International Journal of Development and Sustainability
ISSN: 2186-8662 – www.isdsnet.com/ijds
Volume 6 Number 8 (2017): Pages 575-585
ISDS Article ID: IJDS17061601

In-situ investigation of emitted toxic gases in municipal solid waste dumpsites in Makurdi metropolitan of Nigeria

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Abstract

An in-situ monitoring of toxic gases was performed in selected four dumpsites within Makurdi metropolitan in the month of April prior to commencement of rainfall season. Gasman Monitor was used and five toxic gases were indentified to be emitting from these dump sites. The average daily concentration of emission were found to be 4.4, 0.06, 0.09, 0.24 and 5.0ppm for CO, NO_2, SO_2, Cl_2 and H_2S respectively and are found within their acceptable WID range respectively. High level recorded highest emission of CO followed by Wadata dump site while North Bank and Wurukum sites were less in emission of CO due to the pre historic information on the age of the dump sites. History has it that Wadata and high level were the oldest settlement in Makurdi while North bank is not as old as those two. Unlike CO, NO_2 do not show continuous emission for the period of the survey with Wadatas showing staggering high emissions in some days. Similar trend in emission of SO_2 was observed just as in the case of NO_2 with equal amount of emission except for Wadata and Wurukum that shows staggering increase in emission between 23rd and 26th of the month of survey. There was uniformity in the emission of Cl_2 with the exception been that of Wurukum and High level in some instances. CO and H_2S showed high degree of variation from one site to the another as attested to by their standard deviation of 2.47 and 0.9 respectively. Cl_2, SO_2 and NO_2 do not vary significantly from site to site, their degree of variation as attested by the standard deviation were 0.001. However, it is very important to note that air pollution induced by MSW in Makurdi has not exceeded the WID legal limit. In fact, process engineering of the gas cleaning systems can still be extended to lower emission limits if the environmental legislation so requires.

Keywords: In-Situ; Toxic Gases; MSW Dump Site; Makurdi Metroplitan

Cite this article as: Enokela, O.S. and Kantiok, Y.D. (2017), "In-situ investigation of emitted toxic gases in municipal solid waste dumpsites in Makurdi metropolitan of Nigeria", *International Journal of Development and Sustainability*, Vol. 6 No. 8, pp. 575-585.

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1. Introduction

The activity of municipal solid waste (MSW) may pose environmental problems at various levels, concerning either ambient contamination provoked mainly by gaseous emissions coming from the dump sites after being subjected to solidification/stabilization. The explosive potential of methane, important risks and harmful effects to the environment and public health exist because of the presence of hydrogen sulfide (H_2S), siloxanes, potentially toxic volatile organic carbons (VOCs), benzene, vinyl chloride, dichloromethane, chloroform, toluene, dichlorobenzene, etc as well as compounds responsible for odours (VOCs, sulfur compounds, etc) by about 0.5% (Zmirou et al., 1994). More than 500 trace compounds in dump site gases have been identified. Ultimately, population health living nearby may be adversely affected by carcinogenic and non carcinogenic compounds so that assessing their risk on the potential increase of human diseases is truly advisable. In this ambit some literature studies have addressed this theme. Cangialosi et al. (2008) described the health impact associated to the gaseous emissions of a municipal solid waste dump site, based on an atmospheric dispersion model involving pollutants content and human exposure level. Volatile organic compounds and bioaerosols possibly attributed to a MSW plant in Spain (Vilavert et al., 2011) were checked and potential risks for human health were not identified once pollutants concentrations were similar to those observed in other regions. In a comparative study, Moy et al. (2008) reported that the landfill impact in human health through inhalation is five times higher than the one associated to the incineration operation, with cancer risk for both alternatives considered as acceptable when analyzing data from New York City, whereas non-cancer health problems showed to be unacceptable. Aatamila et al. (2011) reported nuisance potential as a characteristic of an exposure situation, which describes the magnitude of the nuisance that can be expected in a human population when exposed in their living environment to an odour from dumpsites intermittently, but over an extended period of time. The effect of odour exposure according to Immacolata et al. (2012) is rather complex because it depends, as already mentioned above, on different variables, such as individual sensitivity, the kind of smell, the frequency at which it is perceived, the intensity and the whole context. Consequently, the literature has not yet defined a unanimous threshold for the emission of odorous substances. In order to make better use of odour source information, and to combine this information with prevailing meteorological conditions and specialists odour observations (Hutsemekers et al., 2017), there arise a need to have environmental knowledge and available technologies for odour evaluation. This situation has led to development of dispersion model and specific sampling and odour measurement techniques such as; cryocondensation sampling, adsorptive odour sampling and electronic noses that can account for the special needs and requirements of odour annoyance problems.(Juarez-Galan et al., 2010; Boeker et al., 2010; Bootsma and Milan, 2010), The model system can be used to combine this different information using the inherent model physics to produce an integral spatial relation, e.g. in form of instant odour plume maps. These instant odour plume maps or results from wind field modeling may be used to provide observers with an instant feedback, or may be used to question observations

