

# Mwakirunge Dumpsite – A Simmering Disaster: An Environmental Impact Assessment

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## ABSTRACT

With particulate matter tripling the acceptable levels, prohibitive carbon monoxide, higher BOD and COD levels not to mention contamination by heavy metals - leaching to adjacent lands and moving through the food chains – you need not pester anyone to take action now and not later. A true situation of Mombasa's Mwakirunge Dumpsite.



## INTRODUCTION

Mwakirunge dumpsite is the main waste garbage dump for Mombasa County. It is found along the geographical coordinates of 3° 57' 0" South, 39° 40' 0" East. It is found in Kisauni constituency, about 12 Km North of Mombasa Central Business District and about 700 meters Southeast of Colorado Shopping Centre. Currently, it is the main dumpsite particularly after the closure of Kibarani dumpsite, which has since been transformed into a recreational park.

The area generally has a topography of a rugged landscape characterized by valleys and hills. Settlements are clustered and littered over the landscape with some commercial set ups several found meters away. It is located within the coastal strip which generally experiences more than 6 hours of sunshine daily exceeding 8 hours between October and March. The rainfall pattern is bimodal with rainfall averaging between 900-1300mm annually. The long rains come between April and July while the short rains are experienced between November and December.

In terms of inhabitants - there are around 500 people living within the site, majority of whom are women and children. The main source of livelihood for these people is scavenging through the garbage to find items of sale such as plastics, bottles, pieces of metal, clothes, utensils, paraphernalia, furniture etc. Equally, they also scavenge for food – mostly in the initial stages of spoilage and laced with molds or beginning to rot. There are also some temporary structures to act as houses against the scorching sun as well as the rains. Most of those houses are not waterproof and not strongly anchored on the ground. During rainy seasons they fall and further expose them to the vagaries of weather. The road network within the dumpsite is rather haphazard and becomes

extremely slippery and muddy during rainy seasons. The use of drugs especially bangi is rather common coupled with heavy drinking of the alcoholic drink 'Mnazi' – a local brew made from the coconut plums. It is perhaps reasonable to estimate that a good chunk of their income is spent on these two main items – mnazi and drugs. The place is littered with broken pieces of glass, myriad kind of chemicals and different kind of industrial waste of varied toxicity levels. When these enemies of nature are added to the suffocating fumes of poisonous gases and irritating soils, it qualifies as a true definition of hell, just here under our nose in Mombasa County.

Other than the life within the dumpsite, the neighborhood is a burst of life. In the Northern side lies the sprawling estate of Kiembeni – a town growing by leaps and bounds and moving fast towards the fringes of the dumpsite. On the Western side is the town of Colarado – beaming with new up-coming commercial cum residential houses – unfortunately covered by the irritating smoke coming from the dumpsite most of the times – due to the frequent flow of the wind from the North to the South. On the Western side, lies the farming villages like Mwakirunge and Marimani dotted with several schools and churches, typical Giriama villages of the coast. These areas (lying to the West) are equally affected by the effluents emanating from the dumpsite not to mention the spike in unexplained death rates (personal communication and certified by death records from local hospitals as well as death certificates attached) ostensibly arising from the pollution impacts of the dumpsite. On the Eastern side is the Indian Ocean – receiving the effluent flow.

### Scope of Assignment

A group of interested parties approached us to assist unearth the environmental consequences of the dumpsite, long seen as the epicenter of most of their ill health and loss of productivity. Upon acceptance of the task, we set to do this first; by identifying and engaging a National Environmental Management Authority (NEMA) certified laboratory to undertake samples and analyses of various parameters. We finally settled on Polucon Laboratory Services based in Mombasa. Second, we had to select parameters for analysis – these were then segregated into three, namely;

- a. Air quality parameters – which included Carbon Monoxide, Nitrogen Oxides, Particulate Matter, Sulphur Oxides, Hydrogen Sulphides
- b. Leachates – which involved elements that had percolated into the ground usually after the rains. These included pH values, Biochemical Oxygen Demand, Chemical Oxygen Demand, Lead, Copper as Cu, Chromium as Cr, Arsenic as As, Zinc as Zn, Nitrogen as N and Ammonia as NH<sub>4</sub>.
- c. Soils – and these were to involve analysis of Zinc as Zn, Mercury as Hg, Copper as Cu, Cadmium as Cd, Lead as Pb, Nickel as Ni, Chromium as Cr, Calorific value on Dry Matter Basis, Ash Content and Moisture Content

The findings of the analysis done on the various parameters constitutes the backbone of new presentations in this report and detailed in the subsequent pages.

### Adverse air pollution

The biggest challenge of the dumpsite is the ever rising volumes of poisonous gases – spreading far and wide the vicinity of the dumpsite (see fig. 1). This spread can go as far as 5km away from the dumpsite. Both the persons within the 5km radius of the dumpsite are at acute exposure to the toxic air pollutants emanating from the dumpsite. The health risks posed to humans can be through one or a combination of the following pathways;

- i) Breathing contaminated air
- ii) Drinking water contaminated by toxic air contaminants
- iii) Ingestion of contaminated soils – usually for young children during their playing sessions and the often putting their contaminated hands or play objects in their mouths
- iv) Making body contact with contaminated soil, dust or water

Other ways of pathways of the toxic chemicals into the human body are through;

- i) Eating contaminated foods and food products e.g. the fish from contaminated waters especially those

caught at the shores of the Indian Ocean visited by deposits of contaminated surface runoffs, feeding on meat, milk, eggs from animals that fed on contaminated plants, or fruits and vegetables grown in contaminated soils on which air toxics have been deposited



Fig. 1: the surface-ambient view of Mwakirunge during a normal day

### Determination of Ambient air quality within and around the Mwakirunge dumpsite

This is necessary in order to make a determination whether the dumpsite poses an existential threat to those living within and without the dumpsite – especially those living within the 5m radius from the epicenter of the dumpsite. A study was designed to:

- 1) to determine the ambient air quality measurements at 2 locations within the vicinity of the dumapsite and
- 2) to correllate the findings to the Environmental Management Coordination (Air Quality Regulations 2014)

### METHODOLOGY

Ambient air quality monitoring of test parameters was done for four hours at each of the selected two points. The two monitoring locations were selected methodologically to represent the conditions at receptor locations as a result of the dumpsite open burning activities. Both locations were positioned downwind in relation to the wind direction.

