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A Technical Report on Rapid Assessment of Pesticide Contaminated Sites in Kenya: Case Studies of Menengai Crater, Kitengela Pesticide Store and Wajir Lmd Site

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ABSTRACT

Evaluating the risk posed by a contaminated site involves assessing hazards, receptors and exposure pathways. Since risk exists only when all three of these components are present, it is advantageous to use a multiplicative model as the REA rather than a summative model for assessing risk potential. Hazard (contaminant), receptor and exposure pathway scores are developed under a methodological framework that reduces opportunities for judgmental bias. The model was therefore used to categorize and prioritize the visited sites and recommend the sites which require immediate detailed action. The purpose of the site assessments was to identify the existence, source, nature, and extent of POPs contamination of Menengai Crater, Kitengela and Wajir dump sites. From the residual chemical analysis of samples collected, the sites are heavily contaminated with residual POPs (lindane, aldrin, dieldrin, 2,4-DDE, 2,4-DDT, and endrin) and other residual pyrethroids (bifenthrin, cypermethrin, pendimethalin, and permethrin) beyond the set International Standards for such residual pollutants in the environment (USAEPA, Dutch Intervention POPs Levels)(< 0.05 mg/Kg). Menengai Crater 1, Kitengela and Wajir LMD indicated quite high levels of the POPs. The levels of POPs recorded in the analysis are indicative of potential contamination of humans and animals and thus posing a great environmental threat. The pollutants are able to pollute surface and ground water sources, contaminate surface soil both on site and away through long range dust transportation. The analysis of REA questionnaire indicated that Wajir LMD site was the most at risk followed by Menengai Crater Dump Site 1, and Kitengela respectively. Wajir LMD was the most at risk site due to the proximity and easy access to the site by human beings and thus poses a great health threat to the local community members living and accessing the site. There was strong evidence of both horizontal and vertical POPs contamination in all sites. The proximity of receptors such as homesteads and drinking water sources (at Wajir LMD and Kitengela) to the contaminated sites, strongly indicate that the sites are potential human hazard and detailed investigations should be put in place to ascertain the extent of contamination. The study proved with great certainty that the visited sites are heavily contaminated with POPs and measures to reclaim and remediate the sites to avoid future human health and environment catastrophe should be put in place.

Keywords: ***Assessment, Persistent Organic Pollutants, Pollutants, Risks, Contamination***

1. INTRODUCTION

Persistent Organic Pollutants (POPs) are more or less defined as organic chemicals that were used for pest control and are persistent, bioaccumulative, and toxic. Many POPs were widely used during the boom in industrial production after World War II, when thousands of synthetic chemicals were introduced into commercial use. Many of these chemicals proved beneficial in pest and disease control, crop production, and industry. These same chemicals, however, have had unforeseen effects on human health and the environment.

Many people are familiar with some of the most well-known POPs, such as polychlorinated biphenyls (PCBs), DDT, and dioxins. Generally, POPs include a range of substances that are:

1. *Intentionally produced chemicals currently or once used in agriculture, disease control, manufacturing, or industrial processes. Examples include PCBs, which have been useful in a variety of industrial applications (e.g., in electrical transformers and large capacitors, as hydraulic and heat exchange fluids, and as additives to paints and lubricants) and DDT, which is still used to control mosquitoes that carry malaria in some parts of the world.*
2. *Unintentionally produced chemicals, such as dioxins, that result from some industrial processes and from combustion (for example, municipal and medical waste incineration and backyard burning of trash).*

Although many different forms of POPs may exist, both natural and anthropogenic, POPs which are noted for their persistence and bioaccumulative characteristics include many of the first generation organochlorine insecticides such as dieldrin, DDT, toxaphene and chlordane and several other chemical products or byproducts including polychlorinated biphenyls (PCBs), dibenzo-p-dioxins (dioxins) and dibenzo-p-furans (furans). Many of these compounds have been or continue to be used in large quantities and, due to their environmental persistence, have the ability to bioaccumulate and biomagnify. The chlorinated POPs, are generally the most persistent of all the halogenated hydrocarbons and may be found in the environment for periods of years and may bioconcentrate, thus a risk to human health. These compounds have physico-chemical characteristics ($\log K_{ow}$, $\log K_{oc}$) that permit them to a varying degree, resist photolytic, biological and chemical degradation. They may therefore occur in vapor phase and adsorbed onto soil particles. These physico-chemical properties (such as water solubility, vapour pressure, Henry's law constant (H), octanol-water partition coefficient (K_{OW}), and the organic carbon-water partition coefficient (K_{OC}) and persistence), facilitate their long range transport in the atmosphere before deposition occurs and leach into ground water reservoirs (American Conference of Governmental Industrial Hygienists (ACGIH). 1999*)*.

In the year 2001, the International Community responded to the threat posed by POPs by coming up with the Stockholm Convention which intended to protect human health and the environment by reducing and eliminating POPs. The convention began by listing the most notorious twelve POPs which includes lindane, heptachlor, DDT and its derivatives, chlordane, the drins (aldrin, eldrin, dieldrin), mirex and toxaphene (U.S. Environmental Protection Agency, 2002). The Government of Kenya ratified the convention in year 2004 and became part of the Kenyan Laws.

Most of these compounds continue to show up in samples of soil, water, plant materials and animal products. This can be because of their persistence, from continuing uses for certain restricted purposes, from ongoing use of old supplies, or because of releases from old disposal sites and other environmental reservoirs, such as contaminated sediments and soils.

Humans can be exposed to POPs through diet, occupational accidents and the environment (including indoor). Exposure to POPs, either acute or chronic, can be associated with a wide range of adverse health effects, including illness and death. Laboratory investigations and environmental impact studies in the world have implicated POPs in endocrine disruption, reproductive and immune dysfunction, neurobehavioural and disorders and cancer. More recently some POPs have also been implicated in reduced immunity in infants and children, and the concomitant increase in infection, also with developmental abnormalities, neurobehavioural impairment and cancer and tumor induction or promotion (U.S. Environmental Protection Agency, 1994).

