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Level of Toxicity of Leachate from the Mpasa Technical Landfill Site in Kinshasa, Democratic Republic of Congo (DR. Congo)

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Abstract

The leachate (the water that has percolated through the waste stored in a landfill by biologically and chemically loading...) from the Mpasa landfill leaves a noticeable imprint in the wall of the container that contains it. A landfill that produces leachate has multiple environmental consequences such as soil toxicity, subsoils, groundwater and streams. The present study evaluates the degree of toxicity of the percolate of this Mpasa landfill. The samples were taken in one campaign using a canoe in the 250-liter plastic drums. In this study, a pilot consisting of colored plastic cups containing various levels of aqueous solutions of juice (percolate) from Mpasa site of 10^{-5} to 10^{0} ml/ml as well as Gambusia affinis fish were considered bioindicators. Previous physico-chemical analyzes show high values of the parameters studied. It is the pH (12.3); Electrical Conductivity (EC) (7700 µS / cm); the concentration of oxygen (O_2) (1360 µg /l); the suspended solids concentration (MES) (462,000 µg / l) and the chemical oxygen demand (COD) (13,797,000 µgO_2/l). After 4 days on average dissolution, the study shows that the lethal concentration that removes half of all survivors reaches a volume of 0.006 ml of leachate / ml of solution. This confirms a severe toxicity. The ecotoxicology tests on leachates show a 10% change in LD_{50} that ranges from 10^{-4} ml / ml to 10^{-3} ml / ml.

Keywords: Leachate; Toxicity; Landfill; Gambusia Affinis; Mpasa; Kinshasa; DR Congo

Introduction

The amount of municipal waste is increasing in both controlled and uncontrolled landfills in cities and urban areas [1]. The cities of the Democratic Republic of Congo, especially the capital Kinshasa does not escape this rule. It develops intense nuisances with real and bad consequences on the inhabitants. These environments are therefore in full demographic growth supported by anarchic urbanization, by the rural exodus, by mass migrations of populations in search of the best conditions of life. These situations do not favor the development of socio-economic, ecological and environmental factors [2]. In these cities, if less effort is being made to manage solid wastes, there are rarely any bad water pipes, retention ponds and sewage treatment plants and/or even less complex liquids treatment such as leachates. In a biodegradable waste storage center, the bins are built for the containment and compacting of waste. While the drains serve to route the percolation water that seeps through the decaying waste mass and pipes lead the gas to the flare.

Aerobic and anaerobic biological processes under these climatic conditions produce percolation water commonly known as leachate [3,4]. However, according to Kmet quoted by Khattabi, 20% of precipitation leads to leachate production [5,6]. While Stegmann cited by the same author found different percentages depending on the state of compaction of the waste, 15 to 25% of the rain form leachate for compacted landfills and 25 to 50% in the case of an uncompacted discharge [7].

The city of Kinshasa province was endowed since May 2010 with its only storage center (final discharge) of municipal solid waste without prior treatment under the aegis of the European Union [8]. The European Union had built the first bin in May 2010 and the 29th, the last to be built dates from the year 2015. The rains fall 9 months on 12 months in annual average on the site Mpasa, swept by a humid tropical climate. They have a great influence on the technical exploitation of the site, the sizing of traps and retention ponds and the production of leachates [9,10] (Table 1).

The lagoon ponds constructed at Mpasa have shown their purifying limit against the fouling character, the mineral and organic composition of these discharge juices [11-13]. These retention ponds can only be used as a storage place in search of a suitable and more efficient treatment method of the intensive activated sludge type, using bio-coagulants and bio-flocculants to be purified before any discharge into the wild.

