ENVIRONMENTAL POLLUTION AND IMPACT TO PUBLIC HEALTH

IMPLICATIONS OF THE DANDORA MUNICIPAL DUMPING SITE IN NAIROBI, KENYA

Environmental Pollution and Impact to Public Health;

Implication of the Dandora Municipal Dumping Site in Nairobi, Kenya.

A PILOT STUDY REPORT

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In cooperation with

THE UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP)

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Cover Photo:
Korogocho Children dancing during the Children day and inhaling toxic smokes from the Dandora dumpsite.
Courtesy of Andrea Rigon

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We had anticipated some tough and worrisome findings, but the actual results are even more shocking than we had imagined at the outset.

Achim Steiner, UNEP Executive Director

Executive Summary

Environmental factors are a major contribution to the global disease burden. According to the World Health Organisation (WHO), a quarter of the diseases afflicting mankind are as a result of modifiable environmental risks. Most of the environmentally related diseases are not easily detected and may be acquired during childhood and be manifested later in adulthood. As a result, misdiagnosis and mismanagement of environmental related illness may have occurred in numerous cases.

Indiscriminate handling and disposal of waste from various industrial and domestic activities are major contributors of environmental pollutants that pose risks to human health. Although global, the problem of waste disposal is more pronounced in the developing nations and the social-economically underprivileged are most vulnerable.

The Dandora waste dumping site is a major disposal site of waste generated from various activities in Nairobi. There has been concern over the health implications of this dumping site from numerous quarters.

A pilot study was done to determine the impact to the environment and public health attributed to the Dandora waste dumping site.

Environmental samples (soil and water) were analysed to determine contents and concentrations of elements, polychlorinated biphenyls (PCBs) and pesticides. Biological samples (blood and urine) were analysed to determine several health indicators.

High levels of toxic heavy metals were noted in the Dandora soil samples. Health wise, 50% of the children were found to be having blood lead levels above 10 micrograms per deciliter of blood indicating exposure to high levels of environmental lead. The haematological system of most of the children is suppressed with 12.5% having haemoglobin levels below the normal ranges.

The results obtained indicate high potential risk both to the environment and human health that can be attributed to the Dandora municipal waste dumping site. Further studies and placement of appropriate intervention measures are recommended.

Photograph 1 The Dandora Municipal Dumpsite burning at night. The toxic smokes are a 24 hours a day hazards for about 900,000 residents of the area. Courtesy of Andrea Rigon.

CHAPTER 1
1. Introduction

1.1 Background Information

Global concern over the impact to public health attributed to environmental pollution has increased over the last three decades. At the United Nations Conference on Environment and Development (UNCED-1992), it was generally agreed that an expanding human population coupled with insufficient and inappropriate development results to severe environmental health problems in both developing and developed Nations.[1] Living in healthy environmental conditions has been acknowledged as a key indicator towards attainment of utmost human health. According to the World Health Organisation (WHO), some 3.5 billion people are exposed to high levels of air pollutants which the World Bank defines as one of the four critical Public Health problems worldwide.[2] A report by the WHO on the global disease burden indicates that 24% of the disease burden is attributable to environmental factors.

Key environmental factors mentioned to have great contribution to public health include pollution of air, water and soil resulting to potential exposure to chemical or biological agents in the form of toxic heavy metals, endocrine disruptors, carcinogens or airborne particulates. These environmental pollutants contribute or worsen various ailments such as upper and lower respiratory tract abnormalities, cardiopulmonary diseases (diseases affecting the heart and lungs), various forms of cancers, asthma, chronic obstructive pulmonary diseases (COPD), to mental and developmental retardation.[3] [4]

Although environmentally related health problems affect people of all ages and from all sectors, children are more vulnerable than adults.[3] [5] Among children below five years, environmental related illnesses are responsible for more than 4.7 million deaths annually.[6] The proportion of deaths related to the environment in children aged between 0-14 years is 36%. 25% of deaths in developing nations are related to environmental factors while in the developed regions; only 17% of deaths are attributed to the environment.[3]

The recognition on the great risk to children's health from the environment resulted to the WHO appeal for a global movement to create healthy environments at the World Summit on Sustainable Development (WSSD) in Johannesburg 2002.[7]

Although environmentally related health problems affect people of all ages and from all sectors, children are more vulnerable than adults.

This initiative has resulted to various conferences and workshops highlighting issues concerning children's health and environment. In proceedings of a Workshop on Children's Health and the Environment for African Paediatricians and Health Care Providers organized by the UNEP, WHO and International and the local Pediatricians Association (IPA, KPA) in Nairobi in 2005, it was recognized that in developing countries, the main environmental problems affecting children are exacerbated by poverty, illiteracy and malnutrition, and include indoor and outdoor air pollution, exposure to hazardous chemicals, accidents and injuries. Furthermore, as countries become industrialized, children become exposed to toxicants commonly associated with the developed world, creating an additional environmental burden of disease.

Acute intoxication may cause easily discernable signs and symptoms but which would be confused for other illnesses while chronic exposure to low doses of any particular toxin may not be suspected as most of the effects are subclinical (cannot be diagnosed easily by observation of clinical signs or symptoms). Thus, it was observed that emphasis and training of

medical personnel on the recognition, diagnosis and management of environmentally related diseases is required.[4 8]

1.2 Solid Waste Management, Environmental Pollution and Impact to Public Health

Solid waste is any non-fluidic/non-flowing substance that has been identified to be of no use at a particular point or source either as a raw material, end product, expired products, containers or after use remnants. Solid waste is generated from various human activities such as domestic, hospital, industrial and agricultural activities.

o **Domestic waste** is that waste that originates from homes and may range from remnants of/or expired foods to household chemicals, various forms of packaging materials, electrical instruments and utensils,
o **Industrial waste** may consist of falloff or unused chemicals/raw materials used in manufacturing processes, expired products and substandard goods,
o **Agricultural waste** may be chemicals used as pesticides (herbicides and fungicides) and unwanted agricultural products,
o **Hospital waste** includes among others packaging materials and containers, used syringes and sharps, biological waste, and pharmaceuticals.

Depending on the source, the waste may be of no risk, infectious, toxic or radioactive. Waste generated from different sources is disposed of in various ways and some may require special handling and disposal. Most of the waste disposal systems used includes landfills, dumping in a specified location (waste dumping sites), burying in pits, open air burning, incineration or discarding into rivers and large water bodies (ocean and seas).

Waste management poses a great challenge due to potential pollution of water sources, food sources, land, air and vegetation.

The indiscriminate disposal and handling of waste, leads to environmental degradation, destruction of the ecosystem and poses great risks to public health. Municipal waste dumping sites are designated places where waste from various sources is deposited onto an open hole or ground.

In most cases, due to lack of regulations and proper disposal facilities in places generating waste, most of the waste is disposed off into dumping sites. As such, different types of waste find their way into a particular dumping site which exposes the surrounding community to various environmental hazards.

Municipal waste dumping sites have been recognized as a major source of environmental toxicants (ETs) that are of great risk to human health.[9] Major environmental pollutants from waste dumping sites may include heavy metals and persistent organic pollutants (high production volume chemicals, polychlorinated biphenyls, dioxins and furans).

The indiscriminate disposal and handling of waste, leads to environmental degradation, destruction of the ecosystem and poses great risks to public health.

1.2.1 Heavy metals

Heavy metals are metallic elements that are present in both natural and contaminated environments. Heavy metals of public health concern include Lead, Mercury, Cadmium, Arsenic, Chromium, Zinc, Nickel and Copper. Heavy metals may be released into the Environment from metal smelting and refining industries, scrap metal dealers, plastic and rubber industries, several consumer products and burning of waste containing heavy metals. On release to the air, the elements travel for large

distances and are deposited onto the soil, vegetation and water depending on their density. On deposition, the heavy metals are not degraded and persist in the environment for many years. Among the heavy metals, lead is one of the most widely distributed and largely found in municipal dumping sites where lead containing waste is deposited or burning of waste containing lead (e.g. plastics, rubber, painted/ lead paint treated wood e.t.c.) is done.

Heavy metals and their compounds have different physical and chemical characteristics and poses diverse toxicological characteristics.

Human beings get poisoned through inhalation, ingestion and skin absorption. Acute exposures to high levels cause nausea, anorexia, vomiting, gastrointestinal abnormalities and dermatitis. Chronic exposures to heavy metals cause cumulative toxic effects which affect various systems in the body depending on the heavy metal involved.[10]

Major heavy metals known to be detrimental to human health are presented in Table 1.

Table 1. Toxic Heavy Metals with established health effects

Heavy Metal	Sources of Environmental exposure	Minimum Risk level	Chronic exposure toxicity effects
Lead[11]	Industrial and vehicular emissions, paints and burning of plastics, papers etc	Blood lead levels below 10 micrograms per decilitre of blood	Impairment of neurological development, Suppression of the haematological system (anaemia), Kidney failure, immunosuppression etc.
Mercury[12]	Electronics and plastic waste, pesticides, pharmaceutical and dental waste	Below 10 micrograms per deciliter of blood; oral RfD 4mg/kg/day	Gastrointestinal and respiratory tract irritation, renal failure, neurotoxic
Cadmium[13]	Electronic, plastics, batteries-diet and water	Below 1 microgram per decilitre of blood	Local irritation of the lungs and gastrointestinal tract, kidney damage and abnormalities of skeletal system
Arsenic[14]	Herbicides and pesticides, electronics, burning of waste containing the element, contaminated water	Oral exposure of 0.0003mg/kg/day	Inflammation of the liver, peripheral nerve damage-neuropathy, cancer of liver, skin and lungs, irritation of the upper respiratory system-pharyngitis, laryngitis, rhinitis, anaemia, cardiovascular diseases

1.2.2 Persistent organic pollutants (POPs)

These are long-lasting non-biodegradable organic compounds that bio-concentrate in the food chain especially fish and livestock and pose serious health risks to human populations. They do not dissolve in water but are readily stored in fatty tissue. These substances accumulate in human fatty tissue and may be passed to infants through breast milk.