Kenya is primarily an agricultural country with over 80% of the population depending on it for their livelihood. Agriculture accounts for over 25% of the Gross Domestic Product (GDP) and provides the basis of development of the sectors of the economy by generation of foreign exchange, provision of raw materials for local industries, generation of employment, poverty alleviation and provision of food. The use of pesticides has enabled the industry to increase food production, income generation and employment oblivious of the environmental consequences the residual compounds have to the environment if no safe measures are taken to ensure safe use and their disposal alongside ensuring banned compounds don't end up in farmers use.

Studies have linked POPs exposures to declines, diseases, or abnormalities in a number of wildlife species, including certain kinds of fish, birds, and mammals. Wildlife also can act as sentinels for human health: abnormalities or declines detected in wildlife populations can sound an early warning bell for people. Behavioral abnormalities and birth defects in fish, birds, and mammals in and around the Great Lakes, for example, led scientists to investigate POPs exposures in human populations.

In people, reproductive, developmental, behavioral, neurologic, endocrine, and immunologic adverse health effects have been linked to POPs. People are mainly exposed to POPs through contaminated foods and water. Less common exposure routes include drinking contaminated water and direct contact with the chemicals. In people and other mammals alike, POPs can be transferred through the placenta and breast milk to developing offspring. In addition, sensitive populations, such as children, the elderly, and those with suppressed immune systems, are typically more susceptible to many kinds of pollutants, including POPs. Because POPs have been linked to reproductive impairments, men and women of child-bearing age may also be at risk.

2. CONCEPTUAL FRAMEWORK

A conceptual site model (CSM) describes the source, pathway and receptors which are likely to be found in the visited sites. It is hoped that the information given can be used within the site prioritization exercise. In the study of site prioritization, the presence of all three (source, exposure pathway and the receptor) will indicate some level of risk while the absence of or near absence of any of the components will indicate no or minimum risk of the site.

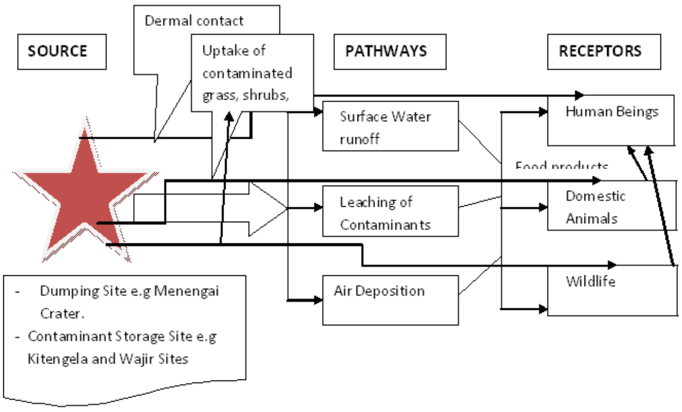

Fig.1. The Conceptual Framework of the C 1

2.1 Experimental Methods

Sampling Sites: The research project was done at three sites in Kenya, namely: Menengai Crater dump site, Kitengela Astra Ranch Site and Wajir Town LMD.

2.2 Site Descriptions

The following cites were visited during the time of assessment. They include: Menengai Crater dumpsite, Kitengela and Wajir.

2.2.1 Menengai Crater

Physiography

Menengai Crater is located 10 km (6 miles) North of Nakuru town – the fourth biggest town in Kenya. The estimate terrain elevation above sea level is 2058 metres. Its coordinates are: Latitude: -0°12'30.89"; Longitude: 36°4'10. Menengai Crater is a massive shield volcano with one of the biggest calderas in the world, located in the Great Rift Valley, Kenya. Several farmlands occupy its flanks. Fig 2 below shows the Landsat map of Menengai Crater.

Fig 2: A Landsat Map of Menengai Crater

Menengai crater is a major physiographic feature in the rift floor and is also important for its geothermal potential. The caldera floor, which is fairly flat, covers an area of about 88 km^2 and is partially covered by young rugged lava flows. The topography is made up of flat grounds.

Hydrogeology and surface drainage systems

Menengai Crater receives an annual average rainfall of between 760 mm and 1270 mm and is within a dry sub-humid equatorial climatic zone. The rainfall regimes are bimodal with the long rains occurring in March to July and the short rains in September to November. Temperatures range from 9.4 to 29.3 ºC. The surface drainage system is largely from the east and the western scarps. On the rift floor, the drainage is mainly from Menengai crater northwards with the exception of the drainage from the southern rim or slopes of Menengai crater into Lake Nakuru.

Geology and soils

The surface of Menengai Crater area is covered by volcanic rocks mostly erupted from volcanic centers that can be categorized into exposed older lava flows, flat grounds that are covered by derivatives of plinian eruptions with few interrupting scarps and the Menengai volcano. The soil profile of the area is shallow, stony and saline.

Land ownership and use

About 60% of the land of the Menengai Crater is public owned comprising of the Menengai Forest which covers the Northern, Eastern and Southern parts. The rest of the land is privately owned with average farm sizes of 4-5 hectares. The local population in the northern and north-eastern parts of the Crater employs the land for small-scale intensive mixed farming, including keeping livestock. The eastern and southern parts of the area consist of suburban and urban developments. The local population in the western part of the project area and in parts of the Caldera floor engages in large-scale wheat and dairy farming.

Water sources for domestic and livestock consumption

Wanyororo Spring and the Crater Stream (Kandutura) serve as the primary sources of water for domestic and livestock consumption in the area. Boreholes and surface runoffs supplement these water sources.

Menengai Crater Dump Sites

Menengai Crater Dump sites (Site 1 and 2) were used by Nakuru Kenya Farmers Association (KFA) in the years 1992-93 as dump sites for disposal of fire razed residues of agrochemicals and other farm inputs from the KFA store. The materials buried in the sites were majorly remains of chemicals, fertilizers, animal feeds, seeds and farm. The main burial site (Menengai Dump Site 1) is about 50 x 100 ft (13 x 30 m) with a trench surrounding it. It is estimated that 338 tons of fertilizers, equipments, chemicals, animal feeds, seeds and tools were transported from the razed KFA store for disposal in the area. There was evidence of chemical cans and remains of burned materials at the sites.