Since the climate of this zone allows the production of a high flow of leachates up to 250.10-6 m3 per second in the rainy season, they are loaded with organic matter and mineral matter, which flow through the massifs of waste. These contain less biodegradable organic matter than refractories and minerals, giving them complex and toxic characteristics [14]. The nature of physical, chemical, biological constituents and the quality of the liquids circulating in this waste storage center can be the subject of intensive research in ecotoxicology. This research is useful for assessing the toxicity of polluted effluents from a medium, microorganisms, dissolved or suspended organic substances and organic substances [15,16]. It has been proven that Mpasa's raw leachates are toxic and difficult to biologically treat [17]. The objective of this research is to determine the toxic chemical, ecotoxicological and microbiological components of landfill leachate from Mpasa to Kinshasa (DR Congo) in relation to conventional release standards, as shown in Figure 1. We have conceived in this research.

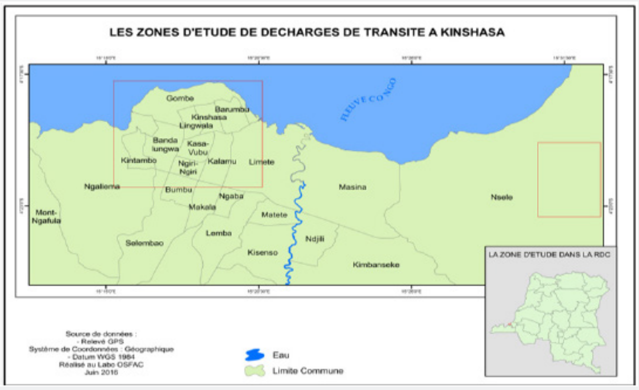

Figure 1: Presents the geographical limits of the intervention zone of 9 municipalities in red.

Materials and Methods

Geomorphology and Environment

The relief of Kinshasa consists of a plateau (Bateke) to the east, a chain of hills to the south and west and a plain to the north dotted with marshy areas in the neighborhoods of the Congo River. The Bateke Plateau is located between 600 and 700 m above sea level and completely dominates the south-eastern part of the city [18]. The Mpasa site is located in the Mpasa 3 district, N'selé commune, 5 km from Lumumba Boulevard, which is withdrawing to the town hall (Figure 2) [19].

Figure 2: Leachate entering the pond.

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The urban area of Kinshasa extends over 9,965 km2, or 0.42% of the area of the Democratic Republic of Congo [20]. It is located in the west between 3.9 and 5.1 degrees south latitude and between 15.2 and 16.6 degrees east longitude. The current population of Kinshasa is estimated at about 12,000. 000 inhabitants with a population growth rate of more than 4.7% per year (INS, 2014).

Soil Permeability

The penetration tests of water injected at depth as a function of infiltration time were monitored using a piezometric probe in four boreholes drilled using an auger, a chronometer and the water to be injected. These tests show that the permeability is greater in the soil used, as shown by the results in Table 1 of this research than in the control, the off-site and out-of-trap area.

Table 1: Heavy metals in raw Mpasa leachate (Mavakala BK, 2016).

N°	Parameters	Concentrations(µg/l)
1	Ag	0,86 ±0,01
2	As	7,01 ±0,13
3	Cd	1,04 ±0,01
4	Co	62,23 ±1,18
5	Cr	169,81 ±3,22
6	Cu	461,16 ±8,76
7	Fe	3380,4 ±152,1
8	Mn	123,73 ±3,46
9	Mo	0,01 ±0,01
10	Ni	116,38 ±2,21
11	Pb	87,22 ±1,65
12	Sb	15,43 ±0,29
13	Sc	0,33 ±0,01
14	Sn	38,95 ±0,74
15	Zn	714,14 ±13,56

Sampling

Figure 3: Leachate removal.

A leachate sampling campaign was held in April 2014 and constituted the sample grid. This period is devoted to violent storms from the end of February to April to produce an abundant flow of Mpasa discharge juice with a flow rate of 250 x 10^{-6} m^3 / second (Figures 3-5). Physico-chemical analyzes were performed using plasma-mediated plasma spectrometry (ICP-MS) and X-ray fluorescence (Spectro XEPOS AMETEK). The acute toxicity method was used for ecotoxicological testing. The HACH HQ40d Multi-Parameter and the HACH 2400 Series Spectrophotometer were used to collect the dissolved oxygen concentration and to assay the major elements of the leachate.