A short description of the monitoring positions is as shown in table 1 below:

Table 1: Description of the air quality monitoring sites

No	Site Name	GPS Coordinates	Description	On-going activities
1	Point 1	3°56'26.19"S 39°40'22.58"E	The location was situated South of the dumpsite, a few meters from the road connecting the dumpsite and Colorado shopping centre.	Burning of solid wastes at the heart of the dumpsite. Occasional dump truck movement
2	Point 2	3°56'21.40"S 39°40'22.05"E	The point was located West of the dumpsite, within the settlement area of the squatters nearby.	The site was characterized by occasional truck movement to and from the dumpsite.



It was important to take care of basic weather parameters, which are shown in table 2. Monitoring point selection was based on the size of the site and expected critical impact and operation areas maintaining at least 10 meters minimum radius between each measurement location.

Table 2: Weather characteristics of the sampling site on the sampling day

Date	Temperature	Humidity	Wind speed/Direction
03/11/2022	27°C	68%	13 km/h NE

Monitoring locations are shown in fig. 2 below:

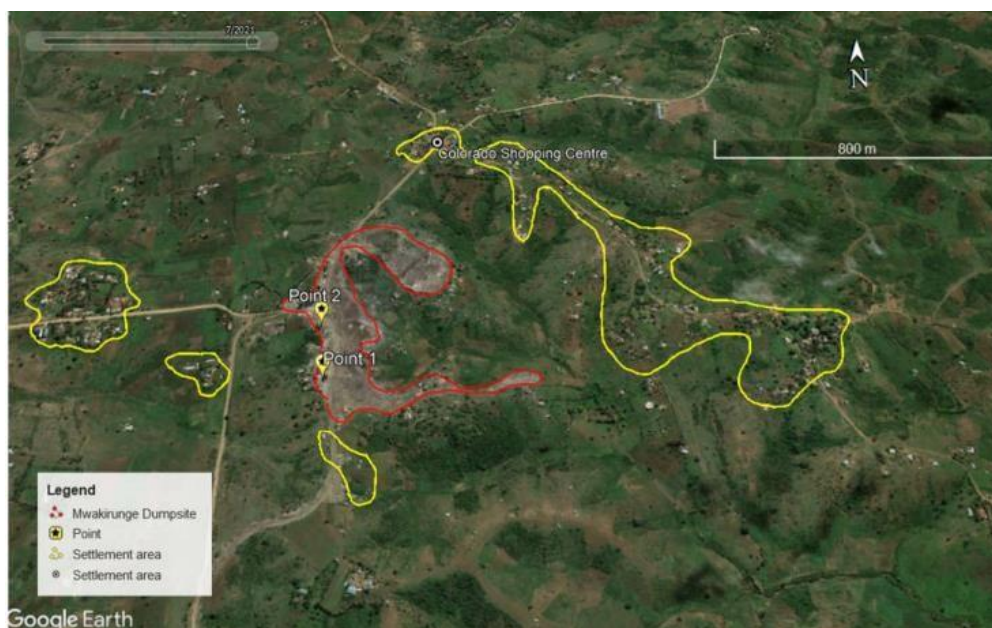


Fig. 2: Aerial photo of the monitoring sites of the Mwakirunge dumpsite

This study involved the sampling for the gaseous and particulate parameters. Ambient air quality monitoring was done by active monitoring methodology by use of a real time equipment (AQM Series). The AQM meter series, a state-of-the-art gas analyzer was used to measure the Particulate Matter (PM) and gaseous parameters levels using modern technologies (see figures 3 and 4 below).



Fig. 3: Sampling for Air Quality at Point 1



Fig. 4: Sampling for Air Quality at Point 2

Active sampling involved the use of an air sampling pump which actively pull air through a collection device such as a filter that much independent of wind speed. Dust sampler which use the laser particle sensors were used for monitoring particulate suspended matter. Air quality monitoring for gaseous and particulate parameters was done using the meter which was mounted about 1-2 meters above the ground surface.

### A brief description and rationale for the air quality parameters measured

#### 1) Nitrogen Oxides (NO<sub>x</sub>)

The oxides of nitrogen (NO<sub>x</sub>) comprise nitric oxide (NO) and Nitrogen Dioxide (NO<sub>2</sub>), which are gases produced from natural sources, motor vehicles and other fuel burning processes. Nitric oxide is colorless and is oxidized in the atmosphere to form nitrogen dioxide. Nitrogen dioxide has an odour and is an acidic and highly corrosive gas that can affect our health and environment. There are also natural sources of Nitrogen oxide gases which include volcanoes, oceans, biological decay, and lightning strikes

#### 2) Carbon Monoxide (CO)

Carbon monoxide is a colorless, odorless, tasteless gas produced by burning gasoline, wood, propane, charcoal, or other fuel. Combustion of fossil fuel such as diesel results in the emission of Carbon Monoxide as a byproduct of combustion. CO can also be generated from combustion of solid wastes in limited oxygen supply.