Menengai Crater Dump sites had been identified as potentially POPs contaminated sites by FAO -Kenya and Ministry of Agriculture, Livestock and Fisheries, thus requiring risk assessment and initiation of possible remedial treatment measures.

2.2.2 Kitengela Pesticide Store

Geographical Information

Kitengela Pesticide Store is located in Kitengela sub location, IIdamat Location, Central Division of Kajiado District in Kajiado County and lies at an altitude of 1640 m absl, longitude 36º East and Latitude 1º South. The site is within the Ministry of Agriculture, Livestock and Fisheries Sheep and Goat breeding area and is approximately 28 kilometers South of Nairobi, the capital City of Kenya. Fig 3 below shows the location of Kitengela Sheep and Goats Breeding site with respect to the Namanga –Nairobi main road.

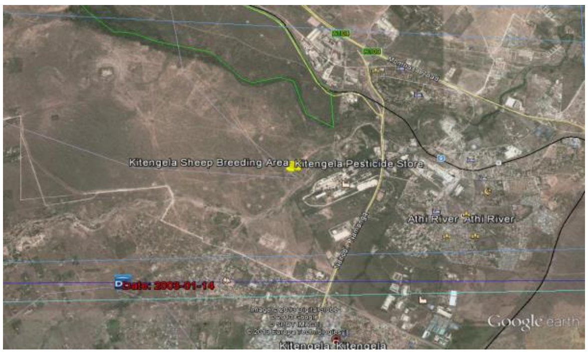

Fig 3: A map showing the location of Pesticide Store with repeat to the Nairobi – Namanga Road

Figure 4: below shows the location of Kitengela Pesticide Store close to the Sheep and Goats breeding area.

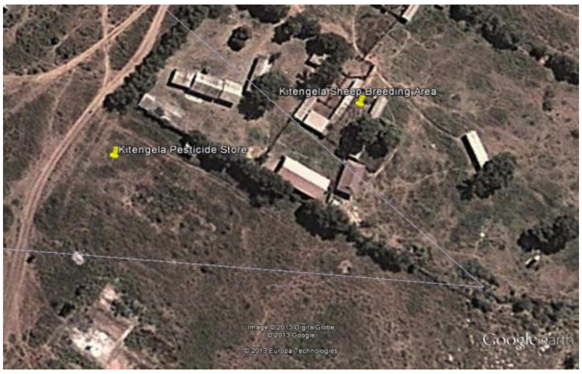

Fig 4: A map showing the location of Kitengela Pesticide Store.

Historical Information

Kitengela Pesticide Store was built by the Ministry of Agriculture in the year 1967 and was being used by the Desert Locust Control Organization (DLCO) for storing pesticides for locust and mosquito control. The store was made of wood and corrugated iron sheets and covered 21,000 square feet. By the year 2000, the store was used as a storage facility for obsolete pesticides and other toxic chemical wastes collected from coffee cooperative societies, flower farms and Kenya Farmers Association stores from all over the country and any unregistered counterfeit pesticide and chemical products seized by government officials. The site was also used as a disposal area for chemical contaminated soils from industries. Some information obtained from the Agrochemical Association of Kenya (AAK) indicates that the store contained aldrin, dieldrin, endrin, furadan, some carbamates and endosulfan. The carbamates were used for malaria vector control along with endosulfan and some fungicides.

The stored chemicals latter corroded the drums, the corrugated iron sheets and some leaked into the ground. In 2000, a decision was made by the Agrochemical Association of Kenya, National Environmental Management Agency, and the Ministry of Agriculture to construct a shade for the chemicals using corrugated iron sheets and concrete slap floor to protect any further soil contamination. A decision was also made to destroy the unmanageable stockpiles and renovate the store. Through the input of consultants, some of the chemicals were diluted (188 tons of stored pesticides and other chemicals) and sold to pineapple farms and pesticide manufacturing firms for use by the Kenya Institute of Waste Management (KIWM), and the drums which contained the chemicals were apparently smelted down by Environmental and Combustion Consultants Limited (ECC). However the report received from the site visit indicated that the dilution and reformulation of the chemicals was done by the ECC and used as fuel in the incinerator. By the time the team visited the site, there as no evidence of chemical drums except used cans and the presence of strong pungent smell of chemicals. The iron sheets used in making the shade had corroded and only a concrete slab floor was still in place and spilled chemicals were evident.

Fig 5: A picture showing spilled chemicals at Kitengela Pesticide Store site.

A study carried out at the site by an NGO, the ENVILEAD (Environmental Liaison, Education and Action for Development) as part of International POPs Elimination Project (IPEP) in the year 2005 estimated the weight of contaminated soil around the store to have been 400 tons. The study also found out that the site was contaminated with a wide variety of toxins, including POPs pesticides and POPs industrial chemicals. A UNEP report entitled "Hotspot Report for a Contaminated Site: Kitengela Obsolete Pesticide Store in Kenya" mentions the Kitengela site to be highly contaminated with toxins, including industrial and agricultural chemicals that are not biodegradable. However, no study was carried out to determine the exact nature of the chemicals.

2.2.3 Wajir Pesticide Dump Sites

Physiography

Wajir is a town in the northeastern region of Kenya located in an arid area prone to drought. It sits at a latitude and longitude of 01°45′00″N 40°03′00″E. Wajir is situated approximately 490 kilometers (300 mi) northeast of Nairobi Capital City of Kenya and is 235 m (771 ft) above sea level. Wajir town has mostly sandy soils. Fig 6 below shows the location of Wajir town in the Kenyan map.

