International Journal of Advance Research, IJOAR .org
Volume 2, Issue 4, April 2014, Online: ISSN 2320-9186

The impact of crude solid waste disposal on the Air-shed conditions of Mwakirunge-Kisauni, Mombasa County, Kenya

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Abstract

This paper presents the effects of crude disposal of solid waste on the air-shed conditions of the Mwakirunge dump site. The dumpsite is located within the air route for aircrafts approaching the Moi International Airport. Crude solid waste disposal has resulted in interference of the air-shed conditions through trucking on gravel and dirt road, and from tipping of the waste, introducing dust particulates into the air; obnoxious odour from decomposing organic matter through emission of hydrogen sulphide and ammonia; emission of smoke and fly-ash, including sulphur dioxide, and polycyclic aromatic hydrocarbons production from both self-starting fires and fires started by scavengers in search of valuables. Wind action has promoted not only the dispersion of toxic contaminants, but also liter –mostly plastics and paper into the neighbourhood. Important air pollutants of concern include suspended particulate matter and hydrogen sulphide. High concentrations of suspended particulate matter, especially if contaminated with toxic heavy metals and Poly Aromatic Hydrocarbons (PAHs) can cause an increase in incidences of respiratory diseases in the population. PAHs such as Benzo [a] pyrene and their photochemical products are known carcinogens, whereas hydrogen sulphide is toxic to mammals. The conditions of solar radiation and wind speed indicate extremely unstable to slightly unstable atmospheric conditions, predominating during daytime. These conditions are significant because they encourage vertical transport and diffusion of airborne pollutants (Gupta 1992). Relatively calmer winds make night atmospheric conditions quite stable, resulting in delayed transport and dispersal of emissions, causing localized air pollution. The stable atmospheric conditions, high relative humidity and increased particulate matter could also result in smog formation, and lowering visibility; occurrences that could be potentially hazardous to public health, crops, farm animals and low flying aircraft. However, for proper assessment and evaluation of risk on human health and on the environment from the dumpsite activities, an inventory of the parameters of concern over a long period needs to be developed.

Key words: crude solid waste disposal, contaminant dispersal, air pollution, health hazards, danger to aircrafts

1 Background

The Mombasa County covers a surface area of about 282 square kilometers, of which 65 square kilometers, is open water. Close to 1,400,000 people live in the County, who according to the 2009 National Housing and Population Census were distributed in its five districts' as follows: Mombasa and Kilindini districts within the Island 523,183, Kisauni District 405,930, Changamwe District 282,279 and Likoni District 176,426. The Island is the most densely populated. However, the growth of population is now northwards, with the population in Kisauni District, growing at the fastest rate (Mwaguni, 2009). Mombasa town is the administrative, commercial, political, industrial and a major tourist attraction center. The town has attracted a significant number of people from rural areas in search of employment and other opportunities. As a result of and natural population growth, the annual population growth rate of the Mombasa County, which stands at 4.1%, is higher than the national average, of 2.5% (Mwaguni, 2009). As the rapid population growth is not matched with infrastructural development to deliver services, the town and its environs faces a number of environmental problems from domestic, industrial and commercial wastes –both solid and liquid. This situation is compounded by the lack of integrated planning and management and lack of equipment for personnel to deliver services and address the waste problem. The subject of interest in this study is however, restricted to solid waste, which is thus dealt with in more detail.

The volume of solid waste produced in Mombasa in the year 2000 when the resident population was about 700,000 people was about 600 tons/day. Fourteen years later, when the population has doubled and consumer the lifestyles more wasteful, the volume of solid waste generated, should have more than doubled to an estimated volume of more than 1,200 metric tonnes per day. The waste originates from various sources including industries, commercial establishments, offices, residential homes, learning institutions, hotels, hospitals etc. About one third of that waste was collected and disposed of at the Kibarani- dumpsite –the official dumpsite adjacent to the busy Mombasa Nairobi highway. At the dumped site was to be found a mixture of degradable and non-degradable waste as well as industrial waste of unknown composition. The waste disposal method is crude dumping without the options for incineration, recycling, or composting. Being close to a major highway and the gateway to Mombasa and on the edge of the sea, the dumpsite became a nuisance and a major point source of pollution to the marine environment. As Kenya's economy is supported significantly from tourism as a business, a decision to remove this eye sore was made by the Minister for Local Government and the exercise of relocating the land-fill fell in the shoulders of the default Mombasa Municipal Council. The Council identified Mwakirunge in Kisauni District as the appropriate candidate site and waste disposal at Kibarani was reduced considerably, but did not cease completely. Since the County government of Mombasa took over the running of affairs, waste collection has improved greatly, and it can be estimated that slightly more than 50% of the waste generated is now collected. Disposal mechanisms however, remain crude at the Mwakirunge land fill.

