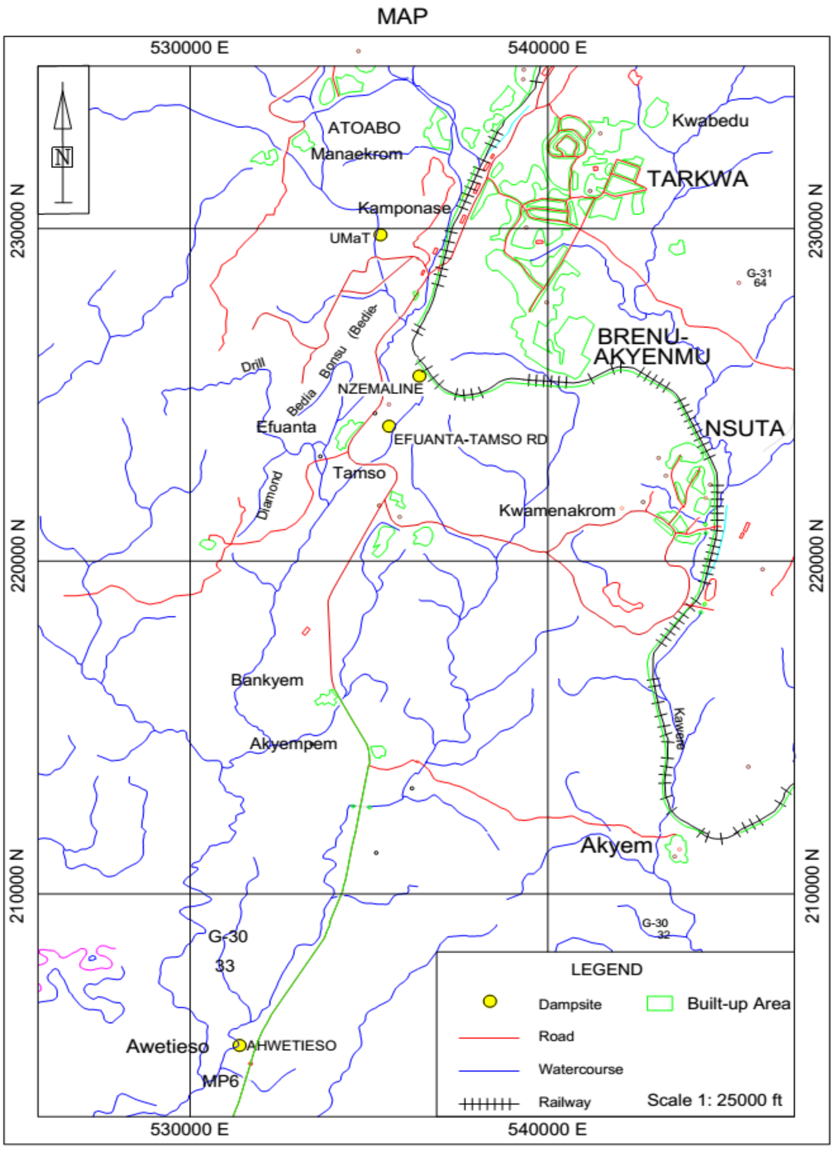

Fig. 1: *Map Showing the Location of the Dumpsites*

Fig. 2: *(a) Crowcon Gas Detectors and (b) Dragger Hand Pump*

Fig. 3: *Personnel with Gas Detectors for Selection of Suitable Locations for the Monitoring*

2.3. Assessment of Air Quality

The Air Quality Index (AQI) model was used for the assessment of the air quality status of the areas. This model is very useful for evaluation of air quality in relation to its impact on human health. Importantly, the AQI provides information on the cleanliness/healthiness of the air and potential health risk in an area and gives recommendations for sensitive populations [25]. The USEPA AQI estimation method was employed in this study (Eqn 1):

$$AQI_p = \frac{AQI_{uc}-AQI_{lc}}{BP_{uc}-BP_{lc}}\left(C_p - BP_{lc}\right) + AQI_{lc} \quad (1)$$

Where AQI_p is the index for a given pollutant (p); C_p is the concentration of the pollutant; AQI_{uc} and AQI_{lc} is the index value corresponding to the upper and lower of each breakpoint category (BP) respectively; BP_{uc} and BP_{lc} are the upper and lower concentration at each breakpoint category respectively. Notably, Ghana Environmental Protection Agency (EPA)'s Index High values (AQI_{uc}) as indicated; NO_2 (200), SO_2 (200), CO (200) and H_2S (150), were used due to the location of study. The matrix for interpreting AQI levels and corresponding health risk and remedial actions needed are highlighted in Table 1.