#### 3) Particulate Matter

Particulate matter refers to is small particles that are classified as PM<sub>10</sub>, PM<sub>2.5</sub> or PM<sub>0.1</sub> depending on their size. These particles have a diameter of less than 10 μm, 2.5 μm and 0.1

μm respectively; particles smaller than 0.1 μm are also called ultrafine particles (UFPs). There is a natural concentration of PM in the atmosphere that consists of marine salt or pollen, but it is enhanced by various human activities such as the burning of fuels or the handling of goods. The combustion of diesel and heavy fuel oil leads to a high amount of PM emissions. PM also develops when certain pollutants meet other substances. The smaller the particles, the worse the effect on human health. Inhalation of inhalable particulate matter pose a great health risk. These tiny particles get into the lungs and are small enough to pass through tissues and enter the blood stream. They can then trigger inflammations which eventually cause heart and lung failures. The World Health Organization estimates that long term exposure to PM<sub>2.5</sub> is associated with an increase in the risk of cardiopulmonary mortality by 6–13% per 10 μg/m<sup>3</sup> of PM<sub>2.5</sub>.



#### 4) Sulphur Dioxides

Sulphur dioxide is a colorless gas with a strong choking odor. It is produced from burning of fossil fuels and smelting of mineral ores such as copper, aluminum, zinc and lead. SO<sub>x</sub> (Oxides of Sulphur) consists of a family of different chemical compounds characterized by the presence of Sulphur and Oxygen. In nature, these emissions are typically produced by volcanoes. They have harmful effects on the human body, as they stimulate nasal and throat nerves causing respiratory problems especially in asthmatic individuals. Considered local and global pollutants at the same time, SO<sub>x</sub> emissions are dangerous to health because they can provoke respiratory problems; moreover, SO<sub>x</sub> gases can react with oxygen in presence of NO<sub>2</sub> resulting in sulfuric acid, which can eventually damage the environment through acid rains. SO<sub>x</sub> gases can raise the eutrophication potential and can also bring a cooling effect on the temperature and consequently to climate change.

#### 5) Hydrogen Sulphide

Hydrogen sulfide is a colorless gas with a rotten-egg odor. Most hydrogen sulfide in the air comes from natural sources. It is produced when bacteria break down plant and animal material, often in stagnant waters with low oxygen content such as bogs and swamps.

Volcanoes, hot springs and underwater thermal vents also release hydrogen sulfide. Industrial sources of hydrogen sulfide include petroleum and natural gas extraction and refining, pulp and paper manufacturing, rayon textile production, chemical manufacturing and waste disposal.

Most of the information on human health effects from hydrogen sulfide exposure comes from accidental and industrial exposures to high levels. Exposure to high levels can cause muscle cramps, low blood pressure, slow respiration and loss of consciousness. Short-term exposure to moderate amounts of hydrogen sulfide in the workplace produces eye, nose and throat irritation, nausea, dizziness, breathing difficulties, headaches and loss of appetite and sleep.

Continued exposure can irritate the respiratory passages and can lead to a buildup of fluid in the lungs

#### Acceptable air quality limits: The legislative guidelines by NEMA (2014)

The Kenya Air Quality Regulations 2014 impose limit values as detailed in the SPECIAL ISSUE Kenya Gazette Supplement No.41, Legislative Supplement No.15, Legal Notice No. 34, compliance with the objectives (prevention, control, and abatement of air pollution to ensure clean and healthy ambient air) is a legal requirement in Kenya. Statutory requirements relevant to this study FIRST SCHEDULE are detailed in Table below.

	Pollutant	Time weighted Average			
			Industrial area	Residential, Rural & Other area	Controlled areas***
1	Sulphur Oxides (SO <sub>x</sub> )	24 hours**	125 µg/m <sup>3</sup>	80 µg/m <sup>3</sup>	30 µg/m <sup>3</sup>
		Instant peak	-	500 µg/m <sup>3</sup>	-
2	Oxides of Nitrogen (NO <sub>x</sub> )	24 hours	150 µg/m <sup>3</sup>	80 µg/m <sup>3</sup>	30 µg/m <sup>3</sup>
3	Nitrogen Dioxide	24 hours	100 µg/m <sup>3</sup>	0.1 ppm	-
		Instant peak	-	0.5 ppm	-
4	Respirable particulate matter (<10 µg/m <sup>3</sup> ) (RPM)	24 hours**	150µg/Nm <sup>3</sup>	100µg/Nm <sup>3</sup>	75µg/Nm <sup>3</sup>
5	PM <sub>2.5</sub>	24 hours	75 µg/m <sup>3</sup>	-	-
6	Carbon monoxide / carbon dioxide	8 Hours	5 mg/m <sup>3</sup>	2.0 mg/m <sup>3</sup>	1.0 mg/m <sup>3</sup>
		1 Hour	10.0 mg/m <sup>3</sup>	4.0 mg/m <sup>3</sup>	2.0 mg/m <sup>3</sup>
7	Hydrogen Sulphide	24 hours**	150 µg/m <sup>3</sup>	-	-
8	Non-methane hydrocarbons	Instant peak	700 ppb	-	-
9	Total VOC	24 hours**	600 µg/m <sup>3</sup>	-	-
7	Ozone	8 hours	120 µg/m <sup>3</sup>	1.25 ppm	-

*Extract of the Ambient Air Quality (Tolerance Limits)*

**Source:** (Environment, Water and Natural Sources Ministry, 2014)

## FINDINGS OF AIR QUALITY

A summary of the air quality assessments of the two selected monitoring sites of Mwakirunge dumpsite are as shown below in table 3.

Parameter	Point 1	Point 2	EMC (Air Quality) regulations, 2014 for residential & other areas
PM2.5 ( $\mu\text{g}/\text{m}^3$ )	282.20	339.20	-
PM10 ( $\mu\text{g}/\text{m}^3$ )	301.20	405.20	100 $\mu\text{g}/\text{Nm}^3$
CO ( $\text{mg}/\text{m}^3$ )	3.216	3.274	2.0 $\text{mg}/\text{m}$
SO <sub>2</sub> ( $\mu\text{g}/\text{m}^3$ )	23.60	44.40	80 $\mu\text{g}/\text{m}^3$
H <sub>2</sub> S ( $\mu\text{g}/\text{m}^3$ )	0.033	0.039	-
NO <sub>2</sub> ( $\mu\text{g}/\text{m}^3$ )	0.062	0.077	0.5 ppm
Ozone ( $\mu\text{g}/\text{m}^3$ )	0.094	0.100	1.25 ppm
Temperature (°C)	29.30	26.78	-
Humidity (%)	63.02	72.04	-

### Graphical presentation of select parameters

The graphs below depict the results graphically in respect to the EMC (Air Quality) Regulations, 2014. Only PM10, CO have been displayed graphically since these are the two parameters that have surpassed the EMC air quality limits.