Assessing health risks for direct and indirect human exposure with dispersion models, the impact of air pollution on health, economy, environment and agricultural sources revealed that irrelevant danger was associated to inhalation while tolerable daily soil intake (TDSI) could be possibly surpassed due to the high deposition levels of those residues (Macleod et al., 2006). According to Margarida et al. (n.d.) a directive, known as Waste Incineration Directive (WID), states that continuous measurements of NOx, CO, total dust, TOC, HCl, HF and SO_2 should be carried out, and at least twice a year for heavy metals (Cd, Tl, Hg, Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V) and dioxins and furans. In fact, WID imposes very restrictive limit values for them.

Air Pollution Control in Municipal Solid Waste according to Korea (Oh et al., 2006) showed that those emissions affected more directly atmosphere quality, with furan levels in air closer to the emitted values than those found in soil. In order to deepen consequences of environment contamination of MSWI, Cordier et al. (2004) analyzed birth malformations in the population surrounding 70 dumpsites in France. Though congenital problems were not significantly more relevant in those groups, higher incidence of some anomalies associated to renal, urology, cardiology and skin pathologies could be ascertained to persistent pollutants accumulated from the old dump sites and road traffic pollution as well. The effect resulting from the application of more restrictive environment EU legislation regarding MSW emissions was considered by Meneses et al. (2004), by determining PCDD/Fs concentrations in air, soil and vegetation, and their danger for human health, having concluded that both pollutants emissions and cancer risk was reduced after those measures implementation. Other contamination sources were, nevertheless, pointed out since pollutants emission levels diminished more significantly than health problems after the installation of new cleaning gas systems. Also, the replacement of old systems (electrostatic precipitator) by new technologies (semi-dry scrubber, fabric filters and charcoal injection) in Spain (Abad et al., 2003) revealed a significant decrease on dioxins emissions spread in stack gas, bottom ash and air pollution control residues, where the higher dioxin content was found. Finally, it is worthy to refer that in September 2009, the Health Protection Agency from UK analyzed the on-going research about health impact of municipal solid waste dump sites and conclusions about the low influence in humans diseases of modern technologies were justified by the fact that emissions are well controlled, imparting, therefore, low contribution to global air pollution.

It is important to remember that monitoring data taken at landfills do not necessarily reflect the levels of contamination to which people may be exposed. However, ATSDR (2001) reported that these data usually offer some insight into general air quality, landfill gas migration, or possible health hazards. According to ATSDR (2001) the monitoring of eminent gases from landfills can be accomplished through; Soil gas monitoring, Near surface gas monitoring, Emissions monitoring, Ambient air monitoring and Indoor air monitoring

Emissions monitoring programs measure the rate at which chemicals are released from a particular source, such as landfill surfaces, flares, or stacks. ATSDR (2001) reported that ambient air monitoring programs measure levels of pollution in outdoor ambient air, or the air that people breathe and the indoor air monitoring programs measure levels of contamination in indoor air spaces. In addition to the sampling location, several methods of landfill gas collection can be used in a landfill gas sampling approach. Examples of these sampling approach and their implications include Portable vs. stationary sampling equipment, Grab sampling vs. continuous monitoring and Analysis of samples in the laboratory vs. analysis in the field (ATSDR, 2001).

