An Assessment of Landfill Fires and Their Potential Health Effects- A Case Study of a Municipal Solid Waste Landfill in Lagos, Nigeria

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***Abstract*-Landfill fires are an ongoing, complex global concern as they pose a threat to the environment and human health through the hazardous chemical compounds they emit. They are usually caused deliberately or by spontaneous combustion of decomposing waste involving methane from landfill gas. They are prevalent in the dry season due to hotter temperatures in this period, when there is a greater chance of spontaneous combustion occurring. The danger and level of toxicity of the pollutants emitted depend on the length of exposure to them and the type of material that is burning. The risk posed by these fires is high in Nigeria where landfills are located within residential quarters, lack collection systems for landfill gas and harbour large volume of waste tyres. Of particular health concern are the tyre fires on these fills which burn for a long time allowing the build up of the by-products of combustion around surrounding homes. Burning tyres are known to emit dioxins and benzene derivatives which have been linked with reproductive impairment and cancer in humans. It is therefore necessary to study these fires and their potential effects on human health. Effective landfill management by the operators is necessary to prevent the occurrence of these harmful fires. This paper attempts to give some insight into landfill fires and their potential health effects using an unsanitary landfill in Lagos, Nigeria as a case study. It calls for the need to construct and operate well-engineered municipal solid waste landfills that are regulated under strict federal and state regulations to ensure the protection of human health and the environment.**

Keywords-landfill fires, spontaneous combustion, waste tyres, tyre fires, hazardous, dioxins, methane, health effects

I. INTRODUCTION

Landfill fires are an ongoing, global environmental and health concern. The environment is threatened by these fires through toxic pollutants emitted into the air, water, and soil. They also pose a risk to firefighters and civilians who are exposed to the hazardous chemical compounds they emit. The degree of risk depends in part on the contents buried in the landfill, the geography of the landfill, and the nature of the fire [1]. Municipal solid waste (MSW) generated in both developed and developing countries contains a greater percentage of organic materials (Table 1), although the organic portion is higher in the latter ([2], [3]). Because of the methods normally adopted to deposit, compact, and cover waste in landfills, the bacterial decomposition of organic waste is largely anaerobic, which results in the production of large quantities of methane and carbon dioxide [1].

Methane is highly flammable and plays a large role in the ignition of landfill fires. Landfills are the largest source of methane emissions in the United States, accounting for 35 percent of methane emissions in 1999 [4]. MSW landfills generate about 93 percent of U.S. landfill emissions; industrial landfills account for the remaining emissions [5]. Methane emissions from landfills are affected by site-specific factors such as waste composition, available moisture, and landfill size [4]. Methane makes up about 40-60% of landfill gas, carbon dioxide accounts for about the same amount, and the remainder is composed of nitrogen, oxygen, hydrogen, ammonia, sulphides and other gases [6].

The risk posed by landfill fires is very high in Nigeria, where the landfills are non-engineered and usually sited close to residential quarters. The absence of a gas collection system at these sites is an indication that the methane produced from the anaerobic bacterial degradation of organic waste is dispersed freely into the environment. This allows the uncontrolled migration of the gas, enabling it pose fire and explosion hazards.

In addition, due to lapses in the implementation and enforcement of environmental regulations governing landfill management practices in the country, these landfills receive numerous scrap tyres which usually fuel and contribute to the intensity of these fires. This is of prime health concern, thus, there is need for proper understanding of landfill fires and their potential health effects. This paper attempts to investigate fires on a MSW landfill located in the Lagos metropolis and their potential health effects.

II. DESCRIPTION OF THE STUDY AREA

A. Climate

The climate of Lagos, including that of the study area is tropical with an annual rainfall of approximately 1408 mm (57.7 inches). Eighty percent of the annual rainfall (1160 mm) falls during the south west monsoon, (April-October) and the remaining twenty percent (250 mm) falls during the northeast monsoon (November-March). The air is very humid throughout the year, with monthly average temperatures ranging from 28°C in July/ August to 32°C in February/ March [18].

B. Waste Disposal Practices

The landfill is located at the extreme east-west area of metropolitan Lagos, operated by Lagos Waste Management Authority (LAWMA) and referred to as Soluos (ll), [19]. The site spreads over an area of 7.8 hectares with an average life span of 5 years. The site is a non-engineered open pit located within the town and bordered by residential houses (Fig. 1). The landfill started operation in 2008 and on an average about 2,250 m^3/ day of waste is dumped on the site with the waste filling heights varying from 12-15 m. The wastes dumped on this site are largely from domestic and commercial sources. Large quantities of waste tyres are also disposed of at this site

(Fig. 2). Waste brought here by PSP (Private Sector Partnership) collection trucks from different parts of the city are dumped haphazardly and segregated by the waste pickers. Compaction of waste occurs occasionally to create space in the fill.