Table 1: *AQI Categories and Related Health Risk*

AQI Level	AQI Category	Category Colour	Action to Protect Health
0 – 50	Good	Green	Air quality is satisfactory and poses little or no risk
51 – 100	Moderate	Yellow	Air quality is acceptable. However, poses health risk to unusually sensitive group
101 -150	Unhealthy for sensitive group	Orange	Sensitive groups likely to experience health effect. General public less likely to be affected.
151 -200	Unhealthy	Red	General public may begin to experience health effects. Sensitive groups at increased risk.
201 – 300	Very Unhealthy	Purple	Higher health risk to general public.
301 – 500	Hazardous	Maroon	General public may experience severe health effect

3. Results and Discussion

3.1. Concentrations of Toxic Gases

Nitrogen Dioxide (NO_2)

Fig. 4 shows the concentrations of NO_2 measured at the various dumpsites and their nearest residences at the selected locations, The result reveals that the presence of NO_2 was detected at all the dumpsites. The levels of NO_2 detected were 0.15, 0.575, 0.2 and 0.2 ppm for Ahwiteaso, Effuanta-Tamso, Nzemaline and UMaT, respectively. The result also shows that NO_2 gas was detected at all the nearest residences except at UMaT. The NO_2 levels measured were 0.1, 0.2 and 0.1 ppm for nearest residences at Ahwiteaso, Effuanta-Tamso and Nzemaline, respectively. Generally, the concentrations recorded at the dumpsites and their respective nearest residences were higher than the recommended WHO limit of 0.11 ppm except the residences for Ahwiteaso and Nzemaline that were slightly below the limit. Practically, the presence of the NO_2 gases measured can be attributed to activities such as microbial decomposition of high nitrogen-containing organic waste (e.g., dead animals) and waste combustion which often occurs on these dumpsites [20, 26, 27, 28]. These situations (burning of materials and decaying of animals) were evident at the various dumpsites. In terms of health implication, the presence of NO_2 should be worrying to the people around since prolonged exposure can cause chronic lung diseases, pulmonary tract irritation which affects the functioning of the lungs [29, 30].

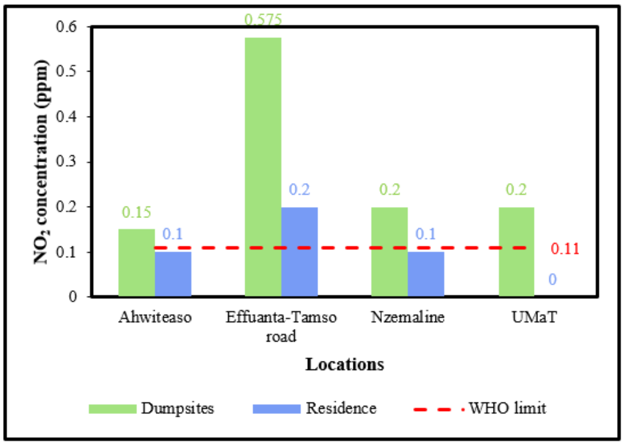

Fig. 4: *The concentration of NO_2 gas recorded at the various dumpsites and their respective nearest residences*

Sulphur Dioxide (SO_2)

Fig. 5 shows the results of presences and concentrations of SO_2 emitted from the various dumpsites and their closest residences. Generally, the results shows that SO_2 gas was present at all the various dumpsites, however, its presence was not noted at the various nearest residences, except that of Effuanta-tamso dumpsite. The concentrations recorded at Ahwiteaso, Effuanta-Tamso, Nzemaline and UMaT dumpsites were 0.8, 1.0, 0.8 and 0.2 ppm, respectively. Also, the concentration recorded at the nearest residence to Effuanta-Tamso dumpsite was 0.1 ppm. It is worth mentioning that the SO_2 recorded at all the dumpsites were above the recommended WHO hourly exposure limit of 0.19 ppm. The generation of SO_2 gases on the dumpsites can be linked to aerobic decomposition of organic waste, uncontrolled burning of waste (such as plastics and car tires) and chemical breakdown of sulphur-containing materials/compounds (such as gypsum and sulphur-rich plastics) [20, 26, 28]. Evidently, uncontrolled burning of the waste was observed during the period of monitoring. Healthwise, prolonged exposure to SO_2 by people, especially the vulnerable, may lead to skin and eye irritations, and cough and mucus secretions [31, 32]. Additional, SO_2 is noted to aggravate asthmatic conditions [33, 34].

