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An analysis of the aspects and impacts to human health caused by effluents from a solid waste landfill: Case study

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Abstract
The decomposition processes of organic matter in landfills of urban solid waste result in the generation of gases and toxic leachate which, if not effectively managed, can result in serious impacts on the environment and public health. The main gases generated during this process are methane (CH_4) and carbon dioxide (CO_2), the first being 21 times more polluting for trapping heat in the atmosphere. In addition, hydrogen sulfide has an unpleasant smell and irritating effect on the eyes, which can cause headache and nausea. On the other hand, leachate has a COD about 200 times greater than domestic sewage, a large number of contaminating organic xenobiotics (XOCs), which are identified as carcinogens, in addition to heavy metals that can be found in large quantities in the acidogenic phase of the landfill. The objective of this work was to analyze, in a succinct way, the impacts caused by the effluents generated in landfills of urban solid waste to human health, based on analyzes carried out at the Aterro da Muribeca, located in the state of Pernambuco, Brazil. The methodology basically consisted of performing periodic measurements of gas concentration at the outlet of the gas tubes and leachate that the leachate treatment station provided. It was observed that, under the cover layer, there is a high concentration of hydrogen sulfide, meaning that this being in the open could cause a great impact on human health, as well as leachate with high organic loads capable of bioaccumulating in living organisms.

Keywords: urban waste, gases, leachate, health, environment

1. Introduction

The mechanism of gas formation in municipal waste landfills is extraordinarily complex due to the diversity of materials and compounds present and their possible physical-chemical and biological interactions over time. During the period of decomposition of residues, microbiological processes are predominant in the formation of gases. However, there are other mechanisms involved that act either in isolation, or in association with microbiology, in the transformation of substances into gases. These mechanisms are those of volatilization and chemical reactions [1].

Some authors indicate two phases of decomposition of organic matter inside the cells of a landfill: the aerobic and anaerobic phase. In aerobic metabolism, microorganisms develop in the presence of molecular oxygen or exceptionally incorporated into mineral elements (nitrates or sulfates). The main microorganisms are bacteria, yeasts, and fungi [2]. Daily garbage coverage promotes aerobic processes, lasting from one day to several weeks, until all the oxygen is consumed. Aerobic decomposition quickly uses the oxygen present in the waste cell and quantities of carbon dioxide and hydrogen are produced, where this process lasts less than a month. In anaerobic metabolism, microorganisms develop in the absence of oxygen, however, they can be tolerated (facultative anaerobes) or not (strict anaerobes). Anaerobic degradation occurs right after the total oxygen consumption inside the landfill. This phase is divided into two stages: the acid fermentation stage and the methanogenic fermentation stage [2]. In the second stage of the first stage (Acid Stage), one of the main fatty acids produced are: acetic acid and ammoniacal nitrogen. These acids mix with the liquid that seeps through the solid waste mass, causing its pH to drop to values between 4 and 6, [3]. The acid character of this mixture helps in the solubilization of inorganic materials, and may present high concentrations of iron, manganese, zinc, calcium and magnesium. The low pH values also favor the appearance of bad odors, with the release of hydrogen sulphide gas (H_2S), ammonia (NH_3) and other gases that cause bad odors. In the last stage (Methanogenic), the simple organic compounds formed in the acetogenic phase are consumed by strictly anaerobic bacteria, called methanogenic bacteria, which give rise to methane (CH_4) and carbon dioxide (CO_2). These methanogenic bacteria develop preferably at pH values close to neutral (pH = 7.0), between 6.6 and 7.3 [4].

It is known that hydrogen sulfide is a highly toxic and irritating gas, which acts on the nervous system, eyes, and airways. Intoxication by the substance can be acute, subacute, and chronic, depending on the concentration of the gas in the air, the duration, the frequency of exposure and individual susceptibility. H_2S is a volatile gas, and the main route of penetration is respiratory. Ammonia is an extremely irritating gas for mucous membranes. When it reaches the upper respiratory tract, sneezing, dyspnea, and coughing appear; these symptoms can evolve towards acute Broncho pneumopathies. When it reaches the eyes, they water, and conjunctivitis can manifest. As for methane, its greatest harmfulness refers to the risk of explosion that it can cause due to the lack of gas drainage in covered landfills. In addition, it is the most important greenhouse gas. Per molecule, an increase in the amount of methane in the air causes a heating effect 21 times greater than the addition of carbon dioxide, because the CH_4 molecules absorb a larger fraction of the thermal infrared photons that pass through it than the molecules of CO_2. So far, it is estimated that methane has produced about a third of all global warming produced by carbon dioxide.

In turn, the polluting potential of leachate is recognized as a serious environmental and geotechnical problem, being pointed out as one of the main disadvantages of landfills as a way of final disposal of the waste. This potential impact depends basically on the characteristics of the deposited waste, on the leachate composition, on the soil's attenuation capacity and on disposal techniques and procedures [5].

The leachate has a COD about 200 times greater than domestic sewage. Studies carried out by the EPA (Environmental Protection Agency), in the United States of America [6], indicated that the leachate concentration exceeds that typical of domestic sewage 700 times in relation to manganese, 500 in iron, 50 in DBO_5, 13 in chloride and 6 in total nitrogen. In addition, leachate contains many contaminating organic xenobiotics (XOCs), most of which have high toxicity, and are identified as carcinogens for humans [7].