Under the POPs treaty (the Stockholm Convention on Persistent Organic Pollutants), chemicals such as aldrin, dieldrin, dichlorodiphenyl-trichloroethane (DDT), endrin, heptachlor, toxaphene, chlordane, hexachlorobenzene, mirex (high production volume chemicals and Pesticides:- Organochlorines, Organophosphates, carbamates) and polychlorinated biphenyl's (polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are to be phased out and eliminated.[4,10,15,16,17]

Polychlorinated biphenyl's (PCBs) are synthetic organic compounds that are either solids or liquids and are colorless or light yellow. During production of PCBs, highly toxic substances known as Dioxins and Furans are produced. Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated

dibenzofurans (PCDFs) commonly referred to as dioxins may also result from low combustion of materials containing PCBs such as plastics, rubber and paper products.

Human beings absorb PCBs, Dioxins and Furans by inhalation, ingestion and absorption through the skin. PCBs, PCDDs and PCDFs has been associated with endocrine disruption (interfere with the body's hormonal signaling system), developmental toxicity, low IQ scores and risks of development of cancers.[4,5,16,17]

1.3 The Dandora Municipal Waste Dumping Site

The Dandora Municipal waste dumping site is a major dumping site located at the East of Nairobi in Kenya. The dumping site is about 8 kilometers away from the city centre and occupies about 30 acres of land. Surrounding the dumping site, are the Kariobangi North and Korogocho slums and low income earners residential estates of Dandora and Babadogo.

Over 2000 tonnes of waste generated and collected from various locations in Nairobi and its environs are deposited on a daily basis and what initially was to be refilling of an old quarry has given rise to a big mountain of garbage.

To create room for more waste, an earth mover is on site to spread the waste and some of the waste end up being pushed to the Nairobi River (Photograph 1). This extends the risk potential to communities living downstream who could be using the water for domestic and agricultural purposes.

Some members of the research team developed respiratory and abdominal irritation and/or experienced long period of fatigue and inactivity due to exposure to this environment.

In the process of the study, the study team experienced the poor air quality that was full of noxious/pungent fumes and choking smoke

Photograph 2 An earth mover on site at the Dandora waste dumping site

Photograph 3 Smoke emanating from the Dandora waste dumping site hangs over residential estates at the background.

emanating from the dumping site as a result of deliberate waste burning and methane fires. Most of the time, the entire area is engulfed by crowds of black smoke (photograph 2).

Some members of the research team developed respiratory and abdominal irritation and/or experienced long period of fatigue and inactivity due to exposure to this environment.

Dumping at the site is unrestricted and industrial, agricultural, domestic and medical wastes (especially used needles) are seen strewn all over the dumping site.

Movement into and out of the dumping site is unrestricted and scores of people are on site scavenging for food products and other valuables that they later sell to others as a source of income (photograph 3). Other people sort out the waste for recycling and compost generation. The compost is sold to potential customers for use in farming. Several people reside inside the dumping site which also harbors criminal elements. Domestic animals such as pigs, cows and goats forage through the waste for feeds.

Apart from the community around the dumping site being exposed to dangerous environmental pollutants in the environment and consumption of contaminated foodstuff, people far off are also at risk of exposure by consumption of meat or poultry products as well as vegetables cultivated using compost from the site.

Residents of Dandora, Korogocho and Kariobangi estates, religious and non religious organizations, the Health Ministry and other arms of the Government have had concern over the possible risk to human health that could be attributed to the dumping site. Despite this, waste dumping continues unabated and appropriate preventive measures that would reduce the impact to the environment and human health are yet to be undertaken.

According to records obtained from the Catholic Church dispensary at Kariobangi, for the period between 2003 and May 2006, an average 9121 people per annum had been treated for respiratory tract related problems at the center. To many of the residents and local health care providers, these abnormalities are exacerbated by the environment around the dumping site. The people are also at risk of contracting blood borne diseases such as HIV

Photograph 4 Children scavenging for valuables at the Dandora waste dumping site.

and hepatitis through accidental injury by used needles and other medical waste.

Table 2 shows records for the period between January 2003 and May 2006 from the dispensary on patients treated for respiratory tract problems at the Catholic Church dispensary.

People far off are also at risk of exposure by consumption of meat or poultry products as well as vegetables cultivated using compost from the site.

Although the need to move the dumping site away from its current site has been recognized, **the biggest contributing factor to the poor environment is the management of the dumping site.**

Table 2. Patients treated for respiratory tract abnormalities at the catholic Dispensary-Kariobangi

Month	2003	2004	2005	2006
January	978	837	890	927
February	901	868	803	701
March	1023	740	1257	1375
April	895	831	940	851
May	885	921	967	975
June	1121	856	1371	
July	1090	919	989	
August	986	581	1067	
September	1111	613	570	
October	956	782	1081	
November	987	698	790	
December	65	534	752	
Total	10998	9180	11477	4829
Monthly average	917	765	956	966

Source: Medical records at the Catholic Church Dispensary at Kariobangi North 2003-2006

While the relocation has been hampered by lack of a suitable place for relocation on the one hand and individuals who earn a living from the dumping site on the other, the dumping of waste goes on unregulated.

Even if the dumping is halted forthwith and relocation effected, its long term effects will continue to be felt by the communities living around as most of the toxic substances persist for long in the environment.

At the same time, in absence of appropriate knowledge on effects of dumping, lack of policies regulating waste disposal and failure to enhance any existing policies, relocation could result to a transfer of the problem to others who would encroach on the dumping site and failure to input preventive measures against adverse effects both to the environment and public health.

This calls for urgent measures towards appropriate management of the dumping site.

Photograph 5 A pig rests in the Nairobi River at the edge of the dumpsite. Animals eat toxic waste creating an health hazard for the humans consuming their meat. Courtesy of Andrea Rigon.

1.4 Objectives of the Study

1.4.1 Broad objective

Carry out a pilot study to establish impact to the Environment and Public Health that can be attributed to the Dandora waste dumping site.

1.4.2 Specific objectives

o Evaluate the environmental impact of the dumping site to the surrounding areas through determination of the contents and concentrations of elements, polychlorinated biphenyls/dioxins and pesticides in environmental samples,

o Determine the effects of exposure and the health status of children through clinical and laboratory analysis,
o Show a cause effect relationship of the environmental pollutants and children's health,

o Determine areas of focus and allocation of resources in implementation of a comprehensive study.

1.5 Significance of the study

Results obtained from this study will be integral in providing more knowledge to health care providers on environmental factors and their contribution to ill health that will be an indicator to appropriate intervention towards prevention and reduction of the disease burden and cost to the health care system. **The information is also relevant to non-health authorities who influence policies with an impact to the environment** such as the National Environment Management Authority (NEMA), the City Council and Ministries of Planning/Development and Housing.

The findings will be part of UNEP's database on the environment and impacts to human health and will be useful as an Africa case study. The study will also be integral in providing information on the availability and requirements in technology and skills for carrying out major studies on environmental and health issues within our setup.

A pilot study has been conducted at the environs of Dandora waste dumping site on the environmental pollutants and children living at the neighbouring estates.

UNEP funded and supported the study that was conducted in collaboration with the St. John Catholic Church in Korogocho. Health experts and Scientists drawn from the University of Nairobi-College of Health Sciences and Institute of Nuclear Science, Kenyatta University-School of Pure and Applied Sciences, Kenyatta National Hospital and the Kenya Agricultural Research Institute played various roles individually and collectively in implementation of this study. This report details the findings of the pilot study.

Box. 1 Update of Table 2. (2009 data).

Patients treated for respiratory tract abnormalities at the catholic Dispensary-Kariobangi.

As it can be observed by comparing these data with Table 2., the situation in the area affected by the dumpsite has worsened. Looking at the monthly average, there is a shocking 440% increase of patients between 2004 (765) and 2009 (3356). In the second part of 2009, dumping at Dandora Municipal Dumpsite has increased to unprecedented levels.

Month	2009
March	3015
April	2382
May	2999
June	4116
July	4894
August	2731
Total (6months)	20137
Monthly average	3356

Source: Medical records at the Catholic Church Dispensary at Kariobangi North 2009

CHAPTER 2
2. Methodology and Results

2.1 Environmental Evaluation

Environmental exposure assessment was done by analysis of soil, compost and water samples collected at the Dandora waste dumping site and its environs. Soil samples were also taken from Waithaka (a rural-urban estate of Nairobi) for the purpose of comparison. A physical environmental assessment was done at the Dandora waste dumping site and at the covariate study area prior to the collection of environmental samples to determine the locations that were suitable for sampling. The sampling sites at the Dandora waste dumping site were selected in a cross-sectional way from a site adjacent to the St John informal school in Korogocho, through the dumping site and to a site at the periphery of the dumping site next to Dandora Estate (Annexure 1).

2.1.1 Collection of soil samples and compost sample

Soil samples were taken using a soil Auger in five locations neighbouring the dumping site. Where possible and depending on how deep the soil Auger would go into the soil, the samples were obtained in three profiles; i.e. of surface (0-20cm), 20-40cms and 40-60cms. Surface soil sample was obtained at site 1, profiles 0-20cms and 20-40cms were obtained at sampling site number 3 and all three profiles were obtained at sampling sites 2, 4 and 6. A total of twelve soil samples were thus obtained from the neighborhood of the dumping site. The profiling was done to determine any difference in deposition of elements based on depth. The positions from which the soil samples were obtained from this locality were marked using Geographical Positioning System (GPS).

A single compost sample was taken from the dumping site and two surface soil samples were taken from Waithaka. Details of the soil sampling are further indicated in annexure 2a.

2.1.2 Collection of water samples

Water samples were drawn from a slow flowing part of the Nairobi River at a point bordering the dumping site and from a water logged quarry adjacent to the river. The water samples were dispensed into appropriate plastic containers (annexure 2a).

2.1.3 Analysis of environmental samples

The soil and water samples were sent to the Institute of Nuclear Sciences laboratory at the University of Nairobi (INS-UON) for elemental analysis and the Kenya Plant Health Inspectorate Services (KEPHIS) for pesticides screen and determination of the concentration of polychlorinated biphenyls (PCBs).