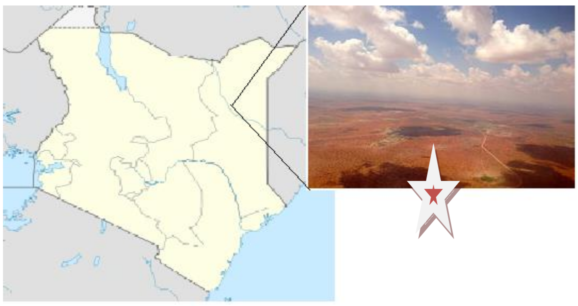

Fig 6: A geographical positioning of Wajir Town in Kenya

Climate of Wajir

Wajir has a warm steppe climate with many warm days. The figure below shows the average temperatures and precipitation values for the year 2012. The region may experience periods with extreme drought and may record not a single drop of rain for years. Chances of precipitation are highest in April as shown in Table 1 below.

Table 1: Historical Weather for Wajir, Kenya as adapted from Weather base: Weather base: 2012.

Climate data for Wajir													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	35 (95)	36 (96)	36 (96)	34 (94)	33 (92)	32 (90)	31 (88)	32 (89)	33 (91)	33 (92)	33 (91)	33 (92)	33.4 (92.2)
Average low °C (°F)	21 (70)	22 (72)	23 (74)	24 (75)	23 (73)	21 (70)	21 (69)	21 (69)	21 (70)	22 (71)	22 (71)	23 (73)	22 (71.4)
Precipitation mm	5	13	20	69	36	0	5	3	5	30	41	23	250

Wajir Sites

There are two contaminated sites which required assessment for the type and level of contamination present. They are: Wajir LMD. Wajir Livestock Marketing Division (LMD) site is situated in Wagberi Village and its geolocation is lat: 1.756 and long: 40.0697. The LMD site is in an open field and the area has been encroached by human settlements thus easily accessed. The sites were originally used by DLCO-EA (Desert Locust Control Organization for Eastern Africa) and Ministry of Agriculture as stores for locust pesticides. Fig 7 below shows locations of Wajir LMD site within Wajir town.

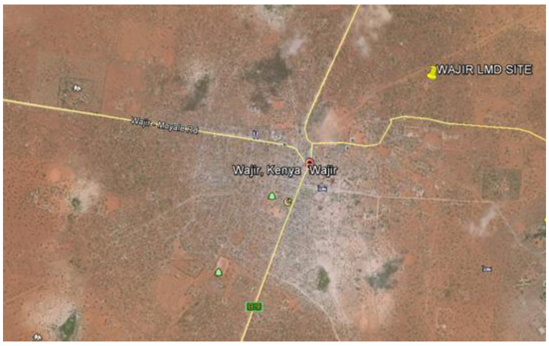

Fig 7: A map of Wajir Town and the respective contaminated sites as adapted from Google maps.

Fig 8: below shows a Google map of Wajir LMD site.

Fig 8: A map showing the location of Wajir LMD site.

2.3 Rapid Environmental Risk Assessment

The rapid environmental assessment involved site visits to the identified areas. Sampling of soil and water (as per FAO sampling protocol) was done together with completing the REA questionnaire, 2013.

2.3.1 Sites Visited

Six sites were visited for assessment of POPs contamination. They were: Menengai Dump Sites (1 and 2), Kitengela Pesticide Store and Wajir Site (LMD) during the period 2013.

2.3.2 Source of Information

Historical information about aspects of contamination of the site(s) was done through interviewing the local community members, leaders and some government officials who accompanied the team during the site visits. The information given also assisted in identifying the centre of the hotspots and the possible extent of contamination. The information was also used to complete the rapid environmental assessment forms for used in preliminary Site Prioritization.

2.3.3 Site Characterization

In order to characterize the sites for levels of contamination, it was important to design a survey which combined a number of requirements such as soil sampling patterns, groundwater investigations in wells and river systems, and the establishment of levels of residual POPs present.

2.3.4 Soil Sampling

Composite surface and point soil samples were collected from each site. For composite soil samples, thirty (30) sampling points (10-30 cm) were randomly selected and surface soil collected into a stainless steel bucket. The collected soil samples were thoroughly mixed to ensure homogeneity and a composite soil sample of 500 gms packed into a well labelled sampling bottle. Point soil samples were collected from the areas considered to be the hotspots using soil auger at depths 0.5, 1.0, and 2.0 m in the identified areas. Soil profiling was also done using soil auger to a depth of 2 m. All samples were stored in a cool box and transported to KEPHIS chemistry laboratory for residual POPs screening and analysis. The labelling of the containers followed the following order: Site Name, Medium, Contaminant, Target or Composite, and Site Identifier.

Water samples were collected in sites which had water resources within 500 m from the respective hot spot. The sample was collected in a well labeled glass amber container and stored for transportation to KEPHIS laboratory.

2.3.5 Sample Analysis

All samples were analyzed for residual persistent organic pollutants (POPs) in collected soil and water samples using Gas chromatography–mass spectrometry *(*GC-MS*)* instrument at Kenya Plant Health Inspectorate Services (KEPHIS) chemistry laboratory. The results were recorded.

3. RESULTS AND DISCUSSIONS

3.1 Site Visits

The rapid environmental assessment on pesticides contaminated sites exercise involved visiting six sites during the period, 2013. They included:

1. Menegai Crater Dump site 1
2. Menengai Crater Dump site 2
3. Kitengela Pesticide Store
4. Wajir LMD

The contaminated site visits involved surveys, assessments, and sampling of soil and water for residual chemical analysis. The assessment of the sites for contamination was highly regulated and strictly adhered to the environmental impact assessment prescribed guidance and legislation as per USEPA.