1.1 Objective of the Study

This study had three objectives:1) generate baseline information on the air shed conditions of the Mwakirunge area prior to the solid waste dumping exercise, 2) predict the possible air-shed conditions resulting from the impacts of the crude waste disposal method to enable assessment of emerging situation, and 3) suggest mitigation measures to address the situation.

1.2 Site description and the Proposed Solid Waste disposal practice

The Mwakirunge refuse tip site is situated along the Zakhem Road 13 kilometers away from the Nyali Bridge and some 17 kilometers from Mombasa's Central Business District. The Zakhem Road, which was a mere earth road has since been tarmacked all the way to the Mwakirunge tipping site. The National Electric power grid passes through the site, and so is the Baricho water pipeline, supplying drinking water to the residents. The site is on P.D.P. No. 12.5 CT 11.93 (sketch attached) and covers approximately of 50 acres. Planned next to the tipping ground was a large housing scheme, separated by"Afforestation - Barrier". At the time of conception of the idea, a sanitary waste disposal landfill was envisaged. There was only a cluster of seven or so squatter settlements on the ground, residing in temporary dwellings, but the situation is now very different as a result of the many squatters who have made the place their abode. Away from the site are the settlements of Nguu Tatu, Marimani, Mwakirunge, Maunguja, Mishomoroni etc, spread out across the plain.

As the waste disposal was to be sanitary, the site was designed to accommodate a new landfill capable of handling the municipal waste beyond the year 2030. The possibility for waste recycling before disposal became a business idea with a profit motive. The idea, it was thought would generate revenue to sustain the waste disposal activity that would contribute to the social welfare of the neighbouring population. Households and other establishments were to put their solid waste in properly secured bags and deposit them in waste bins at designated sites, ready for collection and sorting at the dumpsite. Design attributes foresaw incorporation of features, which allowed for the prospects of methane gas recovery from putrifiable matter. The waste management facility at Mwakirunge included features such as technical assistance to support for sanitary landfill activities; development and application of environmentally acceptable waste management schemes; application of appropriate technologies for waste re-use, recycling and alternative utilization; monitoring for proper operations and maintenance of landfill facilities; enforcement of good practices in hazardous waste management; control of leachates, and providing training for capacity building to improve on waste management practices. Before this vision could be realized, insatiable demand for an alternative waste disposal site over-rid the patience to wait for a sanitary landfill, so crude waste dumping rather than sanitary waste disposal started at Mwakirunge.

2 Methodology

The methods used to generate information on the air-shed condition of Mwakirunge included a field visit to the site to appraise the areas biophysical environmental conditions; a desk top study to obtain documented information, and one-on-one discussions with experts clear matters on grey literature. The information of interest to this study was general climatic type, humidity and its seasonal variations, prevailing wind direction, intensity, turbulence and stagnation; air quality, suspended particles –sources and types, and visibility; wind hazard from dispersal of litter and non-degradable plastic materials; air-shed importance including proximity of aircraft landing approach route and take-off and visibility; and bird hazards.

3 Prevailing Environmental Conditions

3.1 General Climatic Type

The climate in Mombasa is influenced by the blowing of the monsoon winds. The shifting of the monsoons results in two rainy and two relatively dry seasons. The N.E. Monsoon season (November - March) is usually the warmest period of the year. The S.E. Monsoon season occurs from April to September. The long rains fall during the shifting of the monsoons between late March and May, followed by a relatively cooler dry period that lasts until November. The short rains occur during the shifting of the S.E. to N.E. Monsoons between October and November, culminating in the dry warm period.

3.2 Rainfall

The long rains occur between late March and early June, peaking in May. After June the rain decreases until October/November when the short rains produce another peak. The total annual rainfall in Mombasa normally ranges between 1000 and 1200 mm, with about 40 % occurring during the long rains (GOK 1975, NES 1985), and the minimum precipitation experienced between January and February. Presented in table 1 and figure 1 is the average rainfall distribution from 1989 to 1999.

3.3 Temperature

In the 1989 - 1999 period the mean maximum temperature varied from 27.5 °C in August to 32.8 °C in February. Mean minimum temperature ranged from 19.5 °C in July/August) to 22.9 °C in February (table 1, figure 1). The coolest period was during the S.E. Monsoon season, with the warmest period was during the N.E. Monsoon season.