#### Particulate matter

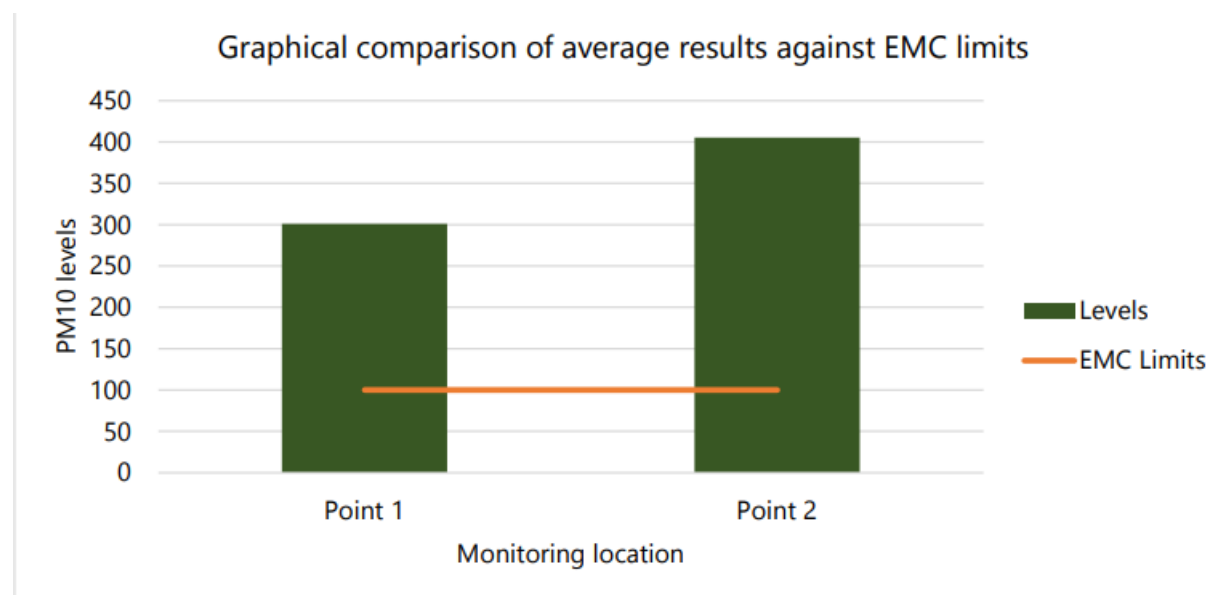


Fig. 2: Graphical comparison of Particulate Matter levels to EMC limits

As shown in figure two – the levels of particulate matter at the sampled sites **are more than triple the acceptable limits.**

### Carbon Monoxide

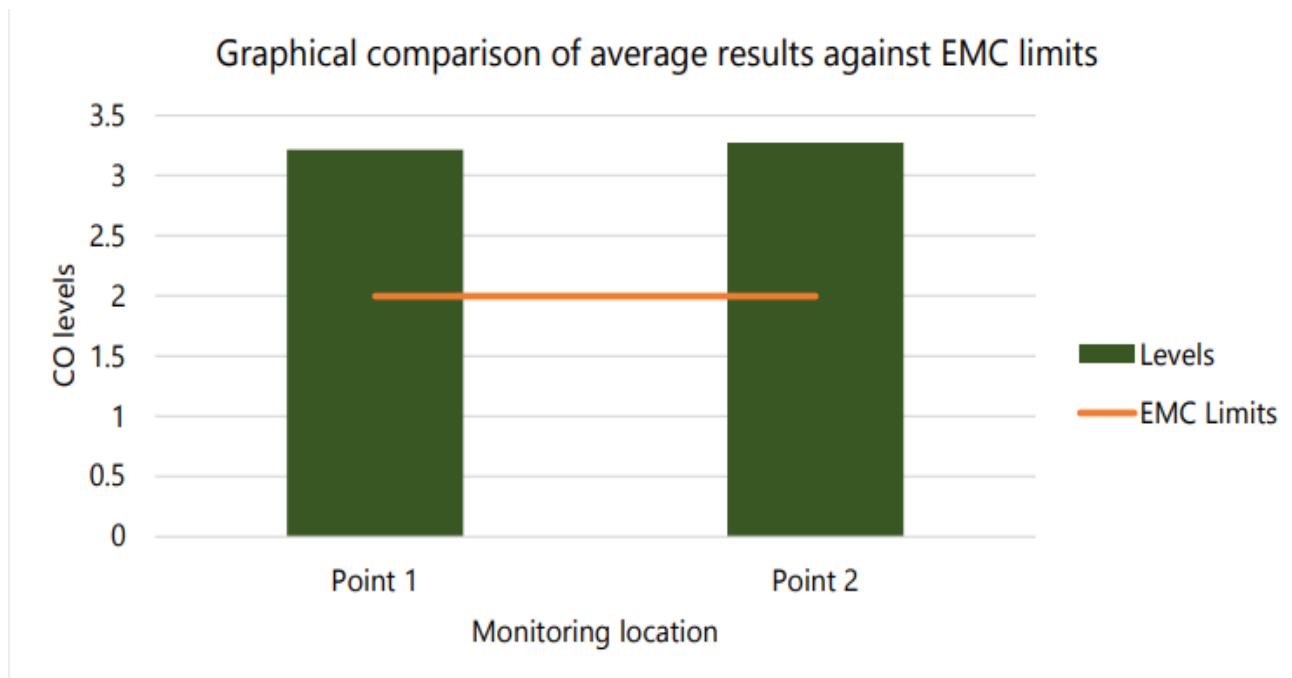


Fig. 3: Graphical comparison of CO levels against acceptable EMC limits

Results show that (figure 3) Carbon Monoxide levels at Mwakirunge Dumpsite is **almost double** the acceptable limits.