2.1.3.1 Elemental concentration

Elemental concentrations were determined using an Energy Dispersive X-Ray Fluorescent (EDXRF) system. The EDXRF is a multi-elemental detector that gives the concentration of various elements in a single sample. The results obtained were reported in parts per million (ppm).[18]

Cadmium was analysed using atomic absorption spectrometry (AAS) at the Kenya Agricultural Research Institute (KARI) since the EDXRF could not determine the element as the source of the EDXRF primary X-rays is made of cadmium. The determination of cadmium was carried out following the methods of soil analysis used at KARI.

2.1.3.1.1 Elemental concentration of soil samples

The soil samples for elemental analysis using EDXRF system were individually homogenized by physical mixing, air dried, grinded into fine particles and made into pellets using cellulose as the soil binder. Three pellets were prepared and analysed for each soil sample. The mean elemental concentration of the three pellets was taken as the final elemental concentration.[18]

For the determination of Cadmium, surface soil samples and below surface soil samples were pooled and analysed as single samples respectively.

2.1.3.1.2 Elemental concentration of water sample

Water samples for EDXRF were prepared by mixing with sodium diethyldithiocarbamate (NaDDTC) to precipitate the metal ions. On addition of 100 micrograms of cadmium to act as a carrier, 1.5% Ammonium Pyroldine Dithiocarbonate (APDC) was added to complex the free metal ions in the solution. The precipitate formed was collected on a 0.45 micrometer nucleophore filter by vacuum filtration which was then air dried and presented to the EDXRF for analysis.[18]

2.1.3.2 Determination of pesticides and polychlorinated biphenyls

Two soil and two water samples were taken to the Kenya plant health inspectorate for the determination of pesticides (organochlorines, organophosphates and carbamates) and polychlorinated biphenyls using chromatographic methods.

Soil samples for the determination of pesticides and PCBs were prepared according to the KEPHIS protocol and procedures for Gas Chromatography. Preparation of water samples for the determination of pesticides and PCBs was done according to the KEPHIS protocol and procedures for Gas Chromatography.

2.1.4 Results of environmental samples

To ensure reliable results for the analysis of environmental samples, the quality control and assurance protocols according to respective analyzing laboratories were followed. Appropriate analytical systems calibration was done and quality control materials were analysed prior to sample analysis.

2. 1.4.1 Elemental concentration (ppm) in soil samples

The concentrations of : - Potassium (K), Calcium (Ca), Titanium (Ti), Vanadium (V), Chromium (Cr), Manganese (Mn), Iron (Fe), Copper (Cu), Zinc (Zn), Arsenic (As), Mercury (Hg), Lead (Pb), Rubidium (Rb), Selenium (Sr), Tholium (Th), Zuridium (Zr) and Nubidium (Nb) in the soil samples were obtained on analysis by the EDXRF system.

Total elemental concentrations for trace elements and heavy metals obtained for individual soil samples from Korogocho/Dandora are as indicated in annexure 2b. Table 3 presents the elemental concentrations in soil samples obtained from specific sampling sites at the neighborhood of the dumping site. Cadmium (Cd) levels as obtained by the AAS analysis are also included.

Table 3 Elemental concentration in soil samples from specific sampling sites of Dandora and Korogocho

Elements	Elemental concentration in Dandora soil samples in ppm				
	E1♠	E2§	E3♪	E4§	E6§
K	19000	22400	25250	21600	15866
Ca	51300	6566	15450	8833	15433
Ti	6000	5033	6450	5633	4767
Cr	BDL	103	BDL	201	110
Mn	5900	3433	3900	4233	5233
Fe	46900	40800	58350	50066	37800
Cu	118	BDL	80	49	198
Zn	1150	280	770	360	312
Hg	BDL	BDL	18.6	BDL	BDL
Pb	185	66	453	560	68
As	BDL	BDL	BDL	BDL	BDL
Cd*	Surface- 52.9			Subsurface- 26.5	

♠ Actual results for the single sample profile analysed
♪ Mean of two sample profiles analysed
§ Mean of three sample profiles obtained
BDL- Below detection limit- Copper (Cu) - 15 ppm, Chromium (Cr)-70 ppm, Mercury (Hg)-15 ppm
* Analysis of pooled samples done by Atomic absorption spectrometry (AAS)

The range and mean concentrations of elements in the total soil sample from Dandora and Korogocho are shown in Table 4. Among the heavy metals, Hg

was detected in the second sample (20-40 Cms depth) from sampling site number three. The rest of the samples had Hg levels below the detection level of 15 ppm. The concentration of Pb in the soil samples ranged from 50-590ppm (mean of 264±229 ppm) and Pb was present in all soil samples analysed. 42% (n = 5) of the soil samples had levels above 400 ppm. Only one of the soil samples had Pb levels of 50 ppm while the rest had Pb concentrations above 60 ppm. The highest concentration of heavy metals in the soil samples was that of Zinc (Zn) of which the lowest and highest concentrations were 175 and 1150 ppm respectively with a mean concentration of 574±378 standard deviation. Cd levels (mean 40±18 ppm) obtained for the surface and subsurface soil samples were 52.9 and 26.5 ppm respectively.

Table 4 Mean total elemental concentration of soil samples from Dandora/Korogocho

Element	Range (ppm)	Mean (Standard deviation in parenthesis)
K	11200-27500	20758 (5499)
Ca	4800 -51300	14558 (12764)
Ti	3700 -7200	5433 (1176)
Cr	BDL - 272	157 (61)
Mn	3000 -6600	4366 (1098)
Fe	30600 -59200	45800 (9177)
Cu	BDL - 198	105 (58)
Zn	175 -1150	462 (287)
Hg	BDL - 18.6	18.6
Pb	50 - 590	264 (229)
Cd	27 -53	40 (18)

Results for total elemental concentration in soil samples obtained at Waithaka were as presented in Table 5. The levels of Iron (Fe) were the highest at 57700 ppm. Cu, As and Hg were below detection levels of the EDXRF system. The mean concentration of Pb and Zn in the Waithaka soil samples EC1 and EC2 were 34.5 and 133 ppm respectively. The concentration of Cd in Waithaka soil samples was not determined.

Table 5 Elemental concentration in Waithaka soil samples

Elements	EC1	EC2	Mean ± Standard deviation
K	10000	5670	7835± 3061
Ca	5900	2700	4300± 2262
Ti	6000	5300	5650± 495
Cr	132	104	118± 20
Mn	2900	1900	2400± 707
Fe	57700	56500	57100± 848
Cu	BDL	BDL	BDL
Zn	144	122	133±15.6
As	BDL	BDL	BDL
Hg	BDL	BDL	BDL
Pb	35	34	34.5±0.7

2.1.4.1.1 Comparison of the concentration of heavy metals in Dandora/Korogocho and Waithaka soil samples and established soil standards.

The concentrations of Pb, Hg, Cr, Zn and Cd obtained for the soil samples from Dandora/Korogocho/dumping site in comparison to the concentration of soil standards of the Netherlands and Taiwan, and elemental concentration of soil samples from Waithaka are indicated in Table 6 and Figure 1.

Heavy metals concentration in the soil samples from the Dandora/Korogocho waste dumping site significantly varied from the concentration in the soil standards and soil samples from Waithaka.

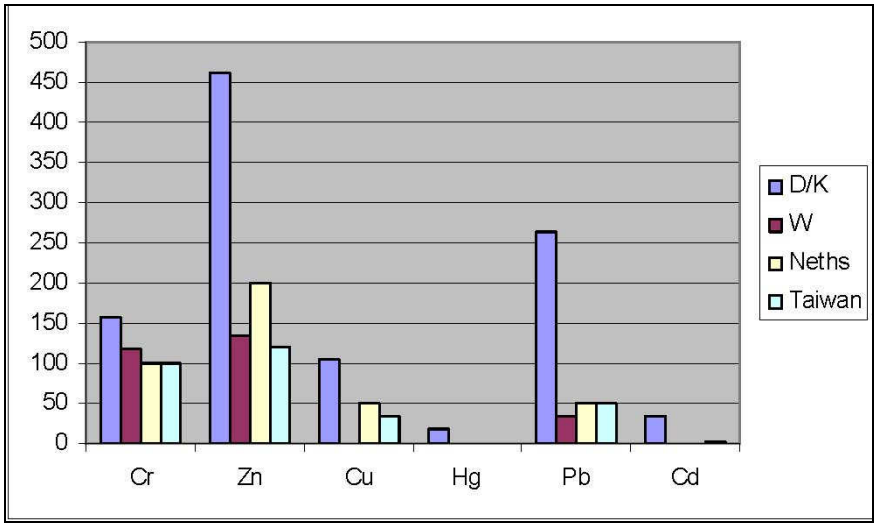
Table 6 Heavy metal concentrations (ppm) in the study's soil samples and soil standards

Element	Heavy metal concentrations in the study soil samples		Reference values in soil standards	
	Dandora/ Korogocho	Waithaka	Neths.[§]	Taiwan[♪]
Cr	BDL (< 70)-272	104-132	100[1]/250[2]	100[A] 400[B]
Zn	175-1150	122-144	200[1]/500[2]	120[A] 500[B]
Cu	BDL (< 15)-198	BDL (< 15)	50[1] 100[2]	35[A] 200[B]
Hg	BDL (< 15)-18.6	BDL (< 15)	0.5[1] 2[2]	0.29[A] 2[B]
Pb	50-590	35	50[1]/150[2]	50[A] 500[B]
Cd	27-53	Not analysed	1[1] 5[2]	2[A] 5[B]

[§] Tentative soil quality standards for Netherlands. [1] Reference value for good soil quality. [2] Limiting value for soil quality having potential for harmful effects on human health or the environment and requiring further investigations.[21]

[♪] Taiwan's standard values to assess soil quality. A The upper limit of the background concentration. B The intervention level at which pollution control is recommended.[22]

Figure 1 Heavy metal concentrations in the study's soil samples and soil standards



2.1.4.2 Compost sample

Elemental concentrations of the compost sample from the dumping site are indicated in Table 7. Iron (Fe) was the element with the highest concentration in the compost sample. Heavy metals (Pb, Hg, Zn, Cd and Cu) were detected in high levels in the compost sample of which Pb was the highest at 13500 ppm while Hg was the lowest at 46.7 ppm. Arsenic was not detected in the compost sample.