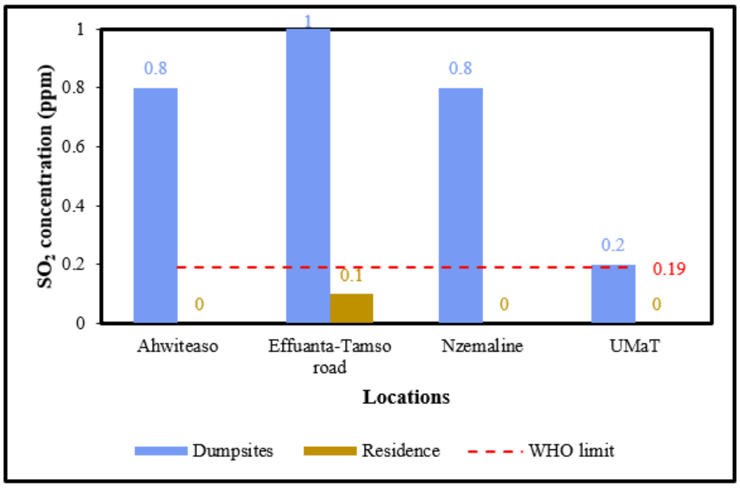

Fig. 5: *The Concentration of SO_2 Gas Recorded at the Various Dumpsites and their Respective Nearest Residences*

Carbon Monoxide (CO)

The presence and concentrations of CO recorded at the various dumpsites and their nearest residences are presented in Fig. 6. The results show that CO was present at all the dumpsites, except that of UMaT. At the nearest residences, no concentration of CO was recorded. The concentrations recorded at Ahwiteaso, Effuanta-Tamso and Nzemaline were 4, 22 and 27 ppm, respectively, and were below the recommended WHO exposure limits of 35 ppm. The presence of the CO at the Ahwiteaso, Effuanta-Tamso and Nzemaline dumpsites can be linked to incomplete/oxygen-starved burning of waste on sites as observed in most cases [20, 35, 36]. Although, no level of CO was recorded at the nearest residences, but health precautions need to be taken since they contribute to total air quality of the surrounding areas. Thus, prolong exposure to high concentration of CO gas can result in dizziness, headaches, confusion, unconsciousness, vomiting, nausea and possibly risk of heart diseases [20, 37].

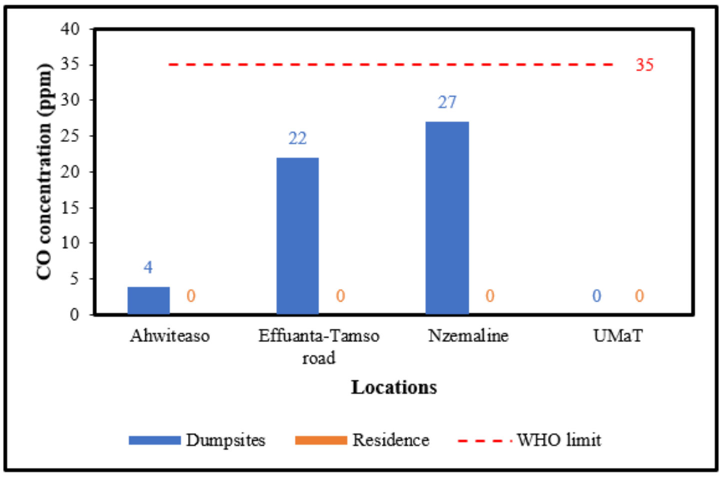

Fig. 6 *The Concentration of CO Gas Recorded at the Various Dumpsites and their Respective Nearest Residences*

Hydrogen Sulphide (H_2S)

The presence and concentrations of H_2S recorded at the various dumpsites and their nearest residences are presented in Fig. 7. Whilst varying concentrations of H_2S gas was recorded at all the dumpsites, no level was measured at the nearest residences. The concentrations measured at Ahwiteaso, Effuanta-Tamso, Nzemaline and UMaT were 14, 10.38, 22 and 3 ppm, respectively. The production of H_2S at the various dumpsites can be attributed to of the CO at the Ahwiteaso, Effuanta-Tamso and Nzemaline dumpsites can be linked to anaerobic decomposition of organic materials (e.g., food waste) and protein-rich waste (e.g., animal waste), and chemical decomposition of waste [20, 38]. Evidently, on the dumpsites, the presence of human excreta, dead animals and food stuffs were observed. It is worth mentioning that, prolonged exposure to this gas may pose health implications (such as cancer risk, neurological effects, respiratory diseases) and atmospheric pollution (i.e., H_2S gas can react with other atmospheric pollutants contributing to the formation of acid rain and ground level ozone) [20, 38].