Figure 4: Leachate Retention Ponds.

Biological Materials

Leachate Collection: Leachate samples were collected using canoe, boots and gloves in the lagoon ponds of the Mpasa landfill. They were kept in 7 barrels of 250 Liters and transported to the garden JEEP (Garden and livestock plots) of the University of Kinshasa (Figures 3-5).

technique consists in preparing 500 ml artificial rearing ponds, a series of decimal dilutions of which 100 (100 ml of leachates or the mother concentration), 10^{-1} (10 ml of leachates + 90 ml of dechlorinated water) , 10^{-2} (10 ml concentration 10^{-1} + 90 ml dechlorinated water), 10^{-3} (10 ml concentration 10^{-2} + 90 ml dechlorinated water), 10^{-4} (10 ml concentration 10-3 + 90 ml of dechlorinated water), 10^{-5} (10 ml of the concentration 10^{-4} + 90 ml of dechlorinated water), and the control concentration (100 ml of dechlorinated water). Each pond was a lodge of 3 Gambusia affinis taken at 5 replicates equivalent to 15 individuals per concentration. The samples were analyzed according to the procedure proposed by Unkittrick and Mac Carty in 1995, concerning investigations and tests in environmental toxicology.

Methods of Analysis of Leachates

Briefly, the physico-chemical analyzes of this research, 5 ml of fruit juice, 0.7 ml of 65% HNO_3 and 0.1 ml of 30% H_2O_2 were put in a Teflon bomb and digested overnight at 100 °C. The mixture was filtered through a 0.45 µm cellulose nitrate membrane and then diluted to 1/200 before assaying with ICP-MS according to the method of Mavakala et al. [23].

Microbiological Analyzes of Leachates

The sedimentation concentration technique (Ritchie method) consists of assembling and dissolving the residues after filtration of the leachates in ether, xylene and formaldehyde. The parasites are dragged to the bottom of the tube by concentration.

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The observation of parasitic worm eggs, larvae and cysts was read on fresh Motic microscope examinations and on the colored preparations according to the method of Gillet et al. [24].

Results and Discussion

The hot and humid tropical climate of Kinshasa is the abundant outcome of infiltration water indicating the difference in permeability in the soil of natural environments than in the one that has already undergone a reversal. The higher rainfall during nine months of rainy season favors the inflow of water percolating through the massive buried waste appearing in the (Tables 2-7). Toxicology tests on leachate from the Mpasa dump were carried out using bioindicators (Gambusia affinis) which is a species of fish adapted to in vitro biological tests. Their sensitivity to water quality is a conclusive indication of a highly polluted environment or not. The test consists in diluting the effluents to low concentrations to determine the lethal concentration 50 (Table 8).

Table 2: Permeability test in the soil of the Mpasa site and its surroundings.

N°	Heights	Infiltration time in the soil			
		Near the pool	1st Locker	29th Lockers	Outside the Site
1	10 cm	00’13’’28’’’	00’48’’52’’’	00’43’’47’’’	00’25’’11’’’
2	20 cm	00’40’’52’’’	01’47’’27’’’	01’28’’09’’’	01’33’’23’’’
3	30 cm	01’37’’28’’’	03’21’’54’’’	02’54’’37’’’	03’01’’08’’’
4	40 cm	03’37’’22’’’	09’32’’38’’’	08’25’’12’’’	06’13’’15’’’
5	50 cm	07’56’’32’’’	37’29’’57’’’	24’33’’29’’’	12’11’’62’’’

Table 3: Concentrations of the major elements of Lixiviats.