Table 7. Elemental concentration in the compost sample from the Dandora waste dumping site

Elements	Elemental concentrations in ppm	Elements	Elemental concentrations in ppm
K	19100	Cu	507
Ca	77000	Zn	2100
Ti	6100	Hg	46.7
Cr	689	Pb	13500
Mn	3500	As	BDL
Fe	84800	Cd	1058

2.1.4.3 Elemental concentration in water samples

Table 8 indicates elemental composition of water samples from Dandora/Korogocho/dumping site. No elements were detected in the water sample from the Nairobi river point of sampling but manganese (Mn), iron (Fe) and copper (Cu) were detected in low concentrations in the water sample obtained from the pool. The levels of Cu obtained were below a guideline value of 2mg/litre23 and the Netherlands water quality standards.[21]

The elements (excluding copper) detected in the water sample from the pool comprises the total dissolved solutes (TDS) in water and no guideline values have been developed for the TDS based on possible health effects.

Table 8 Elemental concentrations of water samples from Dandora /Korogocho /waste dumping site

	Elemental concentration in Dandora water samples		Reference values for water standards	
Elements	E21	E22	Neth.♪	WHO§
Mn	Not detected	2.81	Not established	Not established
Fe	Not detected	0.52	Not established	Not established
Cu	Not detected	0.009	20[1]/50[2]	2

♪Tentative water quality standards for Netherlands.[1] Reference value for good water quality. [2] limiting value for water quality having potential for harmful effects on human health or the environment and requiring further investigations (VROM 1983).

§Guidelines for drinking water quality, 3rd edition. Geneva, World Health Organisation 2004 (www.who.int/docstore/water-sanitation-health/gdwq/updating/draftguidel/draftchap1.htm).

2.1.4.4 Results of PCBs and pesticides in environmental samples

No polychlorinated biphenyls and pesticides were detected in the soil and water samples that were presented for analysis (Annexure 3a).

2.2 Biomonitoring and Health Effects

The laboratory based assessment of human exposure to environmental toxicants and determination of effects to human health was done by analysis of blood and urine samples obtained from children and adolescents living at the neighborhoods of the Dandora waste dumping site. A Medical Camp was conducted in collaboration with Medical teams from the Kenyatta National Hospital Pediatrics' Department and the University of Nairobi Division of Pediatrics and Child Health at the St. John Catholic Church and Informal School in Korogocho to facilitate the process.

2.2.1 Clinical evaluation

328 Children and adolescents aged 2 to 18 years were attended to at the medical camp. Male and females comprised 48% (n=158) and 52% (n=170) of the sample respectively. Demographic data (age, sex, residence) and brief Medical histories of the children were obtained from accompanying Parents or Guardians. Appropriate clinical/physical examination of the children was done and the following presentation or manifestations were recorded in a standard form:-

- **lack or inadequacy of blood (anaemia),**
- **yellowness of the eyes or skin (Jaundice) and hair changes,**
- **inflammation of the lymph nodes (Lymphadenopathy),**
- **Swelling of body or limbs (oedema).**
- **Disorders of the respiratory, cardiovascular (heart and blood circulation) and neurological (nervous) systems,**
- **Skin disorders,**
- **Ear, Nose and Throat, Dental and Ophthalmic (eye) status.**

The children were randomly sent for laboratory examination but focus was placed on those presenting with organomegally (enlargement of body organs), skin and respiratory disorders. A total of 40 (13%) children/adolescents were referred for laboratory investigations.

2.2.1.1 Post-Clinical evaluation analysis

Information on the Medical status of the children obtained during the clinical/physical examination was analysed to determine the case presentations. Most of the children complained and were diagnosed of more than one condition. Table 9 details the various clinical presentations encountered.

Table 9 Clinical presentations of children attended to at the St John Informal School Medical Camp

System affected	Specific Condition	No. of children affected	%with disorders
Dermatological (skin disorders)	o Fungal infection o Allergic Dermatitis o Unspecified Pruritis	48	14.5
Respiratory	o Bacterial URTIs o Chronic Bronchitis o Asthma	154	46.9
Gastroenteritis (GE) (abdominal and intestinal problems)	o Bacterial Enteritis o Helminthiasis o Amoebiasis o Unspecified GE	59	17.9
Dental	o Dental carries/ dental pain	31	9.5
Oto (affecting the hearing system)	o Otitis Media o Bacterial infection	15	4.6
Skeletal /muscular systems	o backpains	8	2.4
Central nervous system	o headaches	7	2.13
Ophthalmic (eyes)	o Allergic conjunctivitis o Bacterial eye infections	32	9.8
Haematological (blood)	o Anaemia	1	0.3
Others*	o Malaria o Septic wounds o Chicken pox o Congenital abnormalities	21	6.4
Normal	o No abnormalities detected	26	7.9

2.2.2 Collection of biological samples

Blood and urine samples were obtained from children whose individual or parent/guardian consent has been obtained.

2.2.2.1 Blood samples

10mls of blood samples were collected from each of the children referred for laboratory investigations by venepuncture (obtaining a blood sample by bleeding from the veins). The blood samples were prepared as follows:-

- 5mls were put into heparinized Vacutainers for Clinical Biochemistry (biochemical changes due to a disease or pathological process) studies.
- 5mls were put into EDTA Vacutainers for Haematological (blood) studies and blood lead levels determination.
- A drop of the blood sample in EDTA Vacutainers was placed on a microscope slide and spread to make a thin blood film for peripheral blood film studies.

2.2.2.2 Urine samples

The participants were provided with appropriate urine containers and requested to give samples of urine.

2.2.3 Analysis of biological samples

2.2.3.1 Blood samples

Blood samples were analysed for Biochemistry evaluation, Haematological evaluation and blood lead levels.

2.2.3.1.1 Biochemistry analysis

Blood samples in heparinized Vacutainers were centrifuged and plasma separated from the cellular matter. The plasma was put in Cryovials and dispatched for biochemistry analysis. Biochemical studies done were to evaluate any derangement in liver and renal functions.

Liver function tests done included: -

- Total protein,
- Albumin,
- Alanine and Aspartate Transaminases,
- lactate Dehydrogenase and
- Alkaline phosphatase.

Evaluation of renal function was done by determining levels of

- Urea,
- Creatinine,
- Calcium and
- Inorganic phosphatases.

2.2.3.1.2 Haematological studies

Haematological studies were done on blood samples in EDTA Vacutainers to determine the status on blood levels, cell morphology and adequacy. The investigations entailed:-

- Red and white blood cell counts,
- haemoglobin levels determination and
- Peripheral blood film studies to determine the percentage (differential counts) of each of the white blood cells (i.e. Neutrophils, lymphocytes, Monocytes and Eosinophils) present and morphology of red blood cells.

2.2.3.1.3 Blood lead levels determination

Blood lead level determination was done using a portable LeadCare blood lead testing system and LeadCare blood lead testing kits manufactured by ESA of Chelmsford, USA (Annexure 4). The analyzer is electrically (AC) or battery (DC) powered. The system carries out an automatic self test to check its electronic functions every time it's turned on. Calibration was performed using a coded calibration button supplied with the kits and quality control samples were analysed prior to analysis of the blood samples. Blood lead levels were determined following the procedures for sample analysis using the LeadCare blood lead analyzer user's guide.[19]

2.2.3.2 Urine samples

A general urinary screen was done using Ames Multistix for urinalysis to determine the qualitative concentrations of various urine constituents that serves as indicators of underlaying problems. Microalbumin and microalbumin/creatinine ratio which are indicators of early and subclinical renal damage were determined using Clinitec Microalbumin strips and reader.

Photograph 6 The toxic smokes of the Dumpsite at the sunset. Courtesy of Andrea Rigon.

2.2.4 Biological samples results

2.2.4.1 Blood samples

2.2.4.1.1 Biochemistry results

Clinical biochemistry results obtained for Total protein, Albumin, Alanine Transaminase (ALT), Aspartate Transaminase (AST), Alkaline Phosphatase (ALP), Lactate Dehydrogenase (LD), Calcium (Ca^{++}), Inorganic Phosphates (pO_4^{2-}), Urea and Creatinine are presented in Table 10. Biochemistry results obtained for individuals are presented in Annexure 5a.

Table 10. Summary of Biochemistry investigations

Profile	Analyte	Reference limit♠	% < lower reference limit	% > upper reference limit
Liver function tests	Total Protein	66-87g/dl	Nil	Nil
	Albumin	35-42g/dl	Nil	Nil
	AST	0-37U/L	Nil	39.5% (n = 15)
	ALT	0-37U/L	Nil	2.6% (n = 1)
	ALP	64-306U/l	Nil	31.6% (n =12)
	LDH	190-360U/l	2.6% (n = 1)	18.4% (n = 7)
Renal function test	Ca^{++}	2.02-2.60	Nil	Nil
	pO_4^{--}	0.84-1.65	Nil	Nil
	Urea	1.7-8.3	7.9 % (n =3)	2.6% (n = 1)
	Creatinine	60-120	Nil	2.6% (n = 1)
	Na^{++}	35-45mmol/l	Nil	Nil
	K^{++}	135-145mmol/l	Nil	Nil
	Microalbumin A:C	< 30mg/g	Nil	Nil

2.2.4.1.2 Haematology results

Haematological results obtained were those of blood cell counts (RBCS, WBCs and platelets), Haemoglobin (Hb) level and peripheral blood film (PBF) studies. Haematological results presented here are those of haemoglobin (Hb) levels and peripheral blood film studies in Table 11 and Table 12 respectively. The reference range for normal haemoglobin levels are 11 to 16 grams per deciliter of blood and vary with sex and age with males having higher Hb levels than females. The lowest, highest and mean ± standard deviation (1SD) Hb levels obtained for the total sample were 10.5, 15.1 and 12.6 ± 0.5 grams per deciliter of blood respectively. Hb levels below the lower limit of the reference range indicates low Hb for the individual and hence anaemia. Males had the highest number of individuals whose Hb levels were below the reference range. Most of the teenagers (ages 12-14yrs (42.8%) and 15-18yrs (100%)) had low Hb levels. The peripheral blood film exhibited microcytosis/hypochromasia of red blood cells (varying sizes with majority of the cells being smaller than normal and low staining) a feature of anaemia and eosinophilia (high levels of eosinophilic white blood cells) which is a manifestation of allergy. Haematology results for individuals are indicated in annexure 5b.