## DISCUSSION AND CONCLUSION AIR QUALITY

Results for Particulate matter (PM10) and Carbon monoxide (CO) were relatively high and surpassed the EMC (Air quality) regulation 2014 limits. All the other studied parameters had notable concentration levels and complied with reference threshold limits.

Burning of solid wastes was ongoing at the time of monitoring. Smoke generated from these activities majorly contributed to particulate matter and CO levels recorded at both locations. Had it not been for the moderate rains experienced a day before the monitoring these values could have been much higher – indicating the inhabitable conditions of high particulate and Carbon Monoxide levels at Mwakirunge.

As mentioned earlier the inhalation of inhalable particulate matter pose a great health risk. These tiny particles get into the lungs and are small enough to pass through tissues and enter the blood stream. They can then trigger inflammations which eventually cause heart and lung failures. The World Health Organization estimates that long term exposure to PM2.5 is associated with an increase in the risk of cardiopulmonary mortality by 6–13% per 10 µg/m<sup>3</sup> of PM2.5. Numerous scientific studies have linked fine and ultrafine particulate matter to a variety of serious health problems including premature deaths in people with heart or lung disease, heart attacks, irregular heartbeats, asthma, cardiovascular disease, decreased lung function, airway irritation, coughing and difficulty breathing

Higher levels of Carbon Monoxide can cause serious tissue damage especially when breathed in large amount for a prolonged period of time. Even in small doses, Carbon monoxide can cause headache, nausea and dizziness. Carbon monoxide poisoning occurs when carbon monoxide builds up in your bloodstream. When too much carbon monoxide is in the air, your body replaces the oxygen in your red blood cells with carbon monoxide. This can lead to serious tissue damage, or even death. It may also cause people to have irreversible brain damage or even die before anyone realizes there's a problem.



## Carbon Monoxide Risk factors

Exposure to carbon monoxide may be particularly dangerous for:

**Unborn babies:** Fetal blood cells take up carbon monoxide more readily than adult blood cells do. This makes unborn babies more susceptible to harm from carbon monoxide poisoning.

**Children:** Young children take breaths more frequently than adults do, which may make them more susceptible to carbon monoxide poisoning.

**Older adults:** Older people who experience carbon monoxide poisoning may be more likely to develop brain damage.

**People who have chronic heart disease:** People with a history of anemia and breathing problems also are more likely to get sick from exposure to carbon monoxide.

Those in whom carbon monoxide poisoning leads to unconsciousness. Loss of consciousness indicates more severe exposure.

Thus operations at Mwakirunge dumpsite are a threat to life and 3 environment.

## ANALYSIS OF THE LEACHATES

This section gives a brief description the major leachates and their consequences in Mwakirunge dumpsite

### Scope

Sampling of leachates from the dumpsite taken and submitted to the laboratory for analysis of pH, Biological oxygen demand, Chemical oxygen demand, Lead, Copper, Chromium, Arsenic, Zinc, Nitrogen and Ammonia.

### Objectives

To collect and analyze samples for the specific contaminants.

Correlate the test results with the tolerance limits set in the Environmental Management and Coordination (Water Quality) Regulations 2006, third schedule legal notice no. 120, for effluent discharge to environment

### Tools and Equipment

#### 1. Sampling Tools

Sampler

GPS

Cooler Box

#### 2. Equipment used for leachates laboratory analysis

Atomic Absorption Spectrophotometer (AAS)

BOD incubator

COD analyser

pH/EC/TDS meter

## Sampling and Testing Methodology

### 3. Field Sampling Methodology

The International Standard ISO 5667 for representative grab sampling was adopted. Of concern were the following parts of the standard:

Part 1: Guidance on the design of sampling programmes

Part 2: Guidance on sampling techniques

Part 3: Guidance on the preservation and handling of samples

### 4. Testing Methodology

Sample analysis was performed by the Polucon Environmental Laboratory in Mombasa, an ISO accredited laboratory. Method of analysis for each parameter analysed is displayed in Table 2-1 below:

Table 4: Parameter and Method of analysis table

Parameter	Method of Analysis	Units
Biological Oxygen Demand (BOD5)	AOAC 973.44 mg/	mg/l
pH	APHA 4500H+ B	@25 °c
Chemical Oxygen Demand (COD)	AOAC 973.46	mg/l
Lead	APHA 3111B	mg/l
Copper	APHA 3111B	mg/l
Chromium	APHA 3111B	mg/l
Arsenic	AOAC 920.205As	mg/l
Zinc	APHA 3111B	mg/l
Nitrogen	APHA 4500-N	
Ammonia	APHA 4500 NH4	

### Sampling location

Leachates were collected at one sampling location. The location is indicated in the google map show below (figure 5)



Fig. 5: Leachates sampling site at Mwakirunge dumpsite

Sampling location were as below

Table 5: Leachate sampling position at Mwakirunge Dumpsite

Location	Type of sample	Coordinates
Sampling area	Grab	3°56'24.72"S 39°40'24.30"E

## Legislation and Guidelines

The Environmental Management and Coordination Act, Water Quality Regulations, 2006/ Legal Notice No. 120 (Kenya) in the 4th Schedule, contains a monitoring guide categorized per industry. Further, the regulation contains Standards for Effluent discharge to the Environment (3<sup>rd</sup> Schedule). The Act underlines the proper management of the Kenya water resources.