N°	Parameters	Concentrations
1	pH	12.3 ± 0.1
2	CE (mScm-1)	7,73±0,1
3	T(°C)	19,1±0,7
4	Na^+ (mg/l)	6.420±17
5	K^+(mg/l)	8.320±225
6	Ca^{2+}(mg/l)	10.320±279
7	Mg^{2+}(mg/l)	820±22
8	PO_4^{2-} (mg/l)	111,65±7,83
9	SO_4^{2-} (mg/l)	3724±156
10	$N0_3^-$ (mg/l)	440±1,8
11	$N0_2^-$ (mg/l)	380±16
13	Cl^- (mg/l)	6440±270

Table 4: Physico-chemical characteristics of raw leachates at the Mpasa CET.

N°	Parameters	Concentration
1	MES(mg/l)	462±107,96
2	Turbidity(FTU)	84,54±6,86
3	Tension Sup(Dyne/cm)	12,17±1,00
4	Density (g/ml)	1,006±0,01
5	Viscosity (mm^2/s)	0,58±0,55

Table 5: Results of physico-chemical analyzes of leachates produced in Mpasa.

N°	Leachate parameters	Concentration
1	DCO(mg/l)	13.797
2	COT(mg/l)	24.675
3	OD(mg/l)	1,36
4	DBO_5 (mgO_2/l)	363,0
5	SVI (ml/g)	1742

OD= Dissolved Oxygen

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Table 6: Characteristics of raw leachates at the Mpasa Technical Landfill.

N°	Leachate parameters	Concentrations
1	TS (mg/l)	6,33±5,29
2	TSS (mg/l)	1,29±0,11
3	VSS (mg/l)	18,71±5,26
4	FSS(mg/l)	0,02±0,01

TS : dissolved solids, TSS : suspended solid content. VSS : suspended solids volatiles FSS : Solids in suspension non flying.

Table 7: Parasitological Tests of Leachate.

	Class	Names		Diagnostics Methods	
		Générique	Commun	Ex. direct	Conc/sedim
Helminthes métazoaires	Trématodes	Schistosoma mansoni	S. intestinal	0	0
		Sch. Haematobium	S. vésical	0	0
		Fasciola gigantica	G.Douve du foie	0	0
		Papragonimus spp.	Douve du poumon	0	0
	Nématodes	Trichuris trichiura	Trichocéphale	0	0
		Ancylostoma duodenale	Ver du mineur	0	0
		Strongyloïdes strercolaris	Anguillule	0	0
		Trichostrongylus spp	-	0	0
Protozoaires	Rhizopodes	Entamoeba histolitica		0	0
		Entamoeba dispar	-	0	0
	Flagellés	Giardia lamblia			
		Dientamoeba fragilis	-	Ex. à frais et coloration,00	
	Retomonadea	Chilomastix mesnili	-	0	0
	Parabasalea	Pentatrchicomonas hominis	-	0	0
	Cilié	Balantidium coli	-	0	0
	Sporozoaires	Sarocystis spp	-	0	0
		Isospora belli	-	0	0
		Cryptoridium spp	-	0	0

Table 8: Percentage of Gambusia affinis survivors of the Mpasa dump at different concentrations.

N°	Concentrations	Number of Deaths				% Survivors
		1st day	2nd day	3th day	4th day	
1	100	3	-	-	-	0
2	10-1	2	0	0	0	33
3	10-2	1	0	0	0	66,7
4	10-3	0	1	0	0	66,7
5	10-4	0	0	0	0	100
6	10-5	0	0	0	0	100
7	Witnesses	0	0	0	0	100