TABLE I MUNICIPAL SOLID WASTE CHARACTERIZATION IN LAGOS AND UNITED STATES OF AMERICA

Components of MSW (%)	Composition in Lagos (2004-2006)[a]	Composition in USA (2007)[b]
Putrescible waste (includes food scraps, animal wastes, and vegetables	68.16	12.5
Garden waste	4.2	13.4
Paper	12.46	32.7
Plastic	3.64	12.1
Glass	1.78	5.3
Metal	2.08	8.2
Others	7.68	7.6

Sources: Adapted from [2][a]; [3][b]

III. CHARACTERISTICS OF FIRES ON LANDFILL SITE

A. Surface Fires

The site is characterized by surface fires (Fig. 3) which is a type of landfill fires that involve recently buried or uncompacted refuse situated on or close to the landfill surface in the aerobic decomposition layer, generally 1 to 4 feet in depth [7]. These fires can be intensified by methane which may cause the fire to spread throughout the landfill. Surface fires generally burn at relatively low temperatures and are characterized by the emission of dense white smoke and the products of incomplete combustion. The smoke includes irritating agents, such as organic acids and other compounds [1]. When surface fires burn materials such as tires or plastics, the temperature in the burning zone can be quite high. Higher temperature fires can cause the breakdown of volatile compounds, which emit dense black smoke [7].

Surface fires on the study site are commonly caused by the spontaneous combustion of materials in the fill as well as deliberate fires, which are used by the waste pickers on the site in search of recyclables in the disposed scrap tyres. They set the tyres on fire to recover steel wires embedded in them.

According to United States Fire Administration (USFA) [1], spontaneous combustion occurs when there is an increase in the oxygen content of the landfill, which increases bacterial activity and raises temperatures (aerobic decomposition). These so-called “hot spots” can come into contact with pockets of methane gas and result in a fire. It can also result from the ignition of certain chemicals or materials when exposed to one another. In addition some materials such as oily rags can spontaneously combust under certain conditions [1].

The landfill is in its methanogenic phase and fires are more prevalent on the site in the dry season (November-March) [19]. This is likely due to the hotter temperatures in these months, when there is a greater chance of spontaneous combustion and hot, smouldering discarded products igniting in the landfill [8].

Fig. 1 A view of Soluos landfill with surrounding houses, 2011

Fig. 2 Waste tyres in abundance at the landfill site, 2009

Fig. 3 Surface fire on landfill site, 2009

B. Tyre Fires

A tyre fire is a slow-burning fire that occasionally occurs at dumps where tyres are being stored and is a specific form of surface fire that occurs on Soluos landfill. Waste tyres are stockpiled in dumps and landfills throughout Lagos. When ignited, these tyres burn with a higher per-pound heat output than most coal; they also produce large amounts of oil and smoke, which can cause serious air and water contamination [13].

According to California Integrated Waste Management Board (CIWMB) [9], tyres are composed of natural rubber from rubber trees, synthetic rubber made from petrochemical feedstocks, carbon black, extender oils, steel wire, up to 17 heavy metals, other petrochemicals and chlorine. A coal and tyre chlorine content comparison showed that tyres may contain as much as 2 to 5 times the chlorine level of western coal. The coal averaged a chlorine weight of 0.04 percent and tyres showed a weight range of 0.07 to 0.2 percent [9].

Tyre fire releases a dark, thick smoke that contains carbon monoxide, sulphur dioxide and products of butadiene and styrene [10]. Further, tyre fires can be extremely difficult to contain and extinguish and therefore burn and smoulder for a long period of time. Even after they are extinguished, tyre fires can flare up again weeks, even months later. This can cause a build up of the by-products of combustion in confined areas such as landfill site buildings or surrounding homes, which adds an additional health hazard [1].

IV. HEALTH EFFECTS OF LANDFILL FIRES

In addition to the burn and explosion hazards posed by landfill fires, smoke and other by-products of landfill fires also present a health risk to those exposed to them. Smoke from landfill fires generally contains particulate matter (the products of incomplete combustion of the fuel source), which can aggravate pre-existing pulmonary conditions or cause respiratory distress [1]. As with all fires, those in landfills produce toxic smoke and gases which can result in headache, nausea, and fatigue due to lack of proper sleep in exposed residents. The danger and level of toxicity of these gases depend on the length of exposure one has to them and on the type of material that is burning [1].