3.2 Menengai Crater Dump Sites 1 and 2

The two dump sites in Menengai Crater are in a relatively remote area within the crater (Fig 8 below). During the visit, the TEAM observed the following:

i) Menengai site 1 has heavy vegetative cover (shrubs and grass) with trench dung around it.
ii) Signs of human activities on sites were evident like livestock grazing and charcoal burning.
iii) Menengai dump site 2 had been interfered with by the road construction company through excavating soil from the site.
iv) The sites are easily accessed by humans especially children who fetch firewood and graze livestock on sites.
v) Debris of burned items was evident.
vi) No surface pesticide odor was evident on the sites however auguring at about 1 m at the hotspot of site 1, strong odor characteristic of POPs was evident.
vii) Residential areas are at more than 1 km from the sites.
viii) Water resources were within 2-3 km from the sites.
ix) Soil type: surface dark volcanic soil with soft brown mixed with fine stones (< 10 mm in diameter). The stones diameter increased down the soil profile by 10%.
x) Remains of pesticides containers at the hotspot dump site 1 were excavated at about 1 m from the surface.
xi) Ground level igneous rock was approximately 3m deep. depth down the dark moist volcanic soil

3.3 Contamination of the Sites

Source of Contaminant(s): Dumped agrochemicals which included: fertilizers, chemicals, seeds, animal feeds, instruments and farm tools.
Identified Receptors: Humans, domestic animals and wild animals
Possible Pathways: Wind during dry season.

Figure 9: A Map of Menengai Crater Contaminated Sites 1 and 2.

3.4 Kitengela Pesticide Store

The following observations were noticed during the site visit of Kitengela Pesticide Store (Fig 10):

i) The hotspot is about 50 m x 60 m in size.
ii) It is within 500 m from the Sheep and Goat breeding field.
iii) The hotspot is bare with no structure in place
iv) The hotspot is not restricted for access in any way (no fence around it).
v) Surface strong odor of pesticides was evident
vi) Evidence of surface soil contamination with obsolete chemicals was evident
vii) A seasonal river is within 500 m from the hotspot NE and a borehole recently constructed at about 50 m from the hotspot in the southward direction.
viii) Remains of chemical containers were evident within the site.
ix) A concrete floor slab was in place during the time of site visit.

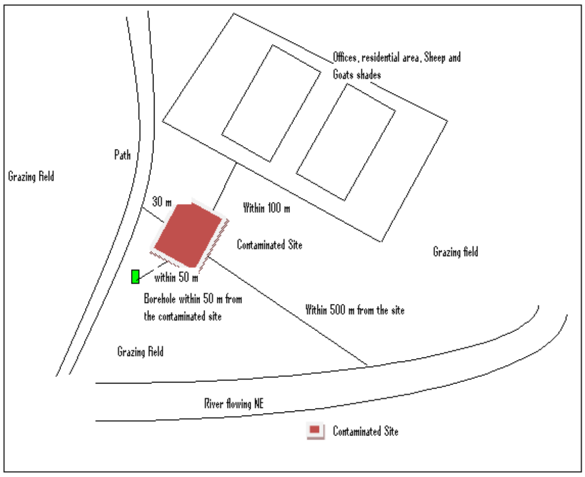

Figure 10: A sketch Diagram of Kitengela Pesticide Store

3.5 Contamination of the Site

The evidence of strong odor, pesticide cans, and contaminated soil was a prerequisite of contaminated site which required rapid environment assessment.
Source of Contaminant (s): contaminated soil with agrochemicals.
Pathways: surface water runoff, dust and wind.

Identified Receptors: Humans, domestic animals and wild animals

3.6 Wajir LMD site

As noted earlier, Wajir LMD site was a storage facility for chemicals by DLCO. The site is located in an open area which is currently used by the locals as a playing ground and road passage. The area is not fenced and there are three buildings within the compound, one used as a chief's office of the administrative area. The buildings were previously used by the livestock department of the Ministry of Agriculture (the current Ministry of Agriculture, Livestock and Fisheries). There was no evidence of buried chemical drums within the site as earlier reported and no smell characteristic of POPs was detected in the area during the visit. Residential houses are within 50 m from the contaminated site with several boreholes (wells) within a 300 m radius from the site. Below is a sketch of Wajir LMD site:

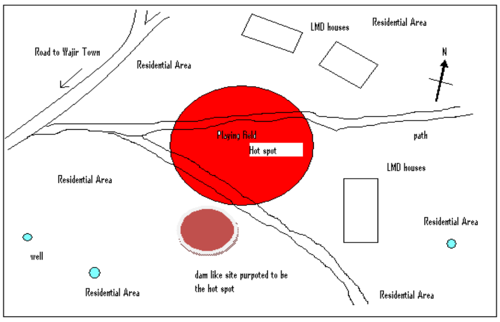

Figure 11: A sketch of Wajir LMD Contaminated Site

3.7 Contamination of the site

Although there was no physical indication of contamination, from reports of the local authorities and the Ministry of Agriculture officials in Wajir it was prudent to subject Wajir LMD site to rapid environment risk assessment.
Source of Contaminant(s): possibility of contaminated soil with agrochemicals.
Identified Receptors: human beings and domestic animals.
Pathways: underground water, dust and wind.

4. RESULTS OF RESIDUAL CHEMICAL ANALYSIS

4.1 List of Samples Collected at Menengai Crater Dump Sites

Table 2 below, shows the list of soil and water samples collected from Menengai Crater Dump Sites.

Table 2: Information of Samples Collected at Menengai Dump Sites

S/ N	Site	Sampl e Type	Sample Code	Descriptio n
1	Menenga i 1	Soil	Men 1.Dump.1.13	Composite soil from dump site
2	Menenga i 1	Soil	Men 1.Trench.2.13	Composite soil from the trench
3	Menenga i 1	Soil	Men 1.Comp.2.13	Composite soil collected at a depth of 110cm
4	Menenga i 2	Soil	Men2.Comp.1.1 3	Composite soil collected at site 2 at Menengai
5	Menenga i	Water	Men 1.W1.13	Water Sampled at the nearby borehole at Menengai

4.2 Results of Chemical Analysis of Menengai Dump Site 1

Composite soil and water samples collected in Menengai Dump Site 1 were analyzed for the presence of residual pesticides by GC/MS and the results recorded as in Figure 11 below. Lindane, aldrin, endrin, dieldrin, 2,4-DDT and pendimethalin residual pesticides were detected in soil samples collected from the site. With the exception of pendimethalin (a dinitroaniline insecticide), the rest were banned or restricted POPs by Stockholm Convention. The detected levels of POPs were above the environmental maximum allowable limit (0.01 mg/kg) by USAEPA. The levels of residual pesticides in water sample were below detection limit as per the analytical instrument method used at KEPHIS.