Table 11. Haemoglobin levels in children at Korogocho

Age of subject (years)	Reference range		No. of subjects	Subjects Hb range	Mean Hb	% < lower reference limit
4-7	male	11.2-14.3	5	11.1-14.1	12.7(1.1)	20 (n =1)
	female	11.3-14.2	3	12.4-13.1	12.8(0.4)	Nil
8-11	male	12.0-14.8	2	11.5-12.4	12.0((0.6)	50 (n=1)
	female	11.5-14.5	7	10.5-14.0	12.4(1.1)	14.2 (n = 1)
12-14	male	12.5-15.0	14	11.5-15.1	12.1(2.8)	42.8 (n + 6)
	female	11.6-14.8	3	11.9-13.2	13.2(1.3)	Nil
15-18	male	13.9-16.3	6	13.0-13.6	13.2(0.2)	100 (n =6)
	female	12.0-15.0				

Table 12. Peripheral blood film results

PBF studies	% of children	No. of children
Normocytic/ normochromic (red blood cells normal in size and staining in peripheral blood film)	62.5	25
Microcytosis (smaller red blood cell's size than the normal)	35	14
hypochromasia (low red blood cell's staining)	12.5	5
Eosinophilia (high numbers than normal of white blood cells referred to as eosinophils)	52.5	21

2.2.4.1.3 Blood lead levels results

Table 13 shows blood lead levels obtained for children at Dandora/ Korogocho.

50% of the children had levels equal to or exceeding the internationally accepted action levels of 10 micrograms per deciliter of blood.

5% (n = 2) of the children had BLLs above 25 micrograms per deciliter and the actual blood lead levels for the two were 29.4 and 32.1 micrograms per deciliter of blood (µg/dl). The results indicate excessive exposure to abnormal environmental lead levels which poses high risk to human health. Blood lead levels for each individual were as indicated in annexure 6.

The results indicate excessive exposure to abnormal environmental lead levels which poses high risk to human health.

Table 13. Blood lead levels

Number of children	38
Lowest blood lead levels obtained	3.9
Highest blood lead levels obtained	32.1
Mean ±SD	12.3 ±6.9
% ≥ 10µg/dl	50% (n=19)
% ≥ 15µg/dl	34% (n=13)
% ≥ 20µg/dl	13% (n=5)
% ≥ 25µg/dl	5% (n=2)

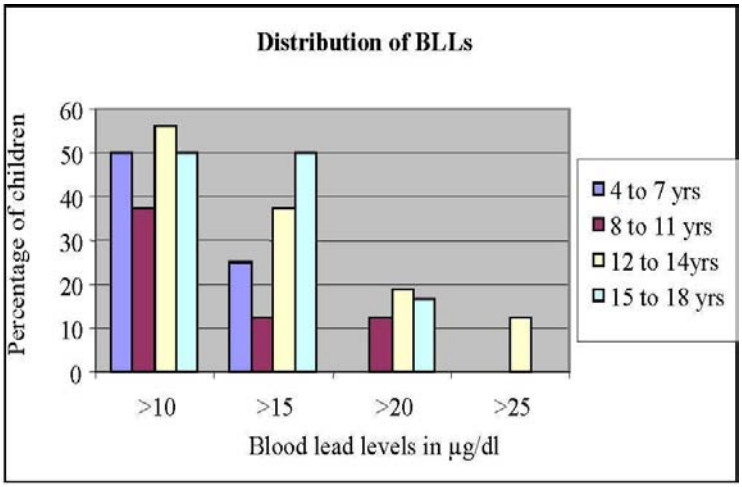
2.2.4.1.3.1 Blood lead levels distribution by age

Table 14 and figure 2 shows how the blood lead levels are distributed amongst children living within or at the neighborhood of the Dandora waste dumping site age wise. The mean blood lead levels in different age sets ranged from 9.0 ±6.1 (8-11 years) to 14.6 ±8.0 (12-14 years) µg/dl of blood. The percentage of children having BLLs above levels of concern in particular age sets indicates individuals aged 12-14 years had the highest BLLs while children aged 8-11 years had the lowest BLLs.

Table 14. Distribution of blood lead µg/dl levels by age

Age set (years)	lowest	highest	Mean ± SD	%≥10	%≥15	%≥20	%≥25
4-7	6.2	17.5	10.5± 4.4	50	25	nil	nil
8-11	3.9	22.8	9.0 ±6.1	37.5	12.5	12.5	nil
12-14	6.0	32.1	14.6 ±8.0	56	37.5	18.8	12.5
15-18	4.9	20.6	12.8 ±6.9	50	50	16.6	nil

Figure 2 Distribution of Blood lead levels



2.2.4.2 Urine samples

The general screen through urinalysis did not indicate abnormal levels of the various urinary contents that are indicators of extensive damage to internal organs. Results of all parameters checked through urinalysis were normal. Microalbumin concentration was <30milligrams per gram and the microalbumin/creatinine ratios were normal for all the children.

CHAPTER 3
3. Discussions and Conclusion

3.1 Discussions

Soil and water samples from Dandora and Korogocho were analysed to determine their contents and concentrations of various elements, polychlorinated biphenyls and pesticides. A compost sample from the Dandora waste dumping site was analysed to give an insight into the contents of the decomposed and burnt out waste. For the purpose of comparing the elemental contents and concentration of the soil samples from Dandora/Korogocho, soil samples from the relatively unpolluted environment of Waithaka were analysed.

The analysis of the environmental samples served to determine the status of the environment around the dumping site and thus an indicator of environmental impact of waste disposal at the site.

The results obtained by analysis of both the environmental and biological samples serves to establish the relationship between the environment and human health.

The soil's elemental contents; "Potassium (K), Calcium (Ca), Titanium (Ti), Vanadium (V), Chromium (Cr), Manganese (Mn), Iron (Fe), Copper (Cu), Zinc (Zn), Mercury (Hg), Lead (Pb) and Cadmium (Cd)" obtained can be categorised into: exchangeable metallic cations and micronutrients (potassium, calcium, magnesium, manganese, copper, iron and zinc) and toxic heavy metals (mercury, lead, cadmium and chromium). The heavy metals are of major concern as they are known to be toxic to human, animals and plants health even at low levels of exposure.

Due to their known toxicities, critical levels of heavy metals concentrations have been established by several authorities. The results obtained on the concentration of the heavy metals were compared to the soil standards used in the Netherlands and Taiwan.

The acceptable levels of exposure to environmental lead in soil based on the Netherlands and Taiwanese standards for quality soil are 50 ppm while soil lead levels that are a risk to human health have been placed at 150 and 500 ppm respectively.

The WHO lead level for good soil standard is 100 ppm. Five (42 %) out of the twelve samples analysed from Dandora/Korogocho had lead levels ranging from 417-547 ppm. These lead levels are four times above the WHO standard and within the levels that pose a risk to human health as per the Netherlands and Taiwan's standards indicating high levels of exposure.

The concentration of lead in the compost sample was 13500 ppm indicating the dumping site to be source of the high lead levels in the surrounding environment.

The concentrations of Mercury in almost all of Dandora/Korogocho soil samples were below the detection limit of 15 ppm of the EDXRF measurement system used. However, potential for exposure to unacceptable levels of mercury cannot be ruled out as the detection limit of the analyzing system is far much above the 2 ppm mercury limit levels in soil that pose no risk to human health.

Likewise, the levels of 18.6 ppm that was obtained for the soil sample from the banks of Nairobi River and the levels that were obtained for the compost sample although not representative of the whole environment indicate possibility of exposure to high levels of mercury. A true status can be established by analysis of more samples and using more sensitive equipment.

Results obtained for cadmium in the soil samples from Dandora and Korogocho indicate the levels to be six times more than the critical levels mentioned by the Dutch and Taiwanese authorities.

The higher concentration of cadmium levels in the surface soil levels relative to those of subsurface

samples indicate a recent increase in deposition of cadmium containing waste. However, further soil sampling and determination of cadmium in biological samples is recommended to get a clearer status.

The mean concentration of copper in the Dandora/Korogocho soil samples was twice and thrice the reference value for good soil quality of the Dutch and Taiwanese soil's respectively.

The levels are above the natural range of copper in soils which ranges from 7 to 80 ppm. In comparison, the concentrations of copper in Waithaka soil samples were below the detection limit of 15 ppm.

The mean concentration of chromium in the soil samples from the Dandora waste dumping site and its environs was slightly above the critical soil levels of the Dutch and Taiwan soil standards. Thus, the results indicate little or no contamination of the environment by chromium.

The mean concentration of Zinc in the Dandora/Korogocho soil samples was above the reference value for good soil quality of Dutch and Taiwan soil standards respectively while the levels were four times higher than soil samples from Waithaka indicating excessive exposure.

Despite the levels of trace elements, micronutrients and heavy metals that were obtained for the soil samples, the levels of almost all of the elements measured in soil samples are not reflected in the water samples apart from the levels of total dissolved solids (TDS-Mn and Fe) and copper that were detected in the water sample from the pool in low quantities. This could be attributed to the flowing nature of the river and heavy cover of vegetation over the stagnant water pool as well as the analytical sensitivity of the measuring system. Further analysis of more samples with application of more sensitive system of measurement will indicate the true status.