Underground or tyre fires can result in CO levels in excess of 50,000 ppm. The Occupational Safety and Health Administration (OSHA) permissible exposure limit for CO is 50 ppm. OSHA standards prohibit worker exposure to more than 50 parts of the gas per million parts of air averaged during an 8-hour time period. Carbon monoxide is harmful when breathed because it displaces oxygen in the blood and deprives the heart, brain, and other vital organs of oxygen, which can cause permanent damage or death, a condition known as anoxemia [11].

Another serious concern in landfill fires is the emission of dioxins. The term *dioxins* refer to a group of environmentally persistent chemical compounds with similar chemical and biological characteristics that are released into the air during the combustion process [12]. Burning of chlorine and chlorinated compounds creates dioxins [9]. The burning of tyres at low temperatures produces dioxins and furans [13]. These toxins biomagnify, which means that as dioxins move up the food chain, their concentrations are repeatedly multiplied. Exposure to high levels of dioxins has been linked to cancer, liver damage, skin rashes, and reproductive and developmental disorders [12].

The United State Environmental Protection Agency, EPA's 2004 draft review of dioxin reassessment concluded that there is no safe level of exposure to dioxin ; even at extremely low levels a wide range of serious health effects are possible, including reproductive impairment, developmental injuries, and increased risk of diabetes [14]. The styrene and butadiene (benzene derivatives) released by burning tyres are suspected human carcinogens and the latter has been linked with leukaemia in humans [15].

Many of the toxic fumes produced have the capacity to cause a genetic mutation that can lead to cancer in future generations and it is believed that the uncontrolled burning of tyres is 8 times more likely to cause genetic mutation than the burning of plastic [16]. Children can be at much greater risk. Because of their body size, they inhale more air per pound of body mass than do adults, and can absorb a proportionately larger dose of toxins. Also, children's bodies are more susceptible to damage from the lead, cadmium and other heavy metals found in tyre smoke because their nervous systems are not fully developed [17].

V. CASE STUDIES

The following surface fire incidents were observed and investigated on Soluos Landfill in Igando New Town, Lagos. Pictures were taken and the operators and rag pickers at the site were also interviewed.

A. Fire Incident in 2009

A large plume of black smoke was seen emanating from a part of the site on the evening of March 22, 2009 (Fig. 4). The surface fire which was caused by spontaneous combustion of decomposing waste was escalated after spreading to piles of nearby tyres which were in abundance on the site. Smoke from the fire drifted to surrounding homes in the direction of the prevailing wind, thus posing serious health risk to the residents. The fire was intensified and had spread to other areas of the landfill by the morning of March 23, 2009 (Fig. 5) which can be attributed to methane. The smoke from the smouldering fire caused haziness posing a significant risk to the commuters. The fire burnt itself out after some days, smouldering for weeks.

Fig. 4 Dense black smoke from tyre fire drifting to nearby residences, 22-03-2009

Fig. 5 Fire spreading to other parts of the fill, 23-03-2009

Fig. 6 Dark thick smoke from tyre fire caused by waste pickers on the site, 31-07-2011

Fig. 7 Tyre fire emitting dense black smoke signifying the breakdown of volatile organic compounds, 31-07-2011

B. Fire Incident in 2011

On the afternoon of July 31, 2011, a couple of deliberate uncontrolled tyre fires (Fig. 6-7) were started by waste pickers at the site in an effort to recover steel wires embedded in the waste tyres. The fire got out of control and the temperature in the burning zone was very high, restricting passers-by. The fires burnt continuously emitting dense dark smoke which spread and built up around surrounding homes. The fire was left to burn itself out and smouldered for a week.

VI. RECOMMENDATIONS AND CONCLUSION

Fire incidents on landfills and dumps in Nigeria, especially those involving burning tyres will continue to pose a serious risk to the health of nearby residents through prolonged or repeated exposure to the toxic chemicals they emit and the contamination of groundwater. Some of the hazardous chemical compounds emitted by burning tyres are capable of causing severe health conditions such as reproductive and developmental disorders, and cancers in humans. Effective landfill management by the operators is therefore necessary to prevent the occurrence of these fires in order to protect the environment and human health.

The disposal of waste tyres should be prohibited at all landfills by thoroughly inspecting and controlling incoming waste. Buried waste should also be compacted on a regular basis to prevent hot spots from forming. Since methane is highly flammable and can pose a fire hazard, gas collection and control systems should be installed at the sites to collect landfill gas which can be flared to convert methane to gases less harmful to the environment or converted to energy. This paper examines the potential health effects of landfill fires in Nigeria and therefore calls for the need to improve on waste management practices and construct well engineered sanitary landfills to ensure the protection of human health and the environment.

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