There are numerous different continuous measuring monitors on the market today. For the most part they are used particularly in measurement networks. Some are portable, which are typically hand-held instruments that can be easily carried around a landfill. This type of device is useful for conducting an initial screening of landfill gas migration pathways. The stationary monitors, on the other hand, usually are installed at fixed locations, where they remain for the duration of the intended monitoring. Stationary monitors are typically, though not always, capable of generating higher quality data than portable monitors (ATSDR, 2001)**.** Jerry and Lucien (2017) in their work emphasized here that all automatic measurement procedures based on chemical-physical principles must be calibrated using (manual) reference procedures. Since automatic equipment in measurement networks often runs for extended periods of time (e.g., several weeks) without direct human supervision, it is indispensable that their correct functioning is regularly and automatically checked. This generally is done using zero and test gases that can be produced by several methods (preparation of ambient air; pressurized gas cylinders; permeation; diffusion; static and dynamic dilution).

Charles (2013) in his work reported that the volume and hazardous nature of wastes generated has increased considerably from the late nineteenth century and has led to the need for disposal to land specifically allocated for the purposes of disposal landfill to avoid environmental impacts and health hazards. Health hazards arise from some air pollutants, from waste not disposed of to controlled outlets, from poorly managed waste sites. Health hazards are, by and large, relevant to developing countries where disposal practice is often primitive (Jha et al., 2011). At present, municipal solid waste incineration (MSWI) in Nigeria and other developing countries has not been fully integrated, the main problems associated to these MSW dump sites are the large volume of gaseous emissions which may pose environmental health risks (if not well cleaned) and the hazardous fly ash or air pollution control (APC) residues that remain after incineration. In Makurdi municipality, there is little or no information on emission of these gases from MSW dumpsites. It is in view of this fact that this study was conducted to provide a data bank on these gases for further studies.

2. Study area

Makurdi lies between latitude 70^{o} 44^{I} N and longitude 80^{o} 54^{I} E in a categorized structure as North Bank, Wadata, Wurukum, and High level municipality. The overall topography of this province is plain (the slope about 0-2%) and groundwater level beneath aquifer is low. The soil characteristic of this province is clay, which is slightly acidic (pH about 6 - 4.5). The economic plants are rice and fruits like arrange mango and banana. Rainfall characteristics between 1994-2004 classified the patterns into dry season (low amount of rainfall) during November-April and wet season (high amount of rainfall) during May-October. The average monthly rainfall in dry season and wet season are 17.88 and 120.85mm, respectively, while the mean annual rainfall in Makurdi is about 1,290mm (Akintola, 1986). In Makurdi, the chance of a wet day over the course of April is very rapidly increasing, starting the month at 29% and ending it at 60%. The rainfall accumulated over a sliding 31-day period centered around each day. Weather Spark (WS), (2017) reported that the average sliding 31-day rainfall during April in Makurdi is very rapidly increasing, starting the month at 1.7 inches, when it rarely exceeds *3.6 inches* or falls below 0.4 *inches*, and ending the month at 3.9 *inches*, when it rarely exceeds 6.1 inches or falls below 1.2 inches. Temperature in Makurdi is however, generally high throughout the year, with February and March as the hottest months. Temperature in Makurdi varies from a daily of 40^0C and a maximum of 22.5^0C (Ologunorisa and Tersoo, 2006). In Makurdi, the month of April is characterized by gradually falling daily high temperatures, with daily highs decreasing by 3°F, from 93°F to 90°F over the course of the month, and rarely exceeding 98°F or dropping below 86°F with April 17 receding the average highest temperature of 73^oT. Daily low temperatures are around 76°F, rarely falling below 73°F or exceeding 78°F (WS, 2017). The humidity comfort level was based on the dew point, as it determines whether perspiration will evaporate from the skin, thereby cooling the body. Lower dew points feel drier and higher dew points feel more humid. Unlike temperature, which typically varies significantly between night and day, dew point tends to change more slowly, so while the temperature may drop at night, a muggy day is typically followed by a muggy night. The chance that a given day will be muggy in Makurdi is increasing during April, rising from 93% to 99% over the course of the month. The average hourly wind speed in Makurdi is essentially constant during April, remaining within 0.1 miles per hour of 4.0 miles per hour throughout (WS, 2017).

3. Materials and method

For the purpose of this study, Portable vs. stationary sampling equipment method was adopted using Gasman Monitor for a period of thirty day (30) in the month of April at four categorized structure of Makurdi urban center.

4. Result and discussion

Table 1 present the mean daily emission of the toxic gases from different dump sites in Makurdi while Figures 1-4 gives the physical appreciation of the concentration of CO, NO_2, SO_2, Cl_2 and H_2S emitted daily from the various dump sites studied.