Results of the post clinical evaluation of information collected on the children and adolescents living within the environs of the Dandora waste dumping site indicated the highest incidence of diseases to be those involving the respiratory, gastrointestinal and dermatological systems. Respiratory problems manifested included upper respiratory tract infections (URTIs), chronic bronchitis and asthma.

In the absence of supportive bacteriological examination, organisms that could be involved in causing the suspected URTIs cannot be determined. Dermatological (skin) disorders included fungal infections which could be attributed to lowered immunity or malnutrition; allergic and unspecified dermatitis/pruritis (inflammation and itchiness of the skin) which could also be related to exposure to environmental toxins. Likewise, exposure to various pollutants could also have attributed to the unspecified gastrointestinal problems. Major causes of/or exacerbation of severity of the abnormalities has been attributed to the environment around the dumping site by the residence of the surrounding residential estates.

Heavy metals concentrations of the soil samples analysed indicates significant public exposure to unacceptable levels of environmental lead and to a lesser extents other metals. This is further evidenced by the concentration of lead in the blood of children which indicated that half of the children had blood lead levels exceeding the internationally accepted toxic levels. Likewise, other clinical effects such as headaches, chest pains, gastrointestinal problems and muscular weakness had been linked to high levels of heavy metals.

Half of the children had blood lead levels exceeding the internationally accepted toxic levels.

The liver is the major organ of metabolism of various substances and detoxification in the body. Biochemistry results obtained for some of the children and adolescents indicates significant high levels of the enzymes Aspartate Transaminases (AST), Alanine Transaminases (ALT), Alkaline Phosphatases (ALP) and Lactate Dehydrogenase (LDH). These enzymes collectively and with other

parameters or individually are analysed to evaluate cellular damage or the presence of a disease process affecting the liver. The results obtained points to a degree of liver dysfunction in some children and calls for further followup and evaluation.

Although the majority of the children did not have results indicating destruction of the renal system, the high levels of creatinine in some of the study subjects indicates the need for closer followup to determine onset of renal dysfunction as the levels of creatinine depends with the muscle mass which is less in children than adults. The routinely analysed markers of renal dysfunction become deranged when over 70 % of the kidneys mass is not functional and at a state when signs and symptoms of renal failure are evident. The use of more sensitive markers such as micro proteins and enzymes specific to the renal system will be more appropriate in determination of subclinical nephrotoxicity.

A major issue of concern is the results obtained for haematological investigations.

The results indicate 50% of the children as having lower haemoglobin levels than the reference ranges.

Apart from the haemoglobin levels, the peripheral blood films indicate size and staining abnormalities of the red blood cells that are features of iron deficiency anaemia (IDA) in over 30% of the children. Exposure to high levels of lead is a known cause of suppression of the haemoglobin synthesis which is manifested by low haemoglobin levels and features that resemble those of IDA.

Results obtained on the blood lead levels of the children indicates that 50% of the children had blood lead levels equal to or above 10 micrograms per deciliter of blood.

34% had levels above 15 micrograms per deciliter of blood, 13% had levels above 20 micrograms per deciliter of blood and 5% had levels above 25 micrograms per deciliter of blood. The blood lead level at which haemoglobin synthesis is suppressed is 25 micrograms per deciliter of blood. However, the percentage of children who had haemoglobin levels below normal levels equals those who had levels above the action levels. 35% of the children had microcytosis (small sized red blood cells) which is a feature of anaemia due to iron deficiency or heavy metal intoxication and this percentage almost equals those who had blood lead levels (BLLs) above 20 micrograms per deciliter of blood. This indicates a possibility of haemoglobin synthesis being suppressed at blood lead concentrations below 25 micrograms per deciliter of blood. The high lead contents of the soil samples and the blood lead levels in children are an indication of an environment highly polluted by lead.

In comparison to the less polluted environment of Waithaka, the mean concentration of lead in the soil samples from Dandora/Korogocho was seven times more than the concentration of lead in Waithaka soil samples.

Likewise, in a previous study, it was established that **the percentage of children with high blood lead levels at Waithaka was 5.8% which is almost ten times less than in Dandora/Korogocho which is 50%.**

The blood lead levels for children in Dandora/Korogocho are higher than areas far away from the dumping site such as Kariobangi North and Babadogo which has been established to be at 10% and 15.2% respectively.[20]

The Kariobangi north and Babadogo are slums bordering Korogocho and Dandora with no clear boundary between them but further away from the dumping site. This indicates that the population living within the vicinity or near the Dandora waste dumping site is in an environment highly polluted by lead compared to areas further away.

An increase in the number of white blood cells referred to as Eosinophils (eosinophilia) is mostly associated with allergic reactions. Peripheral blood film studies of the children from Dandora/Korogocho indicated that 52.5% had marked eosinophilia.

On clinical evaluation, most of the children presented with manifestation of respiratory tract problems that can be due to respiratory allergy that leads to chronic rhinitis (irritation of the nasal cavity) and a high occurrence of asthma;

allergic conjunctivitis and dermatitis which is an indication of high exposure to environmental irritants.

Although no polychlorinated biphenyls (PCBs) were detected in the environmental samples obtained, their presence in the environment cannot be ruled out due to the number of samples analysed and manifestation of some clinical abnormalities such as irritation of the nose and lungs, gastrointestinal discomfort, depression, fatigue and skin conditions attributed to exposure to PCBs were reported in the children. Comprehensive analysis of more samples should be carried out to determine the status of PCBs congeners and their by products such as dioxins and furans in the Dandora waste dumping site environment. Likewise, more samples should be analysed to determine presence of pesticides.

3.2 Conclusion and recommendations

The results obtained in this study are evidence that waste dumping at the Dandora waste dumping site is a potential source of environmental pollution and a great risk to the health of people living within and surrounding the dumping site.

The results call for immediate action to prevent continued public overexposure to environmental pollution

Although indicating the need to carry out a comprehensive study, the results call for immediate action to prevent continued public overexposure to environmental pollution. Close monitoring of children should be done to monitor their heath and provide appropriate medical attention meant to check effects of the pollution. A general checkup on the children and adolescent should be conducted with a focus on establishing the extent of overexposure to environmental toxicants.

The results need to be correlated to observation from other areas that are at specified distances away from the dumping site and other non polluted environments. More environmental samples including air samples should be analysed to evaluate the environment. More sensitive markers of toxicity should be used to ascertain long-term effects of exposure.

Experience gained in the process of conducting this study indicates a great need to link environmental pollution and human health. Thus, systems are required to be put in place for providing more knowledge that will be useful in recognition, diagnosis and management of environmentally related illness. Health facilities should be equipped with appropriate analytical systems that will enable use of biological samples for the purpose of diagnosis and monitoring of suspected environmental related cases. Sensitive equipments for carrying out environment and health related research are needed to provide a better and quicker approach in data generation. This indicates the need to establish an institution that will appropriately address environmental vs. health issues. Such a facility will be handy for long-term monitoring, provision of guidance and be a reference point in future studies.

There is need for measures to be instituted for proper waste management to minimize the risk of environmental pollution that pose a risk to human health. **Likewise, generation of waste should be reduced by using less waste generating means in various human activities.** This less waste generating means may include use of more oral medication than injectables, using recyclable or reusable products wrappers or containers and discourage the use of non biodegradable materials.

There is need for measures to be instituted for proper waste management to minimize the risk of environmental pollution that pose a risk to human health.

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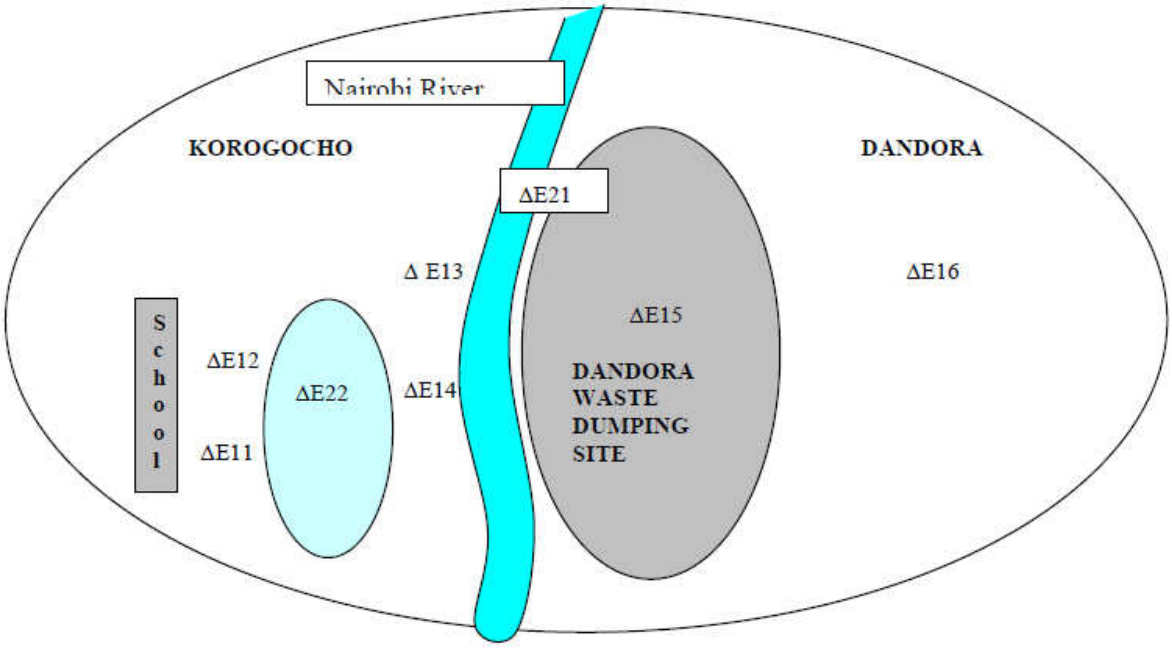
20. Njoroge GK, UNEP. Blood lead levels in Kenya: A case study for children and adolescents in selected areas of Nairobi and Olkalou, Nyandarua District. 2005.