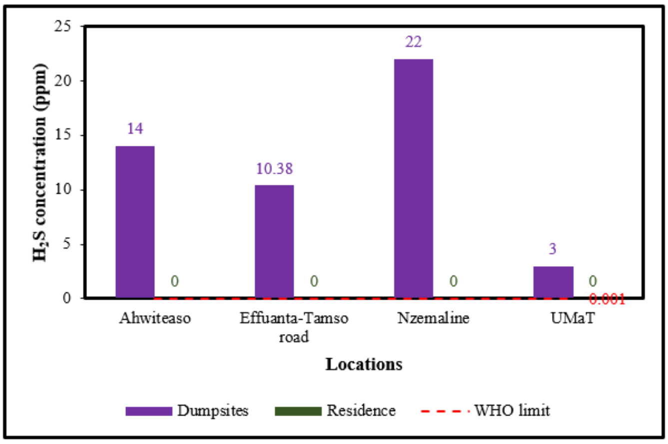

Fig. 7 *The Concentration of H_2S Gas Recorded at the Various Dumpsites and their Respective Nearest Residences*

3.2. Air Quality Indices (AQIs) for the Dumpsites and their Nearest Residences

The quality of air around the various dumpsites was also assessed using the Air Quality Index model (Eq. 1). This model provides a numerical scale to measure the level of air pollution in a given area based on some selected major pollutants/gases [39] as highlighted in Eq. 1. Notably, the assessment was necessary due to the potential health risk these gases may pose to people/residences situated within 8 – 15 m away from the dumpsites. Generally, estimation of the overall AQI based on multiple pollutants in the situation like in this involved determination of AQI for each pollutant followed by selection of dominant pollutants based on the pollutant with the highest AQI. The overall AQI of the area is then determined by the identified dominant pollutant. Tables 2, 3, 4 and 5 show the AQI for each gas, the overall AQI of the areas and the related health implications or actions for public health protection.

Ahwiteaso Dumpsite and the Nearest Residence

The results for the Ahwiteaso dumpsites (Tables 2 and 4) shows that the AQI for NO_2, SO_2, CO and H_2S gases measured were 15, 80, 16 and 21, respectively. Based on the results, the SO_2 appeared as the dominant pollutant, hence the overall AQI at the dumpsite is 80. This means that the AQI category is moderate implying that air quality is acceptable, however, unhealthy for unusually sensitive group (Table 4).

In terms of the quality of air at the nearest residence, the results for AQI for NO_2, SO_2, CO and H_2S gases were 10, 0, 0 and 0, respectively (Table 3). In this case, the NO_2 appeared as the dominant pollutant, hence the overall AQI at the nearest residence is 10. In terms of AQI category and health related health risk (Table 5), it is evident that the AQI category is good (implying satisfactory air quality that poses little or no risk).

Effuanta-Tamso Road Dumpsite and the Nearest Residence

The results for the Effuanta-Tamso road dumpsites (Tables 2 and 4) highlighted that the AQI for NO_2, SO_2, CO and H_2S gases estimated were 57.5, 100, 88 and 15.57, respectively. Based on the results, the SO_2 appeared as the dominant pollutant, hence the overall AQI at the dumpsite is 100. This implies that the AQI category is "Moderate" meaning that air quality is acceptable, however, unhealthy for unusually sensitive group (Table 4).

For the quality of air at the nearest residence, the results for AQI for NO_2, SO_2, CO and H_2S gases were 20, 10, 0 and 0, respectively (Table 3). In this case, the NO_2 appeared as the dominant pollutant, hence the overall AQI at the nearest residence is 20. For AQI category and health related health risk (Table 5), it is evident that the AQI category is "**Good**" (implying that Air quality is satisfactory and poses little or no risk).

Nzemaline Dumpsite and the Nearest Residence

From Table 2, the AQI for NO_2, SO_2, CO and H_2S gases estimated were 20, 80, 108 and 33, respectively. It is evident from the results that CO is the dominant pollutant, hence the overall AQI at the dumpsite is 108. Table 4 shows that the overall AQI category is "Unhealthy for sensitive group" meaning that Sensitive groups likely to experience health effect with the general public less likely to be affected.