## Environmental Management and Coordination (Water Quality) Regulations 2006

Table 6: Standard for Effluent Discharge into the Environment

Parameter	Units	Limits
	mg/kg	Intervention Value
Biological Oxygen Demand (BOD)	mg/kg	30 max
pH	mg/kg	6.5min – 8.5max
Chemical Oxygen Demand (COD)	mg/kg	50 max
Lead	mg/kg	0.1 max
Copper	mg/kg	1.0max
Chromium	mg/kg	2.0 max
Arsenic	mg/kg	0.1 max
Zinc	mg/kg	0.5 max
Nitrogen	Cal/g	-
Ammonia	% by wt	100 max

## Results and Discussion for Leachates

Table 7: Summary of leachate analysis

Parameter	Units	Dumpsite Leachate levels	Limits
	mg/kg		Intervention Value
11Chemicakl	mg/kg	<b>1150.00</b>	30 max
pH	mg/kg	6.98	6.5min – 8.5max
Chemical Oxygen Demand (COD)	mg/kg	<b>3520</b>	50 max
Lead	mg/kg	<0.01	0.1 max



Copper	mg/kg	<0.01	1.0max
Chromium	mg/kg	<0.01	2.0 max
Arsenic	mg/kg	<0.01	0.1 max
Zinc	mg/kg	<0.01	0.5 max
Nitrogen	Cal/g	163.29	-
Ammonia	% by wt	82.88	100 max

The levels of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were notably high and surpassed the EMCA limits. Results for elemental parameters were low depicting limited contamination of the sample from metallic wastes. The levels of ammonia were relatively high but did not surpass the limits. Nitrogen on the other hand had notable levels, however, there were no set limits in the reference standard, to compare against.

The high level of BOD and COD is an indicator of massive contamination of organic and inorganic wastes, draining from the dumpsite to the surrounding environment. BOD and COD are dissolved oxygen depleting parameters. Their high concentration in a sample is an indicator of limited oxygen availability hence a significant threat to life supporting processes. Massive influx of inorganic compounds can have profound effects to flora and fauna, especially where these compounds are stable against disintegration. When assimilated, the contaminants can be biomagnified resulting into a myriad of effects to other organisms within the food chain. Results showed limited contamination of heavy metals in the sample. This however, does not rule out the presence of heavy metals at the site. Sample size should be increased in the sample size (in subsequent studies) to determine their distribution and concentration at the site.

## SOIL SAMPLE ANALYSIS

### Scope

Here soil grab samples were collected and submitted for analysis of moisture content, ash content, Calorific value of dry mass basis and Heavy metals (Chromium, Mercury, Nickel, lead, Cadmium, Copper and Zinc).

### Objectives

To collect and analyze samples for the specific contaminants.

Correlate the test results with the tolerance limits set mentioned in the Dutch Soil (here there are still not set standards by NEMA, hence they were compared to the Dutch Standards Remediation Circular of 2013).

### Tools and Equipment

#### 5. Sampling Tools

Soil Sampler

GPS

Cooler Box

#### 6. Equipment used for Soil laboratory analysis

Atomic Absorption Spectrophotometer (AAS)

Digestion Block

Scrubber

Fume hood

## Sampling and Testing Methodology

### 7. Field Sampling Methodology

The top soil was scrapped using a shovel to eliminate undesired particles from being part of the sample. The soil sampler (Soil auger) was drilled into the ground to about 0.3m and used to collect grab samples into clean sampling bags. Sampling bags were clearly labeled then transported to the laboratory in a cooler box for analysis. Collected samples were in the custody of the field technician until the samples were relinquished to another party (sample receiving) for registration. Special care was taken not to contaminate samples.

### 8. Soil Testing Methodology

A homogeneous sample were dried, grounded digested and analyzed for the heavy metals concentrations in the samples by plasma atomic emission spectrometry. Moisture content in soil samples were determined gravimetrically and results expressed as a percentage of sample weight.


### Sampling Location


Subsurface soil samples were collected from 2 points and used to make one homogenous sample. Sampling locations are shown in the map below (figure 6):



Fig. 6: Soil sampling sites at Mwakirunge Dumpsite

Table 8: Sampling locations

Label	Type of sample	Coordinates	Pictorials
Point 1	Grab	3°56'17.82"S 39°40'24.49"E	

Point 2	Grab	3°56'20.27"S 39°40'25.27"E	
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## Legislation & Guidelines

Kenya is yet to formulate the guideline limits for soil monitoring and therefore the Dutch Target and Intervention Values as detailed in the Dutch Soil Remediation Circular of 2013 was adopted (Table 9). These guidelines are the baseline values below which pollutants are assumed not to affect the natural properties of soil and ecological interactions. The guidelines are expected to guide in determining the appropriate mitigation measures for remedying soil contamination from anthropogenic activities.

Table 9: Standards excerpt from the Dutch Soil standards

Parameter	Units	Soil/Sediment (mg/kg) dry matter
	mg/kg	Intervention Value
Zinc	mg/kg	720
Nickel	mg/kg	100
Mercury	mg/kg	4
Chromium	mg/kg	78
Lead	mg/kg	530
Arsenic	mg/kg	76
Cadmium	mg/kg	13
Copper	mg/kg	190
Calorific value on dry matter basis	Cal/g	-
Ash content	% by weight	-
Moisture content	% by weight	-

## RESULTS AND DISCUSSION OF THE SOIL SAMPLES

Table 10: Summary of results from the analyses of the soil samples from Mwakirunge Dumpsite

Parameter	Units	Dumpsite Values	Soil/Sediment (mg/kg) dry matter
	mg/kg		Intervention Value
Zinc	mg/kg	665.80	720
Nickel	mg/kg	0.86	100



Mercury	mg/kg	1.47	4
Chromium	mg/kg	1.56	78
Lead	mg/kg	5.03	530
Cadmium	mg/kg	3.92	13
Copper	mg/kg	167.92	190
Calorific value on dry matter basis	Cal/g	61.45	-
Ash content	% by weight	71.74	-
Moisture content	% by weight	19.86	-

Test results were compared against the relevant standards to determine compliance. The levels of Zinc, mercury and copper were notably high in the tested sample. These levels however did not surpass the Dutch remediation limits set to protect the edaphic properties from pollution emanating from anthropogenic activities. Amount of ash in the sample was relatively high however, the standard does provide reference limits to compare against. The results of ash content further show that ash (majorly incombustible inorganic compounds) is easily drained from the dumpsite to soils around the settlement areas.