4. Annexures

Annexure 1. Sampling sites for soil and water samples at the Dandora waste dumping site



Sch — St. John Catholic Church informal School approximately 100 meters from dumping site

- Quarry full of water adjacent to the school

E11- 1st sampling site for soil; across the school's fence and next to the schools outlet overlooking the dumping site
E12- 2nd sampling site for soil in a cultivated area next to the school
E13- 3rd sampling site for soil at the banks of Nairobi River
E14- 4th sampling site for soil in a shamba between the Nairobi River and water logged quarry
E16- 6th sampling site for soil; bordering the dumping site on the Dandora side
E15- 5th Sampling site for compost sample; a site within the dumping site
E21- 1st sampling site for water at a slow moving part of the Nairobi river adjacent to the dumping site
E22- 2nd sampling site for water at the quarry

Annexure 2. Environmental samples; sampling and results

Annexure 2a Summary of soil and water sampling process at the Dandora/Korogocho waste dumping site

E=Environmental, 1st digit = type of sample (1 = soil, 2 = water), 2nd digit = sampling site, 3rd digit (if included) = sample profile in Cms (1= 0-20, 2= 20-40, 3 = 40-60).

Sampling site No.	Sample Code	Sampling site (GPS readings)			Profile (Cms)	Weight/ volume of sample
Soil samples		Altitude	S1°	E036°		
1	E111	1613	14.944	53.548	0-20	2229.35
2	E121	1598	14.892	53.559	0-20	3190.47
	E122	1598	14.892	53.559	20-40	3121.27
	E123	1598	14.892	53.559	40-60	3216.93
3	E131	1590	14.921	53.624	0-20	1647.75
	E132	1590	14.921	53.624	20-40	1979.25
4	E141	1592	14.938	53.604	0-20	1711.20
	E142	1592	14.938	53.604	20-40	1950.10
	E143	1592	14.938	53.604	40-60	2743.55
6	E161	1611	14.748	54.098	0-20	3882.66
	E162	1611	14.748	54.098	20-40	3624.89
	E163	1611	14.748	54.098	40-60	2021.25
Compost						
5	E151	1613	14.771	53.921	0-20	1032.28
Water samples						
7	E21	1590	14.921	53.624		2000mls
8	E22	1597	14.938	53.604		2000mls

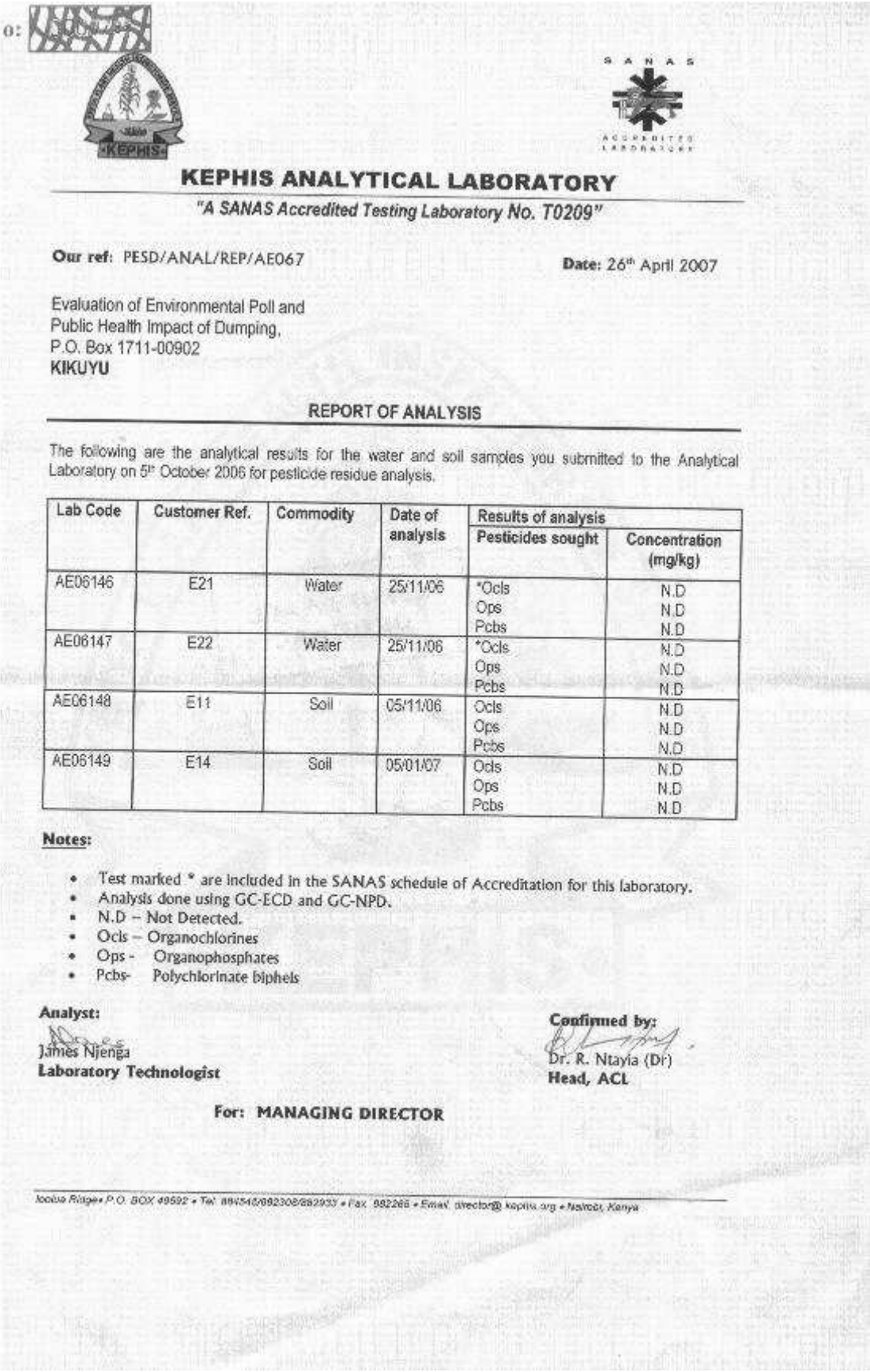
Annexure 2b Elemental Concentrations in individual soil sample profiles from the Dandora /Korogocho /waste dumping site by EDXRF*

Elements	Elemental concentrations (ppms) in individual soil samples.											
	E111	**E121**	**E122**	**E123**	**E131**	**E132**	**E141**	**E142**	**E143**	**E161**	**E162**	**E163**
K	19000	25000	14700	27500	25500	25000	24400	15400	25000	21700	14700	11200
Ca	51300	7800	4800	7100	15900	15000	9500	10900	6100	20500	19700	6100
Ti	6000	5000	3700	6400	6100	6800	5600	4100	7200	5800	4800	3700
Cr	BDL	103	BDL	BDL	178	BDL	185	147	272	122	BDL	97.8
Mn	5900	3700	3000	3600	4200	3600	4200	3600	4900	5400	6600	3700
Fe	46900	39500	35000	47900	57500	59200	49400	42900	57900	43700	39100	30600
Cu	118	BDL	BDL	BDL	70.1	90.4	BDL	49.1	BDL	BDL	198	BDL
Zn	1150	323	279	239	781	759	408	404	267	426	334	175
As	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Hg	BDL	BDL	BDL	BDL	BDL	18.6	BDL	BDL	BDL	BDL	BDL	BDL
Pb	185	76.09	60.9	60.7	417	488	590	544	547	87.6	66.6	50.2
Cd *	Surface 52.9 ppm						Subsurface 26.5 ppm					

♠ BDL: Below detection limit- Copper (Cu) - 15 ppms, Chromium (Cr)-70 ppms, Mercury (Hg)-15 ppms

* Cadmium (Cd) was analysed using atomic absorption spectrometry (AAS) on two soil samples (surface and subsurface) that has been obtained on pooling soil samples from the different levels of sampling.

Annexure 3. Pesticides screen and polychlorinated biphenyls determination



KEPHIS ANALYTICAL LABORATORY

"A SANAS Accredited Testing Laboratory No. T0209"

Our ref: PESD/ANAL/REP/AE067 **Date:** 26th April 2007

Evaluation of Environmental Poll and
Public Health Impact of Dumping,
P.O. Box 1711-00902
KIKUYU

REPORT OF ANALYSIS

The following are the analytical results for the water and soil samples you submitted to the Analytical Laboratory on 5th October 2006 for pesticide residue analysis.

Lab Code	Customer Ref.	Commodity	Date of analysis	Results of analysis	
				Pesticides sought	Concentration (mg/kg)
AE06146	E21	Water	25/11/06	*Ocls	N.D
				Ops	N.D
				Pcbs	N.D
AE06147	E22	Water	25/11/06	*Ocls	N.D
				Ops	N.D
				Pcbs	N.D
AE06148	E11	Soil	05/11/06	Ocls	N.D
				Ops	N.D
				Pcbs	N.D
AE06149	E14	Soil	05/01/07	Ocls	N.D
				Ops	N.D
				Pcbs	N.D

Notes:

- Test marked * are included in the SANAS schedule of Accreditation for this laboratory.
- Analysis done using GC-ECD and GC-NPD.
- N.D – Not Detected.
- Ocls – Organochlorines
- Ops - Organophosphates
- Pcbs- Polychlorinate biphels