Table 1. Mean Daily concentration of emitted CO (ppm) in selected Dumpsites in Makurdi

Emitted Gas	Dumpsite locations							
	Wadata	High level	North Bank	Wurukum	Mean	Std	Range	Legal limit
CO (ppm)	5.50	5.80	2.40	3.90	4.4	2.47	2-45	50
NO_2 (ppm)	0.06	0.10	0.04	0.03	0.058	0.001	20-180	200
SO_2 (ppm)	0.10	0.08	0.07	0.12	0.093	0.001	0.2-20	50
Cl_2 (ppm)	0.23	0.27	0.26	0.21	0.242	0/001	0.1-6	10
H_2S (ppm)	5.00	5.00	5.00	5.00	5/0	0.9	5.00	50

4.1. Discussion

From the plot it could be observed that the dump site at high level recorded highest emission of CO (5.8) followed by Wadata dump site while North Bank and Wurukum sites were less in emission of CO. this phenomena could be attributed to the pre historic information on the age of the dump sites. History has it that wadata and high level were the oldest settlement in Makurdi while North bank is not as old as those two (Figures 1).

Unlike CO the plot is showing that NO_2 do not show continuous emission for the period of the survey. However, Wadata is showing a staggering high concentration of emissions in some days of the period under survey especially toward the end of the study period. It could also be observed that the remaining dump sites show equal concentration of emission for the study period. Similar trend in emission of SO_2 was observed just as in the case of NO_2 with equal amount of emission except for Wadata and Wurukum that shows staggering increase in emission between 23rd and 26th of the month of survey (Figures 2).

Nearly uniform emission of Cl_2, SO_2 and NO_2 were observed with high concentration from the emission H_2S in all the selected dump sites in Makurdi. This an indication that the inhabitant of Makurdi are facing serious health challenge with the dumping of waste in location close to the residential areas (Figures 3-5).

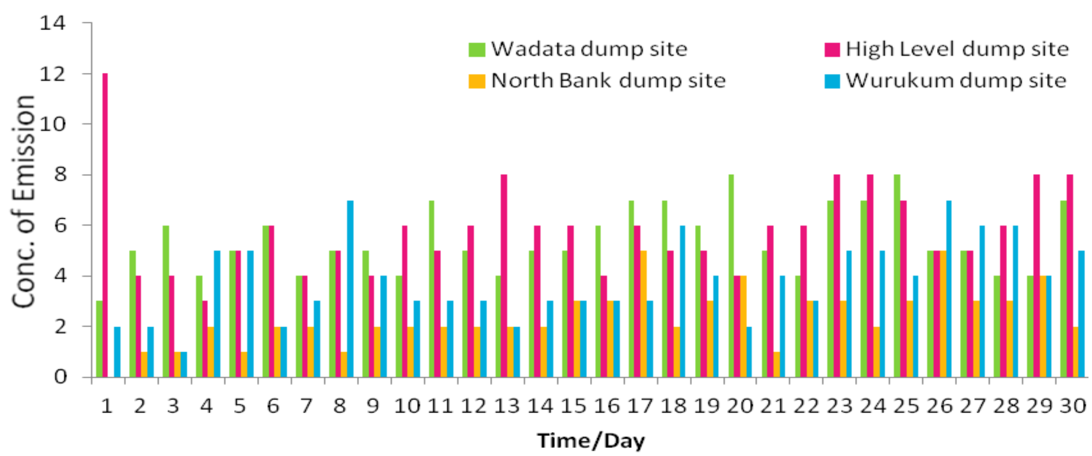

Figure1. Concentration of CO in selected dumpsites

By comparing the results obtained in Tables 1, CO and H_2S showed appreciable high degree of concentration from the emissions corresponding to higher degree of variation from one site to the other as attested to their standard deviation of 2.47 and 0.9 respectively. Cl_2, SO_2 and NO_2 do not vary significantly from site to site, their degree of variation as attested by the standard deviation were 0.001. The concentration of all the gases tested at the different dump sites falls below the legal limit of emission according to WID standard hence there is no need for treatment of flue-gas (crude flue-gas) at Makurdi as at moment. However, CDPH (1977) posited that the sulfide gases coming from the landfill are unlikely to affect reproduction, but the levels are high enough to produce strong odors. These odors may be highly unpleasant and at times, may be sufficient to make people feel ill. It should be kept in mind that such illness is a reaction to the odor and should improve once the odor dissipates. Shusterman, (1992) in his opinion said that these concentrations are well below the level needed to produce toxicity This means that landfill odors represent more of a public nuisance than a community health hazard, with the odors not being a good indicator of whether other chemicals are present. However adequate precautions can be put in place against sudden change in trend as anticipated with increase in waste generation by the exploding population.