3.4 Humidity

The relative humidity showed seasonal variations with about the lowest humidity experienced during the warm period of January to March, and the highest during the relatively cool and wet season of May to July. There is a markedly diurnal variation in the relative humidity with the highest humidity, occurring at night and early morning and the lowest occurring in the afternoon (GOK 1975). The yearly mean relative humidity at 09:00 hrs ranged from 75 to 86 % (overall mean 81 ± 3 %), and at 15:00 hrs, 59 to 72 % (overall mean 66 ± 4 %) (Figure 1)

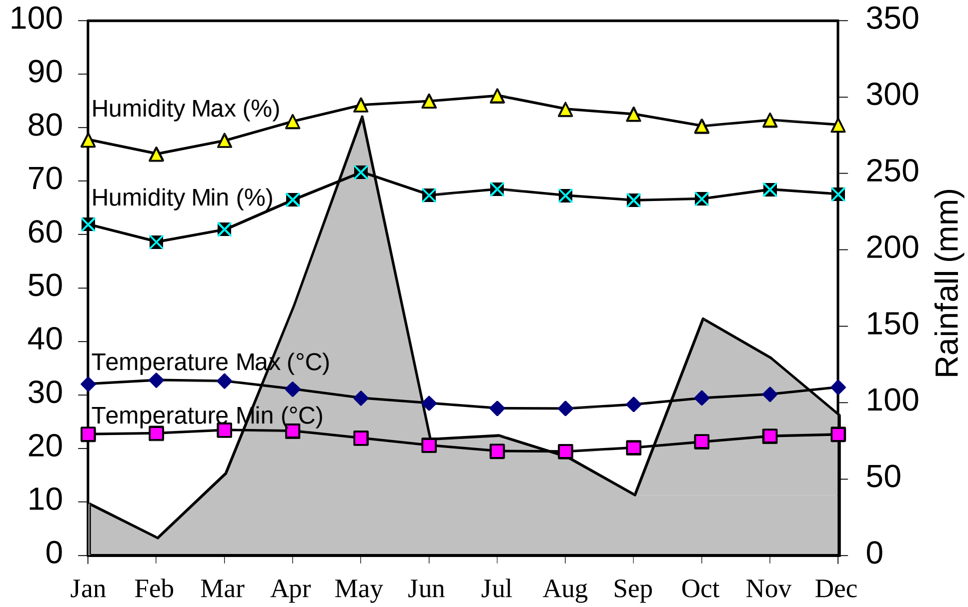

Figure 1: Temperature, relative humidity and rainfall averages for Mombasa

3.5 Solar Radiation

The average daily solar radiation reflected the seasonally varying cloud cover, with the minimum radiation received during the relatively wet period of May to July. Thus the average radiation ranged from a mean of 17.57 MJ m^{-2} for the months of May - July to 21.57 MJ m^{-2} for the rest of the year (table 2).

Table 2: Average solar radiation and wind direction and speed
(Source: Kenya Meteorological Department, Moi International Airport, Mombasa)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Radiation	(MJ m^{-2})	21.86	22.61	22.71	20.55	17.72	17.87	17.11	19.28	22.02	22.72	21.95	20.47
Winds 0900 hrs	Direction	202	208	141	204	199	212	215	201	188	166	121	205
	Speed (knots)	6	6	5	7	8	9	8	8	7	6	4	6
Winds 1500 hrs	Direction	91	105	114	165	182	181	178	168	155	152	135	107
	Speed (knots)	11	12	11	10	10	11	11	10	10	11	10	10

3.6 Winds

The surface wind regime in the Mombasa coastal area is dominated by the monsoon winds and greatly influenced by the land-sea breeze. Presented in table 2 are the average wind speeds and direction for the area. The daily pattern shows a drop in the wind strength at night, which gradually picks-up during the afternoon. The overall average wind speed was 6.7 and 10.6 knots at 0900 hrs and 1500 hrs, respectively. GOK (1975) reported low wind speed blowing with variable direction at night. The winds of the S.E. Monsoon are relatively stronger and less influenced by the land-sea breeze (table 2, GOK 1975). This is clearly shown by the wind direction from May to June, which is predominantly south to southeasterly as compared to December to February which has a strong westerly to northwesterly component.

3.7 Air Quality

Mwakirunge is a low population-density rural area. Potential sources of air pollution to the area include the gravel and dirt road that is a source of mainly dust particulate matter and occasional bushfires which are a source of smoke, fly-ash and other particulates. The Bamburi Cement manufacturing company operates open stone quarries in the neighbourhood of the proposed dumping site. An indication of the contribution of the sparse road traffic and stone quarrying to air pollution in the area is presented in table 3.