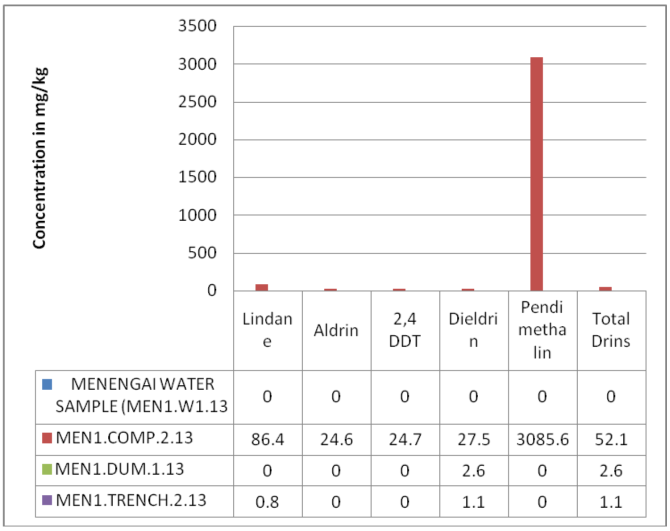

Fig 12: A graph Showing the presence and levels of pesticides in Menengai Crater Site 1

The results in Fig 12 above indicate presence of POPs at the hotspot of Menengai Dump site 1 at a depth of 100 cm (Men.1.Comp.2.13) and within the trench (Men1.trench.2.13). The analysis of surface composite soil collected at the site (Men1.dump.1.13) indicated the presence of dieldrin an indication of a possible contamination of subjects accessing the site. The presence of heavy vegetative cover within the site is an indication that the surface soil has organic matter in it thus it is able to bind any POPs present and make them less mobile. The physical properties of the detected POPs also contribute to their high concentrations in the soil. The results confirmed that the site is a contaminated area which requires a detailed assessment to ascertain the extent of contamination.

4.3 Results of Chemical Analysis of Soil Sample Collected at Menengai Dump Site 2

The results of composite surface soil (Men 2.Comp.1.13) sample collected at Menengai Dump Site 2 indicated the presence of lindane and diendrin (Fig 13).

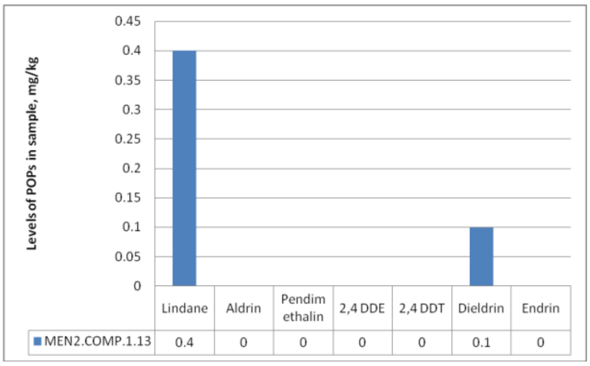

Figure 13: Level of Contamination of Menengai Site 2

4.4 Kitengela Store Site

4.4.1 List of Samples collected at Kitengela Pesticide Store Site

Table 3 below shows the list of soil and water samples collected from Kitengela Pesticide Store.

Table 3: List of samples collected at Kitengela Pesticide Store.

SN	Site	Sample Type	Sample Code	Description
	Kitengela	Soil	Kit/ Comp/1/13	Sample collected at the site
	Kitengela	Soil	Kit/ Comp/2/13	Sample collected at the grazing land across the road
	Kitengela	Soil	Kit/ Comp/3/13	Sample collected at the grazing land next to the site
	Kitengela	Soil	Kit/ Comp/4/13	Sample collected at residential area
	Kitengela	Soil	Kit/ pt/5/13	Point Sample collected at 171cm depth
	Kitengela	Soil	Kit/ pt/6/13	Point Sample collected at in the pit next to site
	Kitengela River Athi tributary	Water	Kit/w1/2013	Collected 300m east of the site

4.4.2 Residual Chemical Analysis Results

Figure 14 below shows a graph indicating the presence and levels of detected residual chemicals found in soil samples collected at Kitengela Pesticide Store. The graph shows the presence of the following POPs: lindane, aldrin, 2,4-DDE, 2,4-DDT, dieldrin, and endrin. Other pesticides detected were several pyrethroids, namely: bifenthrin, cispermethrin, transpermethrin, and alpha cypermethrin, pendimethalin (dinitroaniline herbicide), and permethrin.

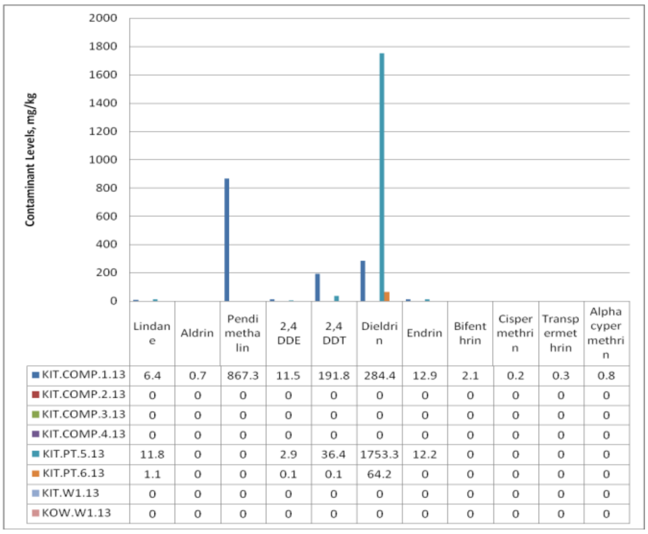

Figure 14: Presence and Levels of Residual Pesticides identified in Kitengela Pesticide Store

The composite soil sample collected at the hotspot indicated the presence of several POPs which included lindane, aldrin, pendimethalin, 2,4-DDE, 2,4-DDT, endrin, and dieldrin alongside bifenthrin, cispermethrin, transermethrin and alphacypermethrin pyrethroids. Water samples collected at the nearby river had levels of residual chemicals below the detection limits.