The prevailing weather condition was considered from selected metrological factors such as temperature, rainfall, humidity and wind speed. The daily trends of these factors shoes a decreasing trend in temperature and wind speed with an increasing trend in precipitation and humidity in the month of April. This behaviour do not necessary translate to corresponding concentration of emission of the various gases investigated at the different dumpsites.

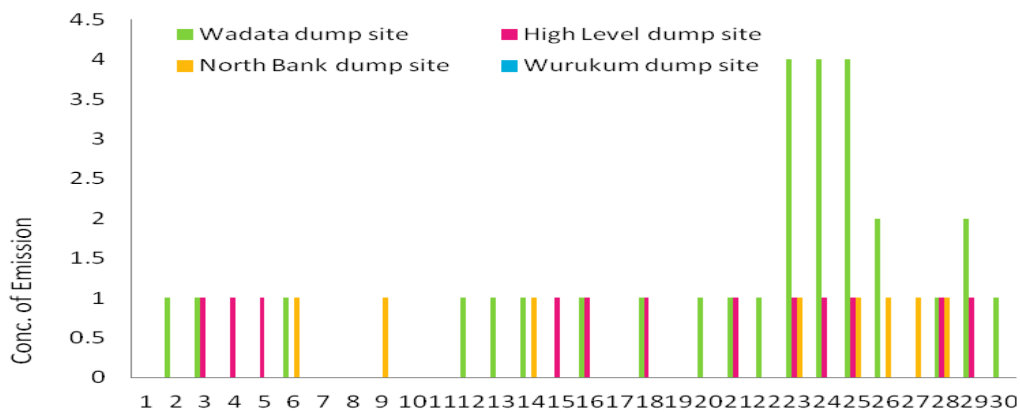

Figure2. Concentration of HCl in selected dumpsites

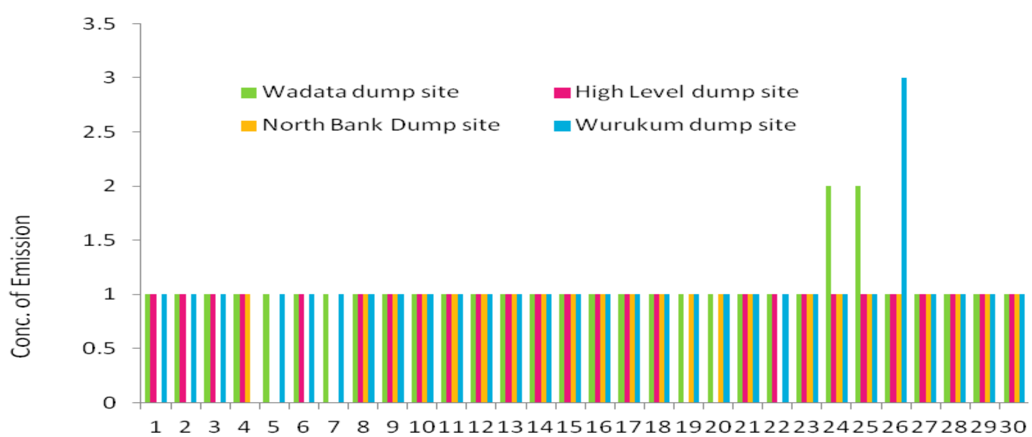

Figure 3. Conc. of SO_2 in selected dump sites

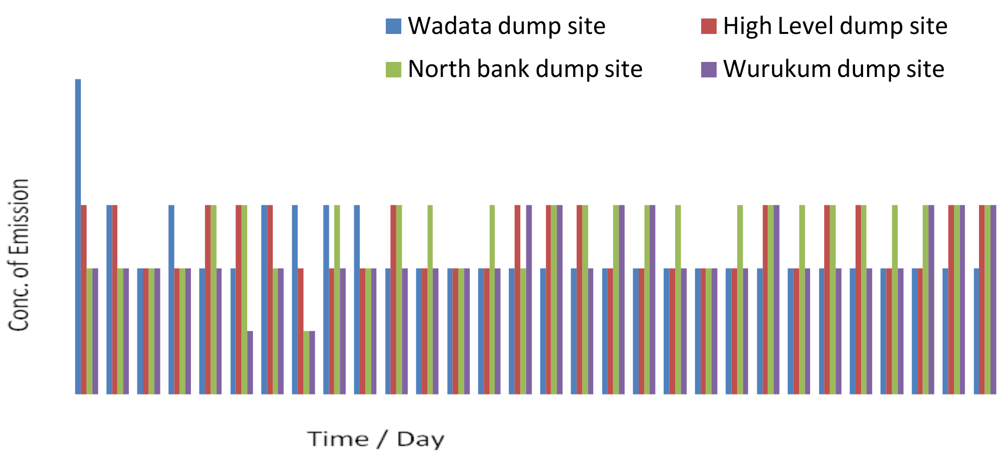

Figure 4. Conc. of Cl_2 in the selected dump sites

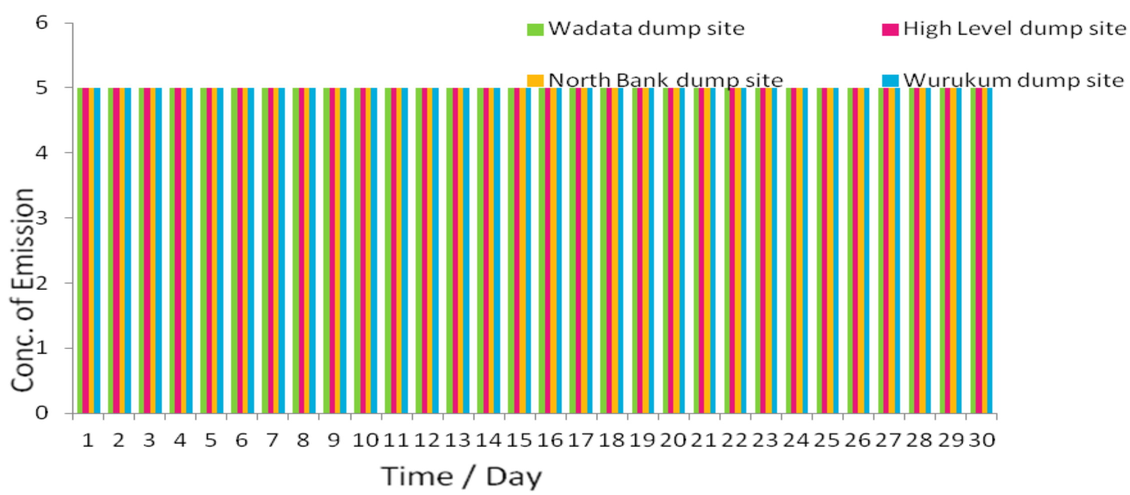

Figure5. Concentration of H_2S in selected dumpsites

5. Conclusion and recommendations

5.1. Conclusion

The study was centered on accessing the level of concentration of emitted gases from MSW dumpsite into Makurdi municipal environments. In order to achieve its objectives, the daily concentration of emission was monitored for 30 day in the month of April. Comparison between level concentration and daily average values of some meteorological factors was also carried out to verify their effect on the concentration of the emission. As a result of the comparison, it was noted that concentrations of emissions were location sensitive and meteorological factor do not do not influence their concentrations within period of investigation. The concentration of the emitted gas was staggered for the period of investigations from one dumpsite to the other. with H_2S, CO and HCl showing higher values. However, it is very important to note that air pollution induced by MSW has not exceeded the WID legal limit. In fact, process engineering of the gas cleaning systems can still be extended to lower emission limits if the environmental legislation so requires. It is only a question of overall cost of operation per ton of incoming waste to be handled. Some studies that analyzed in detail the health impact associated to the gaseous emissions of MSW have revealed that no relevant health problems may be associated to modern MSW dumpsites.

5.2. Recommendations

Dumpsites can be minimized or controlled. The following measures should therefore be implemented to curtail the menace of dumpsites in Makurdi municipal.In this research project the evaluation of the toxic gases was not exhaustive; it is therefore recommended that further study be carried out to determine the concentration of more number of toxic gases which are the major problem to health.That Government should provide/construct landfills for dumping of MSW to prevent hazardous emission to human health

Research institution should make available digital Equipment in Research laboratory that will facilitate the continuous monitoring of toxic gases on dumpsite.

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