Table 3: Engine exhaust emissions and fugitive dust
(Source of emission factors WHO, 1989)

Source	Unit	TSP t/unit	SO_2 t/unit	NO_x t/unit	CO t/unit	VOC* t/unit
Light transport:						
Petrol engine	1000 km	0.11	0.05†	1.4	3.2	1.7
Fugitive dust:						
Open quarry						
Blasting	tn	0.08				
Primary crushing	tn	1.25				
Transport						
6 wheeler truck	1000 km	685				
4 wheeler truck	1000 km	90				

* Volatile organic compounds
† Sulphur content of diesel about 0.4 % by weight (WHO 1989).

4 Analysis and Prediction of Environmental Impact Resulting from Operating the Dumping Ground

The presumption for the impact assessment is that the EIA is to be used as a planning tool to minimize adverse impacts caused by the implementation of the project. Thus, the overall aim of the EIA study is to help in the formulation of an environmental management plan to sustain mitigation efforts at the dumpsite. The assumed strategy is to optimize the pollution control costs against the pollution costs, such that the total cost of maintaining the air quality is minimized. An elaborate procedure for the impact assessment study would involve the development of an air-shed simulation model based on airborne concentrations of the pollutants, especially the type of contaminants that are subject to transformation processes, such as photochemical reactions (e.g. PAHs). However, due to the paucity of data on the prevailing local conditions at, and around the Mwakirunge dumping site, the assessment at this juncture aimed at the reduction of total primary emissions from the dumpsite.

4.1 Air Quality

The activities that contribute to the deterioration of air quality as a result of operating the Mwakirunge solid waste dumpsite include the following:

i) Trucking on gravel and dirt road which introduces dust particulates into the air
ii) The action of dumping and/or tipping contributes dust particulates into the immediate dumping area and neighbourhood
iii) Decomposition of organic matter, emit odour due to the production of hydrogen sulphide and ammonia
iv) Uncontrolled fires emit smoke and flyash and may include carbon monoxide, sulphur dioxide and polycyclic aromatic hydrocarbons (PAHs)
v) Wind action would not only disperse toxic contaminants but also litter, most of it being plastic materials and paper into the neighbourhood

High concentrations of suspended particulate matter, such as fly-ash, especially if contaminated with toxic heavy metals and PAHs can cause an increase in incidences of respiratory diseases in the population. In addition some PAHs such as Benzo [a] pyrene and their photochemical products are known carcinogens, whereas hydrogen sulphide is toxic to mammals and produces a strong unpleasant odour. Presented in table 4 are some of the extremely hazardous substances and their levels of concern.

Table 4: Extremely hazardous substances produced in large quantities and their level of concern in the air (Graber 1992)

Substance name	Level of Concern (mg m^{-3})
Hydrogen sulphide	42
Sulphur dioxide	26

An estimate of the envisaged contribution of trucking to the dumping ground to air pollution is shown in table 5.

Table 5: Predicted daily contribution of trucking to air pollution along the access road and the Dumpsite

Source	Approximate Distance (km)	Particulates	Pollutants (kg/day) SO_2	NO_x	CO	VOC*
Exhaust emissions (heavy duty diesel-powered trucks > 3.5 tons)	1000	5.4	1.56	16.0	15	11.0
Fugitive dust from† gravel road	1000	1024				

* volatile organic compounds
† quantity in tonnes/day.

In the table above, the existing number of refuse carrying vehicles is 16, and the present rate of refuse collection and disposal at Mwakirunge is about 200 tons/day. However, considering the projected total refuse production of 1,200 tons/day in the Mombasa Island and the Nyali/Bamburi/ Shanzu area, the estimated emissions are expected to increase 6 fold.

Therefore, important air pollutants of concern include suspended particulate matter, which is composed of smoke and fly-ash, and potentially associated with toxic heavy metals and PAHs, and hydrogen sulphide. However, for proper risk assessment and evaluation of the impact of the contaminants on the environment, an inventory over a long period needs to be developed.

4.2 Atmospheric Stability and Pollutant Transport

The atmospheric stability is used to qualitatively describe the condition of the atmosphere that governs vertical motion of an air parcel, and thus directly influences pollutant transport and diffusion. The stability of the atmosphere can be categorized according to the wind strength and solar radiation and wind strength; class A is an extremely unstable condition which results in positive vertical acceleration, class D is neutral and class F is moderately stable characterized by negative vertical acceleration (WHO 1989). The broad classes of atmospheric stability or instability with the corresponding wind strength and solar radiation is presented in table 6.