Potential sources of heavy metals at the site included metallic wastes as well as other hazardous materials dumped at the site. The moisture content results were also, relatively low indicating that the soil aggregates and colloids were generally dry. This could be as a result of influx of compounds which have drying effects to soil particles.

Since the grab samples were collected on the fringes of the dumpsite i.e. along the boundary of the dumpsite and the neighboring human settlement, the results show evidence of accumulation of contaminants from the dumpsite to soils at the nearby receptors. Heavy metals such as Mercury, Zinc and Copper can be absorbed into farm crops which when ingested by humans and other animals, can bio-accumulate and also be biomagnified along the food chain. Based on the analysis results, contaminants which leach into soil of the dumpsite have the potential to harm edaphic chemical, physical and biological properties and the environment at large.

## SUMMARY OF KEY FINDINGS

Environment al dimension	Key findings	Implications
Air Quality	<p><b>Particulate Matter (PM 10)</b> for the two sites were 301.20 and 405.20 <math>\mu\text{g}/\text{Nm}^3</math> exceeding the acceptable limit of 100<math>\mu\text{g}/\text{Nm}^3</math> by far. <b>Carbon monoxide</b> levels were: 3.216 and 3.274<math>\mu\text{g}/\text{Nm}^3</math> for the two sites – exceeding the acceptable limits of 2.0 <math>\text{mg}/\text{m}^3</math> higher than acceptable levels</p> <p>Nm<sup>3</sup> (Normal cubic meter) refers to gas volume occupied at normal temperature and pressures which are 0 deg c and</p>	<p>Particulate matter, the order PM10, can travel long distances by wind. They are tiny enough to get into lungs, body tissues and even blood stream. Have the potential to trigger inflammations causing eventual heart and lung failure. At low doses, they have been linked with heart attacks, irregular heartbeats, asthma, cardiovascular diseases, decreased lung function, airway irritation, coughing, and difficulty in breathing among others. The effects are much more pronounced in babies, expectant mothers as well as older or immune compromised persons.</p> <p>There were also exceeding levels of carbon monoxide – CO is when breathed for a prolonged period of time can</p>


	<p>14.7 psia. Am<sup>3</sup> refers to gas volume at actual operating conditions of the process. Use <math>P_1 \times V_1 / T_1 = P_2 \times V_2 / T_2</math> for the conversion.</p> <p>µg - microgram</p>	<p>result in serious tissue damage and eventual death. In small doses it can cause headache, nausea and dizziness</p>
Leachates	<p>Biological Oxygen Demand (BOD) levels were 1150.00mg/kg way far beyond the acceptable level of 30max.</p> <p>Chemical Oxygen Demand (COD) levels were 3520 mg/kg again almost six times higher than the acceptable limit of 50 max.</p> <p>Other parameters like Ammonia was equally high but below limits.</p>	<p>The high levels of BOD and COD is an indicator of massive contamination of organic and inorganic wastes draining from the dumpsite to the neighboring areas – draining dissolved oxygen hence a big threat to life supporting processes and with profound effects to flora and fauna. Those organic and inorganic substances causing high levels of BOD and COD, can be assimilated and bio-magnified resulting into different negative effects to other organisms and affecting food chains reaching human populations.</p>
Soils	<p>Levels of Zinc (665.80 mg/kg), Mercury (1.47mg/kg), Copper (167.92mg/kg), Ash content (71.74% if total dry weight) were higher albeit not past the limits – the Dutch remediation limits since our NEMA does not have set limits still.</p>	<p>Since the grab samples were collected on the fringes of the dumpsite i.e. along the boundary of the dumpsite and the neighboring human settlement, the results show evidence of accumulation of contaminants from the dumpsite to soils at the nearby receptors. Heavy metals such as Mercury, Zinc and Copper can be absorbed into farm crops which when ingested by humans and other animals, can bio-accumulate and also be biomagnified along the food chain.</p> <p>Based on the analysis results, contaminants which leach into soil of the dumpsite have the potential to harm edaphic chemical, physical and biological properties and the environment at large.</p>

## REFERENCES

1. Dutch Soil remediation Circular 2013, Version of 1st July 2013.
2. Methods of Plant, Soil and Water analysis: Manual for West Asia and North Africa region, ICARDA 3rd Edition
3. The Environmental Management and Coordination Act, Water Quality Regulations, 2006/ Legal Notice No. 120

## ANNEXES

### Annex 1: Leachates Laboratory Analysis Report

	<p>LEACHATES SAMPLING AND ANALYSIS SUMMARY REPORT FOR BENARDS OKEYO</p> <p>REPORT NO. 202216020679</p> <p>REVISION VERSION 00</p>	<p><b>BENARDS OKEYO</b> <b>P.O BOX 41460-80100</b> <b>MOMBASA, KENYA</b></p>
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#### 4 ANNEX: LABORATORY RESULTS