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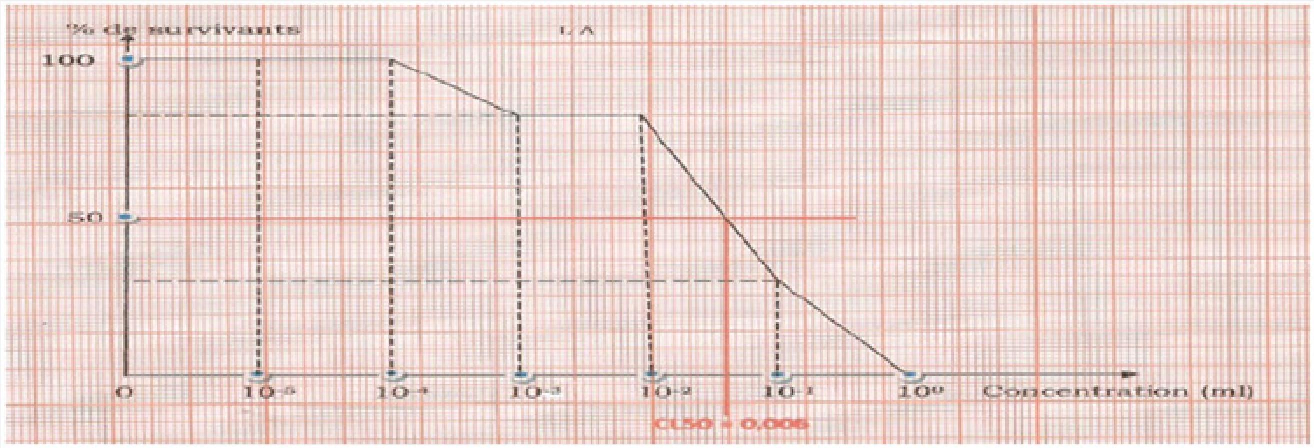

Figure 5: Leachate Retention Ponds.

The evaluation of the toxicity of the leachates produced at the Mpasa final discharge and tested in the laboratory for the level of toxic exposure level (LD50 of 0.006 ml / ml). The result of ecotoxicological tests in a population of 3 individuals of Gambusia affinis per pond reveals that within thirty minutes of breeding, all are killed at the concentration of 100 or 100% of deaths observed, then 77% of deaths the second day of concentration 10^{-1}, then 33.3% of deaths in concentrations 10^{-2} and 10^{-3} on the third day. Exposure of this same population to the control at concentrations of 10^{-4} and 10^{-5} gave the result of 100% survivors until the last day of rearing.

Conclusion

This work being multi-disciplinary informs us that the leachates preserved more than twelve months from 12/04/2016 to 19/12/2017 continue to remain toxic for the populations of Gambusia affinis in its concentrations of 100, ie 0% of survivors observed, followed by the 10^{-1} dilution with 33% survivors, 66.7% in the 10^{-2}, 10^{-3}, and 100% dilution of the survivors in the 10^{-4}, 10^{-5}, and in the Witness solution. The range of concentrations 10^{-2} and 10^{-3} are close to the theoretical threshold of the LC50. The lethal dose of leachates is 0.006 ml / ml. The results of the physicochemical analyzes exceed the recommended normal thresholds (Pb (87.22 μg /l), Ar (7.07 μg /l) and Fe (3.3080 μg /l). The older the leachate, the more its constituents sediment. while retaining its toxic character [24] The toxic character of Mpasa leachates comes from the complex mixtures of domestic garbage collected in a set of industrial waste and household waste, without pre-treatment at source and which correspond to absolutely different lifestyles The hot and humid tropical climate of Kinshasa is the culmination of the abundance of seepage water indicating permeability ranging from 00 'to 07' and from 00 'to 12' in both environments in the first trap built by PARAU, the infiltration is from 00 'to 37', while it is from 00 'to 24' in the last trap, the more abundant rainfall during nine months of rainy season. ie favor the inflow of water percolating through the buried waste. This character is also the expression of the manner of burying the waste predisposed to the increase of the internal temperature which kills the parasites (0 Helminths, 0 Metazoans and 0 protozoa), but which selects the bacteria. Anaerobiosis conditions are established under the impetus of methanogenic bacteria causing numerous interactions between water and waste in the middle of which the polluting loads are carried to the retention pond. Finally, the sequence of fermentation and waste degradation processes, biochemical and chemical reactions, and the alternative of the aerobic and anaerobic biological states of the waste from the decomposing landfill contribute to the high toxic load leachates [22-24].

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