Table 6: Atmospheric stability classes* with wind strength and solar radiation

Surface Wind Speed (at 10 m) knots	Day Incoming solar radiation			Night	
	Strong	Moderate	Slight	>4/8 Low cloud	Thinly overcast or <3/8 Cloud
< 3.9	A	A – B	B		
2.9 – 5.8	A – B	B	C	E	F
5.8 – 9.7	B	B – C	C	D	E
9.7 – 11.7	C	C – D	D	D	D
> 11.7	C	D	D	D	D

* A – Extremely unstable, B – moderately unstable, C – slightly unstable, D – neutral, E – slightly stable, F – moderately stable (WHO, 1989).

The solar radiation in the Mombasa area may be qualitatively described as strong to moderate (solar altitude 35 – 60° with clear skies) during a better of the day and slight (solar altitude 15 – 35° with clear skies) during the early part of the day and late afternoon. In addition the average daily radiation varies according to the season, with the minimum occurring during the relatively more overcast S.E Monsoon season (17.11 – 17.72 MJ m^{-2}) (Table 6). On average the wind speed ranges from a low of 4 knots at 09:00 hrs to a high of 12 knots at 15:00 hrs. These conditions of solar radiation and wind speed indicate class A to C stability or extremely unstable to slightly unstable atmospheric conditions predominate during daytime. These conditions are significant because they encourage vertical transport and diffusion of airborne pollutants (Gupta 1992). However during nighttime, with relatively calmer winds the atmospheric conditions are quite stable. These conditions have implications of delayed transport and dispersal of emissions, which may result in localised air pollution. Under such stable atmospheric conditions and the usually high relative humidity (maximum 75 – 86%) and particulate matter emissions from incinerators or open fires at the dumpsite could result in smog formation and lowering of visibility. Such occurrences could be potentially hazardous to public health in the neighbourhood, crops, farm animals and low flying aircraft.

The strong winds (4 – 12 knots) usually experienced in the area are capable of dispersing litter and particularly the ubiquitous non-degradable plastic materials beyond the designated dumpsite boundaries and may be aesthetically unacceptable and may even be hazardous to animals.

4.3 Air-shed Importance

The Mwakirunge dumpsite is located within the air-route for aircraft approaching the Moi International airport for landing. The aircraft are normally at 1,200 ft altitude above the dumpsite (Kitao per. comm.). Stable atmospheric conditions, high relative humidity and high particulate emissions encourage smog formation. In an extreme case, such a situation could lower visibility sufficiently to become a potential hazard to aircrafts.

Increasing populations of carrion birds at the dumpsite are a source of potential hazard to low flying aircraft. The most common birds, the Indian crow spend most of their time on or near the ground foraging, except when retreating to their nesting grounds.

5 Conclusions

In conclusion, the study has found that the crude disposal of solid waste at Mwakirunge is resulting in degradation of environment quality of the area with effect on aesthetic value. The activity has impact on air quality with potential effects on heath of both humans and animals. It also has the potential to introduce smog, causing lowered visibility in the air-route flight path, which in addition to the bird hazard problem identified, could be dangerous for planes that fly low as they approach landing.

6 Recommendations

The environmental measures outlined below have the primary objective of minimizing emissions or the introduction of contaminants into the air. These include:

i) The development of a green belt around the dumpsite to serve as a wind breaker that reduces the effects of strong winds, controlling the dispersal of odour, particulate matter and litter into the neighbourhood. The green belt could also provide perching and nesting grounds for the high population of foraging birds, thereby localizing their movements.

ii) Controlled dumping of solid waste can go a long way towards minimizing emissions into the air. It is important that hazardous wastes, especially waste originating from industries, are treated separately for proper disposal.

iii) Open uncontrolled fires should be avoided to minimize emissions of smoke, and other hazardous particulate matter. While the disposal of hazardous solid wastes by incineration is a viable option, appropriate measures should be incorporated to control the emission of hazardous gaseous substances into the air.

iv) Tarmacking of the access road to the dumpsite has largely eliminated the contribution of refuse trucks to dust particulates emission in the air. However, the road maintenance efforts should be sustained.

v) The emission of sulphur dioxide, nitrogen oxides and PAHs with truck engine exhaust fumes is not a big issue as most of it is dispersed and diluted by the winds throughout the entire route to the dumping site, however, the emissions can be further minimized through proper engine servicing and the incorporation of catalytic converters.

Acknowledgement

The authors wish to thank Mr. Mohamed Abdalla Skanda, a retired Chief Public Health Officer, Municipal Council of Mombasa for obtaining the grant, which supported the study from the Council. Secondly, we would wish to thank the Coast Development Authority for providing the funds for secretarial services during the research.

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