The hotspot is heavily contaminated with POPs as indicated by the levels of chemicals detected in composite surface soil collected at the site (Kit.Comp.1.13). The results also indicate high levels of dieldrin at soil depth of 171 cm (Kit.pt.5.13). There was no indication of residual chemicals at the area surrounding the hotspot and in water collected from the nearby stream.

4.5 Wajir Sites

4.5.1 List of Samples Collected at Wajir LMD

The list of samples collected at Wajir LMD site is presented in Table 4 below.

Table 4: list of samples collected at Wajir LMD site.

SN	Site	Sample Type	Sample Code	Description
	LMD Wajir	Soil	LMD.Comp.1.13	Hot spot (dam like area)
	LMD Wajir	Soil	LMD.Comp.2.13	Composite soil collected at the site next to chief office
	LMD Wajir	Soil	LMD.Comp.3.13	Composite soil collected at the site 2ft depth
	LMD Wajir	Soil	LMD.Comp.4.13	Composite soil collected at the residential area

4.5.2 Chemical Analysis Results of Samples Collected at Wajir LMD

The analysis of soil samples collected at LMD site did not indicate much of the POPs except aldrin, dieldrin and lindane whose levels were quite low as compared to the levels indicated in Menengai dump sites and Kitengela pesticide store contaminated areas although the levels were higher than the recommended levels of such pesticides in environmental matrices (0.03 mg/kg) (USEPA). The hotspot (dam like area) surface soil (LMD.Comp.1.13) did not show much of POPs except dieldrin except the soil collected at 100 cm deep LMD.Comp.3.13) indicated high levels of aldrin, dieldrin and lindane. The soil samples collected next to the chief's office (LMD.Comp.2.13) had dieldrin and lindane. The composite sample collected at the residential area (LMD.Comp.4.13) however indicated the highest level of dieldrin as compared to the other sampling points within LMD.

During the site visit, several homesteads are found within the LMD area with children, women and adults accessing the site at any time. Since there is a chief's office within the hotspot area, many people do access the site as they visit the administrative office. There is a playing field within the site which is often used by youth and children. The above is an indicative of high likelihood of dermal contamination of the local community. There were reports that there were several homesteads which are contaminated through soil which had been scooped from the hotspot and used in eradicating livestock pests.

There is strong evidence that the site is highly contaminated with POPs and due to the climatic conditions, physical characteristics of the soil and high population accessing the site, there is a need to carry out more investigations. The level of residual POPs in water samples collected at the well (within 300 m from the hotspot) was below the detection limit of the analytical method used.

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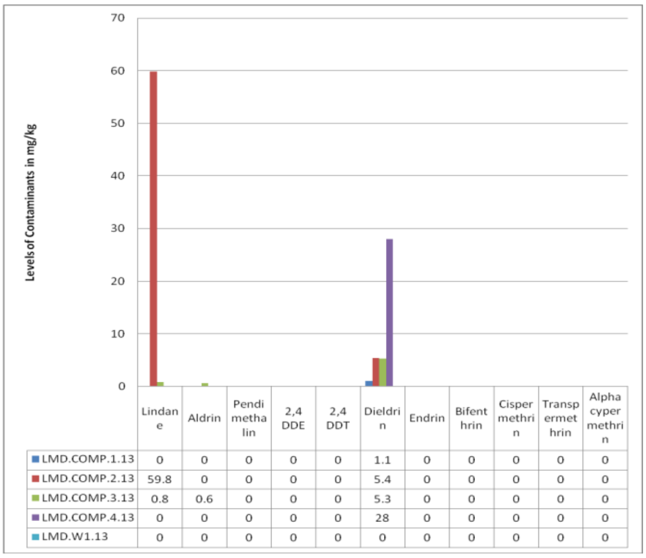

Figure 15: A graph showing the chemical results of analyzed soil samples of LMD.

4.6 Hotspot Site Prioritization

4.6.1 REA Model

Evaluating the risk posed by a contaminated site involves assessing hazards, receptors and exposure pathways. Since risk exists only when all three of these components are present, it is advantageous to use a multiplicative model as the REA rather than a summative model for assessing risk potential. The REA model is essential in facilitating the comparison of contaminated sites on the basis of the risks they pose. Hazard (contaminant), receptor and exposure pathway scores are developed under a methodological framework that reduces opportunities for judgmental bias. The weighted scores of the contaminated sites are used to categorize risk level. The model was therefore used to categorize and prioritize the visited sites and recommend the sites which require immediate detailed action. The model was used to ensure that the number of sites visited was managed in an efficient, effective, and environmentally and fiscally responsible manner. Table 5 below is a summary of the REA questionnaire items with their weighting.