The AQI for NO_2, SO_2, CO and H_2S gases at the nearest residence were 10, 0, 0 and 0, respectively (Table 3). Notably, the NO_2 appeared as the dominant pollutant, hence the overall AQI at the nearest residence is 10. For AQI rating and health related health risk (Table 5), it is clear that the AQI is classified as "**Good**" (implying that Air quality is satisfactory and poses little or no risk).

UMaT Dumpsite and the Nearest Residence

The AQI for NO_2, SO_2, CO and H_2S gases calculated were 20, 20, 0 and 4.5, respectively (Table 2). It is evident from the results that NO_2 and SO_2 are the dominant pollutants, hence the overall AQI at the dumpsite is 20. The overall AQI rating according to Table 4 is "**Good**" meaning that the Air quality is satisfactory and poses little or no risk.

For the nearest residence, the AQI for NO_2, SO_2, CO and H_2S gases were 0, 0, 0 and 0, respectively (Table 3), hence there is no dominant pollutant. This places the overall AQI rating as "**Good**" (implying that Air quality is satisfactory and poses little or no risk) (Table 5).

Table 2: *Air Quality Indices for Gases Recorded at the various dumpsites*

Gases	AQI for Each Gas at Dumpsites			
	Ahwiteaso	Effuanta-Tamso Road	Nzemaline	UMaT
NO_2	15	57.5	20	20
SO_2	80	100	80	20
CO	16	88	108	0
H_2S	21	15.57	33	4.5

Table 3: *Air Quality Indices for Gases Recorded at the Nearest Residences to the Various Dumpsites*

Gases	AQI for Each Gas at the Nearest Residences			
	Ahwiteaso	Effuanta-Tamso Road	Nzemaline	UMaT
NO_2	10	20	10	0
SO_2	0	10	0	0
CO	0	0	0	0
H_2S	0	0	0	0

Table 4: *Air Quality Ratings (Overall for the Various Dumpsites)*

Locations / Dumpsites	Overall AQI	AQI Category	Health Implication
Ahwiteaso	80	Moderate	Air quality is acceptable. However, poses health risk to unusually sensitive group
Effuanta-Tamso road	100	Moderate	Air quality is acceptable. However, poses health risk to unusually sensitive group
Nzemaline	108	Unhealthy for sensitive group	Sensitive groups likely to experience health effect. General public less likely to be affected.
UMaT	20	Green	Air quality is satisfactory and poses little or no risk

Table 5: *Overall Air Quality Rating at the Nearest Residences to the Various Dumpsites*

Locations / Dumpsites	Overall AQI	AQI Category	Health Implication
Ahwiteaso	10	Good	Air quality is satisfactory and poses little or no risk
Effuanta-Tamso road	20	Good	Air quality is satisfactory and poses little or no risk
Nzemaline	10	Good	Air quality is satisfactory and poses little or no risk
UMaT	0	Good	Air quality is satisfactory and poses little or no risk

4. CONCLUSIONS

This study assessed the presence and levels of selected toxic gases produced from four unmanned dumpsites and their nearest residences within Tarkwa-Nsuaem Municipality in Ghana. The outcomes of the study indicate that:

- All the dumpsites recorded the presence of NO_2, CO, SO_2 and H_2S gases at varying concentrations, except that located at UMaT area which did not record CO gas.
- The nearest residences to the various dumpsites did not record any presence of CO and H_2S gases at the time of the assessment, however, some level of SO_2 gas was recorded at the resident close to Effuanta-Tamso road dumpsite.
- Except the residence close to the dumpsite located within the UMaT area, all other residences nearest to the dumpsites at Effuanta-tamso road, Ahwiteaso and Nzemaline recorded varying concentrations of NO_2 gas.
- Generally, the AQI rating at the nearest residences of the various dumpsites were classified as "Good" meaning satisfactory in terms of air quality and poses little or no health risk.
- The overall AQI for Ahwiteaso and Effuanta-Tamso road dumpsites were classified as "moderate" implying acceptable air quality but poses health risk to unusually sensitive group.
- The air quality rating for Nzemaline dumpsite is categorized as "Unhealth for sensitive group" implying that sensitive groups likely to experience health effect whilst the public is less likely to be affected.
- The dumpsite at UMaT area also had overall AQI classified as "Good" indicating satisfactory air quality that poses little or no health risk.

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