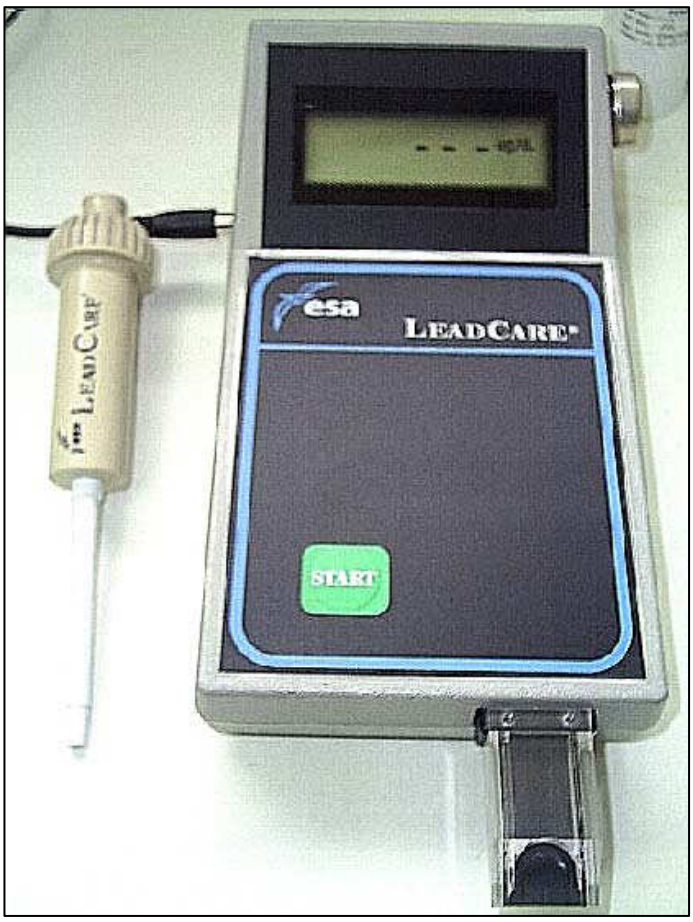
Analyst:
James Njenga
Laboratory Technologist

Confirmed by:
Dr. R. Ntayia (Dr)
Head, ACL

For: MANAGING DIRECTOR

Jacaba Ridge• P.O. BOX 49592 • Tel: 8045[illegible] • Fax: 882266 • Email: director@ kephis.org • Nairobi, Kenya

Annexure 4. The Lead Care blood lead analyzer



Annexure 5. Biological samples results

Annexure 5a Clinical Biochemistry results for children at the Dandora waste dumping site

ANALYTE			UREA	CREAT.	T.PROT	ALB	AST	ALT	AST:ALT	ALP	LDH	CA	I.PHOS
Reference Ranges			1.7-8.3mmol/l	60-120umol/l	66-87g/l	35-52g/l	0-37u/l	0-37u/l	1	64-306u/l	190-360u/l	2.02-2.60mmol/l	0.84-1.65mmol/l
Lab. No.	AGE	SEX											
28	5	M	1.4	66	76	45	37	12	3.08	147	378	2.54	1.07
2	7	M	2.7	63	68	42	49	13	3.76	208	363	2.52	1.3
6	7	F	1.2	69	77	45				215	313	2.57	1.33
7	7	F	4.1	80	77	46	37	11	3.36	195	350	2.35	1.4
26	7	M	3	77	73	42	41	24	1.71	523	433	2.47	1.17
27	7	M	1.2	63	80	44	18	15	1.2	300	343	2.44	1.22
30	7	M	3.4	63	69	41	49	9	5.44	256	318	2.42	1.24
4	9	F	3.5		71	43	45	12	3.75	268	219	2.35	1.44
15	10	F	3.7	90	76	45	44	9	4.89	317	215	2.5	1.5
20	10	F	4.2	63	69	43	34	10	3.4	217	329	2.57	1.48
21	10	F	3.6	62	74	44	46	13	3.54	217	347	2.43	1.45
45	10	F	4.8	72	74	44	32	11	2.9	154	228	2.49	1.32
1	11	M	2.7	67	71	42	42	14	3	374	331	2.37	1.12
5	11	F	11.5	95	73	43	29	11	2.64	213	342	2.53	1.12
9	11	M	3.2	71	75	42	41	16	2.56	227	315	2.53	1.12
11	12	M	7	93	78	44	32	20	1.6	219	294	2.58	1.49
12	12	M	4.5	66	75	43	33	9	3.67	266	273	2.44	1.22
17	12	M	3.2	159	73	42	29	22	1.31	177	435	2.52	1.29
18	12	F	3.2	64	74	43	32	12	2.67	320	464	2.42	1.31
31	12	M	3.5	84	75	43	40	15	2.67	335	417	2.55	1.44
34	12	M	3.4	61	72	43	BH	272		386	468	2.38	1.3
44	12	M	3.7	74	75	43	30	13	2.3	251	315	2.38	1.36
10	13	M	5.2	84	71	43	42	11	3.81	215	182	2.46	1.23
32	13	M	3.8	76	81	44	32	9	3.56	213	341	2.45	1.41
33	13	M	5	81	68	40	33	9	3.67	497	314	2.54	1.43
36	13	M	4.3	58	79	46	34	11	3.09	290	316	2.49	1.4
37	13	M	7.6	76	76	45	34	15	2.27	236	306	2.32	1.33
42	13	F	2.9	78	73	43	29	9	3.22	271	204	2.4	1.51
3	14	M	3.7	59	73	43	40	12	3.33	543	232	2.25	1.28
13	14	M	3.7	68	72	42	40	11	3.64	394	222	2.49	1.41

Annexure 5a cont.

38	14	M	1.7	84	77	42	12	9	1.33	393	208	2.38	1.38
43	14	F	3.9	74	80	45	44	12	3.67	251	338	2.45	1.6
39	15	M	2.8	87	79	44	G	GL		131	207	2.46	1.38
40	15	M	3.1	71	76	45	27	7	3.86	376	285	2.32	1.38
41	15	M	6.2	96	78	42	27	14	1.93	407	236	2.44	1.57
14	16	M	4.3	84	74	44	33	16	2.06	259	166	2.37	1.2
35	17	M	2.9	71	71	44	39	9	4.33	257	206	2.23	1.3
19	18	M	6.5	100	79	45	24	14	1.71	302	216	2.19	1.22

Annexure 5b Haematological Indices

INDICES			HB	WBCs Differential counts				RBCs Morphology
REF. RANGE			Male 11.2-16.3 Female 11.3-15.0	Neutrophils	Lymphocytes	Monocytes	Eosinophils	
Lab No.	AGE	SEX						
28	5	M	12.9	37	54	7	2	Few microcytes with slight hypochromasia noted
8	6	F	13.1	47	46	3	3	Few microcytes with slight hypochromasia noted
2	7	M	11.1	30	52	7	11	Slight microcytosis/hypochromasia
6	7	F	12.4	36	57	6	1	Normocytic normochromic
7	7	F	13	37	48	11	2	Target cells present/slight hypochromasia basophilia noted
26	7	M	12.1	36	54	7	2	Target cells/slight hypochromasia noted
27	7	M	14.1	46	36	10	8	Normocytic normochromic
30	7	M	13.2	51	37	5	7	Normocytic normochromic
4	9	F	11.9	34	50	8	8	Few microcytes observed
15	10	F	12	29	62	7	2	Normocytic normochromic
16	10	F	12.3	45	47	4	2	Normocytic normochromic
20	10	F	14	46	52	1	1	Normocytic normochromic
21	10	F	13.3	61	35	3	1	Normocytic normochromic
45	10	F	12.9	44	47	3	6	Normocytic normochromic
1	11	M	11.5	36	51	11	2	Normocytic normochromic
5	11	F	10.5	18	63	7	12	Microcytosis/hypochromasia
9	11	M	12.4	39	56	5		Normocytic normochromic
11	12	M	11.5	24	53	7	16	Microcytosis/marked eosinophilia
12	12	M	13.9	40	40	5	15	Normocytic normochromic/marked eosinophilia
17	12	M	12.1	32	57	8	3	Target cells observed/normocytic normochromic
18	12	F	14.6	54	38	4	4	Microcytosis noted
31	12	M	13.3	39	42	7	12	Microcytosis with slight hypochromasia/Marked eosinophilia
34	12	M	12.2	48	40	5	7	normocytic normochromic
44	12	M	12.6	53	43	6		Microcytosis observed
10	13	M	12.7	33	62	5		Normocytic normochromic
32	13	M	12.8	22	50	7	21	Microcytosis/marked eosinophilia
33	13	M	13.4	48	43	2	7	Few microcytes noted
36	13	M	15.1	37	50	7	6	Normocytic normochromic
37	13	M	11.6	37	50	4	9	Target cells microcytic hypochromic
42	13	F	11.9	44	48	3	5	Microcytic hypochromic
3	14	M	12.9	32	44	14	10	Normocytic normochromic
13	14	M	12.2	54	34	9	3	Normocytic normochromic
38	14	M	13.4	43	35	8	14	Marked eosinophilia
43	14	F	13.2	31	56	7	6	Normocytic normochromic
39	15	M	13.4	25	57	9	6	Normocytic normochromic
40	15	M	13	55	36	2	7	Normocytic normochromic
41	15	M	13	53	36	7	4	Normocytic normochromic
14	16	M	13.6	35	52	4	9	Normocytic normochromic
35	17	M	13.5	57	35	4	4	Normocytic normochromic
19	18	M	13.2	30	53	6	11	Normocytic normochromic

Annexure 6. Blood lead levels for children at the St John Korogocho

SAM. NO.	AGE	SEX	BLL µg/dl
28	5	M	6.6
8	6	F	10
2	7	M	10.5
6	7	F	6.2
7	7	F	16.7
26	7	M	7.3
27	7	M	17.5
30	7	M	9.4
4	9	F	22.8
15	10	F	10
16	10	F	6.1
20	10	F	11.3
21	10	F	7.4
45	10	F	3.9
1	11	M	6.6
9	11	M	4.2
11	12	M	29.4
12	12	M	32.1
17	12	M	8.7
18	12	F	8.4
31	12	M	12.6
34	12	M	11
44	12	M	16.8
10	13	M	8.9
32	13	M	18.7
33	13	M	13
36	13	M	8.4
37	13	M	19.3
42	13	F	6
13	14	M	8.3
38	14	M	8.5
43	14	F	22.9
39	15	M	6.8
40	15	M	8.3
41	15	M	4.9
14	16	M	19.5
35	17	M	16.7
19	18	M	20.6

Annexure 7 Topographical map of the Dandora waste dumping and its environs; circled area indicates area where study was conducted