Table 5 List of Items in the REA Questionnaire

Number on Questionnaire	Description	Weighting
Gi4	Previous land use	8
S1	Extent of staining	2
S2	Area of contamination	4
S3	Volume of contamination	9
S4	Spread of contamination into other media	6
S5	Smell of contamination	2
S6	Persistent nature of contamination	7
S7	Bioaccumulation of contamination	6
S8	Different number of classes of contaminants	6
S9	Ratio between the measured contaminant concentration and applicable guidelines	10
S10	Date that pesticides were last in use	5
S11	How were pesticides used? One off/occ./freq.	6
S12	Are pesticides still used	7
R1	Future land use	8
R2	Proximity of people from the site	3
R3	Proximity of people from the site within 50m	3
R4	Proximity of people from the site within 100m	3
R6	Poisonings at the site	7
R7	Exposure of plants and/or soil invertebrates	3
R8	Accessibility of site to wild animals	5
R9	Distance to sensitive marine or aquatic ecological area	5
R10	What is the distance to sensitive terrestrial ecological area	5
P1	Annual rainfall	5
P2	Windspeed	5
P3	Temperature	7
P4	Has the contamination been affected by the weather?	6
P5	Presence of surface water	6
P6	Evident high water table	7
P7	Depth to the top of the water table	6
P8	Site flooding	7
P9	Closest river or water body	6
P10	Closest well	7
P11	Groundwater flow towards receptors	9
P12	Soil type	5
P13	Infiltration	7
P14	Depth of soil to the strata beneath	6
P15	Bed rock type	6
P16	Relative position of the contaminant(s) to the slope?	5

P17	Contamination containment	9
P18	Site surface coverage	7
P19	Site disturbance	3
P20	Proximity to contaminated water for drinking / bathing	3
P21	Human ingestion of contaminated soils possible?	7
P22	Consumption of food generated from the site	7
P23	Grazing pattern	5
P24	Proximity of crops to the contaminated area	5
P25	Alternative water supply	8
P26	Dermal contact with contaminated surface water, groundwater, sediments or soils	7
P27	Vapor	6
P28	Soil particles size	5
P29	Dust exposure and distance to crops, animals or humans downwind of the site?	5
P30	Access to the contaminated area	6
P31	Reliance of local people on natural resources for survival	5
P32	Ground coverage	7

All these items gave a summary of the site geographical and climate conditions, site land use (current and in future), contamination history, sources of contamination present, pathways and receptors. The weightings are assigned according to the contribution the item gives to the risk assessment of the site to humans. All items which expose humans to humans are assigned higher numbers.

Table 6: Summary of Prioritization of the sites

Number	Name of Site	Source Score	Receptor Score	Pathway Score	Sum of Scores
1	Wajir_LMD	227	89	710.5	1026.5
2	Menengai_Crater_1	300	73	454.5	827.5
3	Kitengela	236	80	429.5	745.5
4	Menengai_Crater_2	199	73	468.5	740.5

Table 6 above shows the different weightings of the source of contamination, receptors and pathways and from the analysis of REA assessment exercise, Wajir LMD is rated number one with total REA assessment scores of 1026.5 followed by Menengai Crater 1 (827.5), Kitengela (745.5) and Menengai Crater 2 (740.5). The close proximity of receptors at Wajir LMD and several pathways for distribution of the contaminants (water, dermal contamination, air transportation of dust etc) made Wajir LMD to be the most highly risk area followed by Menengai Crater 1. Menengai Crater Dump site 1 scored highly on source due to the high levels of POPs found in the site. There is a high possibility of dermal contamination of the people who visit the site and the animal products of the livestock grazing at the site could be a major source of human contamination with POPs.

5. CONCLUSIONS

The purpose of the site assessments was to identify the existence, source, nature, and extent of POPs contamination of Menengai Crater, Kitengela and Wajir dump sites. From the residual chemical analysis of samples collected, the sites are heavily contaminated with residual POPs (lindane, aldrin, dieldrin, 2,4-DDE, 2,4-DDT, and endrin) and other residual pyrethroids (bifenthrin, cypermethrin, pendimethalin, and permethrin) beyond the set International Standards for such residual pollutants in the environment (USAEPA, Dutch Intervention POPs Levels)(< 0.05 mg/Kg). Menengai Crater 1, Kitengela and Wajir LMD indicated quite high levels of the POPs. The levels of POPs recorded in the analysis are indicative of potential contamination of humans and animals and thus posing a great environmental threat. The pollutants are able to pollute surface and ground water sources, contaminate surface soil both on site and away through long range dust transportation.

The analysis of REA questionnaire indicated that Wajir LMD site was the most at risk followed by Menengai Crater Dump Site 1, and Kitengela respectively. Wajir LMD was the most at risk site due to the proximity and easy access to the site by human beings and thus poses a great health threat to the local community members living and accessing the site.

There was strong evidence of both horizontal and vertical POPs contamination in all sites. The proximity of receptors such as homesteads and drinking water sources (at Wajir LMD and Kitengela) to the contaminated sites, strongly indicate that the sites are potential human hazard and detailed investigations should be put in place to ascertain the extent of contamination.

Potential concerns of the visited contaminated sites include but not limited to threatened water supply, impaired indoor air (vapor intrusion as in Wajir LMD) that can be an elevated threat to children, pregnant women and all community members at such sites. Flooding water and wind storms in Wajir are other "preferential pathways" that can alter and exacerbate the migration of pollutants in the sites. Current and future use of the sites is of concern as most of the areas may be inhabited by humans and can also be used as underground water sources and with the evidence of vertical soil contamination in some sites (Menengai and Kitengela), the sites can create human POPs contamination catastrophe if urgent attention is not put in place.

The study proved with great certainty that the visited sites are heavily contaminated with POPs and measures to reclaim and remediate the sites to avoid future human health and environment catastrophe should be put in place.

6. RECOMMENDATIONS

The following are the specific recommendations from the preliminary site prioritization study carried out:

i) Mapping the extent of contamination through extensive soil and water sample analysis within Menengai 1 & 2, Wajir LMD and Kitengela sites. This should be done during detailed site investigation visits.

ii) Measures that will restrict human and animal access to the sites (Wajir LMD, Menengai 1&2, and Kitengela) should be considered as a matter of urgency to control access to the areas contaminated.

iii) Mapping of households in Wajir LMD affected by the present contamination.

iv) Determination of contaminated soil volume(s) within each site should be established in the detailed site investigation visits

v) Establishment of presence and levels of such POPs in water sources (wells) found in Wajir LMD site by use of alternative technology (like the use of passive solid phase gadget).

vi) A project should be initiated to focus on the impact of the found POPs contamination in humans living in Wajir LMD.

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