BENARDS OKEYO  
P.O. BOX 41460-80100  
MOMBASA, KENYA

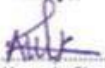
TEST REPORT NO: 202216020679				
SAMPLE DATE & PLACE SAMPLED DATE ANALYSIS STARTED SAMPLING METHOD MARKINGS		EFFLUENT 03 <sup>rd</sup> November 2022 at Mwakirunge Dumpsite- Mombasa 04 <sup>th</sup> November 2022 POL/FTS/001 Dumpsite Leachate- Mwakirunge Dumpsite		
TESTS	TEST METHOD	RESULTS	UNITS	STANDARDS FOR EFFLUENT DISCHARGE INTO THE ENVIRONMENT
*pH value	APHA 4500-H-B	6.98	@26.30°C	6.5Min-8.5Max
Biochemical Oxygen Demand	AOAC 973.44	1550.00	mg/L	30Max
Chemical Oxygen Demand	APHA 5220C	3520.00	mg/L	50Max
*Lead as Pb	APHA3111B	<0.01	mg/L	0.01Max
*Copper as Cu	APHA 3111B	<0.01	mg/L	1.0Max
Chromium as Cr	APHA 3111B	<0.01	mg/L	2.0Max
Arsenic as As	AOAC 920.205As	<0.01	mg/L	0.1Max
*Zinc as Zn	APHA 3111B	<0.01	mg/L	0.5Max
Nitrogen as N	APHA 4500-N	163.29	mg/L	-
Ammonia as NH <sub>4</sub>	APHA 4500 NH <sub>4</sub>	82.88	mg/L	100Max

\*\*\*\*\*End of test results\*\*\*\*\*

**Comment:** Based on the above tests only, the effluent does not conform to EMCA (Water Quality) Regulation LN 120 of 2006 Standards for effluent discharge into the Environment due to high Biochemical Oxygen Demand and Chemical Oxygen Demand.

**Recommendation:** The failure of the above mentioned parameters can be improved by treatment of the waste water.

Mombasa Lab  
15<sup>th</sup> November 2022

Analyst  
  
A. Karong'o-Chemist



\*Indicates test(s) covered under the KENAS accreditation schedule while '-' indicates test(s) subcontracted to an approved Laboratory holding ISO/IEC 17025 accreditation.  
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## Annex 2: Soils Laboratory Analysis Report



BENARDS OKEYO  
P.O. BOX 41460-80100  
MOMBASA, KENYA

TEST REPORT NO: 202216012875				
SAMPLE		SOIL		
DATE & PLACE SAMPLED		03 <sup>rd</sup> November 2022 at Mwakirunge Dumpsite		
DATE ANALYSIS STARTED		04 <sup>th</sup> November 2022		
SAMPLING METHOD		POL/FTS/002		
MARKS		Dumpsite Soil		
PARAMETER	METHOD	RESULTS	UNITS	REQUIRED SPECIFICATIONS
Zinc as Zn	EPA 3050B	665.80	mg/kg	-
Copper as Cu	EPA 3050B	167.19	mg/kg	-
Cadmium as Cd	EPA 3050B	3.92	mg/kg	-
Lead as Pb	EPA 3050B	12.75	mg/kg	-
Nickel as Ni	EPA 3050B	0.86	mg/kg	-
Mercury as Hg	EPA 3050B	1.47	mg/kg	-
Chromium as Cr	EPA 3050B	5.03	mg/kg	-
Calorific Value on Dry matter Basis	ISO 1928	61.45	Cal/g	-
Ash Content	ASTM D3174	71.74	% by wt	-
Moisture Content	ASTM D3173	19.86	% by wt	-

\*\*\*\*\* End of test report \*\*\*\*\*

Mod - Method modified by using microwave plasma atomic emission spectrometer (MP-AES)

Mombasa Lab  
15<sup>th</sup> November 2022

Analyst

  
E. Mutwii - Chemist



Where a statement of conformity is made, the following decision rules are applied not considering uncertainties: 'conform/comply' – Results are within limits while 'does not conform/comply' – Results exceed limits  
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"Unless otherwise stated the results shown in this test report refer only to sample(s) tested and such sample(s) are retained for 90 days only (if non-perishable)."

### Annex 3: Equipment calibration certificate

	AMBIENT AIR QUALITY MONITORING REPORT FOR BENSONS OKEYO, MWAKIRUNGE DUMPSITE	
	REPORT NO. 202214010083	
	D.O.I – 03 <sup>RD</sup> NOVEMBER 2022 REVISION VERSION: 00	

### ANNEX 2: CALIBRATION CERTIFICATE





#### TEST CERTIFICATE FOR AQM-900

Certificate No: AQM900/22-23/RC/645

Name of the Client : M/s. Polucon Services (K) Limited, Kenya  
Model No. : AQM-900  
Serial No. : 12183  
Date of Testing (DD/MM/YYYY) : 27/06/2022

Sr. #	Parameters	Value on Device Under Test	Standard Value	Deviation	Remarks
		(a)	(b)	(a)-(b)	
1	Temperature in °C	26.5	26.6	-0.1	Acceptable
2	Humidity in %	30.4	29.9	0.5	Acceptable
3	PM2.5 : in µg/m <sup>3</sup>	97.0	98.0	-1.0	Acceptable
4	PM10 : in µg/m <sup>3</sup>	66.0	65.0	1.0	Acceptable
5	CO : in mg/m <sup>3</sup>	1.928	1.931	-0.003	Acceptable
6	SO <sub>2</sub> : in mg/m <sup>3</sup>	0.100	0.099	0.001	Acceptable
7	NO <sub>2</sub> : in mg/m <sup>3</sup>	0.006	0.005	0.001	Acceptable
8	O <sub>3</sub> : in mg/m <sup>3</sup>	0.090	0.088	0.002	Acceptable
9	NO : in mg/m <sup>3</sup>	0.031	0.032	-0.001	Acceptable
10	H2S : 0 – 139 mg/m <sup>3</sup>	0.074	0.076	0.002	Acceptable

Remark: The average deviation in the above test has been found to be within acceptable limits as per standards.

Certificate Prepared by:	
Naeem K.	
Certificate Checked by:	
Radheshyam K.	



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