The leachate has a high load of organic and inorganic pollutants and, when in contact with the soil and water (superficial and underground), it can intensively modify the physical, chemical, and biological characteristics of the environment [6]. state that "no effort is exaggerated when it is desired to avoid contamination of the water table, since the time required for the self-cleaning of an aquifer can take tens of years and the artificial removal of pollutants from a table is still economically unfeasible".

[8] developed toxicity tests on leachate samples collected in various landfills in France using microalgae, rotifers, crustaceans, protozoa, and luminescent bacteria, which are species belonging to the three trophic levels of the food chain (producers, consumers, and decomposers). Regarding the levels of toxicity, the results of the tests revealed that the leachate resulting from domestic waste is more toxic than that resulting from exclusively industrial waste. Understanding the chemical and biological mobility, the persistence, the toxicological and ecological significance of the compounds present, as well as the possible effects on organisms, populations and the community exposed to such substances, is of vital importance in the assessment of the polluting potential of leachate [5]. Soil contamination in the landfill area occurs whenever basic waterproofing techniques are not used. Heavy metals and organic compounds that are difficult to biodegrade can accumulate in the soil. The high concentrations of sodium and chloride ions in the leachate can cause a breakdown of the colloidal clay particles used at the base of the landfills, increasing the amount of voids and soil permeability, facilitating leachate percolation and the consequent contamination of groundwater and or surface [9]. [10] the leachate in contact with the soil promotes the increase of organic matter and elemental nutrients, also increases the concentration of heavy metals, and sometimes generates a drastic change in pH, modifying the entire composition and properties of the soil. [11] stated that the leachate still increases the phosphorus solubility, forming phosphomimic complexes and sesquioxide particles that cause the reduction of the phosphorus fixation capacity by the soil.

Given this context, this work aimed to analyze, in a succinct way, the impacts caused by the liquid and gaseous effluents emitted and possible damage to human health, based on analyzes carried out at the Aterro da Muribeca for a period of one year.

2. Materials and methods

2.1. Study Area

The Aterro da Muribeca has operated as an open-air garbage dump since 1985. In 1994, a physical diagnosis was carried out in the area, with the purpose of recognizing the geology, hydrogeology, geotechnics, morphology, water resources and meteorology of the entire area. of the landfill, through these studies the knowledge and characterization of the subsoil, of the superficial and underground water sheets and of the rock failures were allowed [2]. With the completion of the diagnosis, the waste treatment and environmental recovery process was started that same year, with a view to increasing the useful life of the disposal area and transforming the landfill into a controlled landfill, where nine cells lined with a waterproofing soil layer where the waste was deposited and compacted. The cells have average width and length dimensions of, respectively, 200 x 200 m, with height ranging from approximately 20 to 40 m [2].

The Aterro da Muribeca was the largest landfill in operation in the Metropolitan Region of Recife in the State of Pernambuco, Brazil, between 1985 and mid-2009.

At this time, it received an average of about 3,000 tons/day of waste from the municipalities of Recife and Jaboatão dos Guararapes. In November 2001, the landfill management agreement was signed between the municipalities of Recife and Jaboatão dos Guararapes and the state government, through shared management, with the aim of transforming the controlled landfill into a sanitary landfill, through specific actions, with the construction and operation of the Muribeca leachate containment and treatment station, thus complying with the current Environmental Legislation, the technical control standards of the State Environment Agency - CPRH. Muribeca's operational activities came to an end in mid-2009 (Figure 1).

Where the entire remaining area continues with mitigating actions aimed at the remediation of environmental liabilities in accordance with the Muribeca-PE Landfill Closure Project, prepared by the Federal University of Pernambuco (UFPE), through the Solid Waste Group, with approval by the State Environment Agency (CPRH) according to the Environmental Authorization under nº 04.10.00874-1 dated in January 2010.

Currently, the activities carried out in the Aterro da Muribeca corresponds to the activities of environmental and geotechnical monitoring, maintenance and construction works for the closure of the landfill.

Fig 1: Place of study: Aterro da Muribeca, Pernambuco, Brazil. Source: Google Earth.

2.2. Methodology

2.2.1. Monitoring of Biogas

At first, the monitoring methodology basically consisted of performing periodic measurements of the concentration of methane (CH_4) and oxygen (O_2) gases, only in the gas drainage system. Over time, it was found that the analysis of biogas monitoring would be more complete with the realization correlated with the second main component, carbon dioxide (CO_2). With the incorporation of CO_2, the monitoring was also extended to the inspection tubes that, in conjunction with the main drainage, performed the sub-surface monitoring of the gases at 16 investigation points in each cell. Surface monitoring consists of determining the behavior of gases in the cell's covering system. This determination was obtained with the development of a flow plate, whose main objective was to estimate the release of gases into the atmosphere by the cover layer. This flow plate is a closed and isolated chamber that serves to trap gases escaping from the soil of the final layer of the cell. In this way, the process of reading gas concentrations over time can be successful. Another prominent parameter in this surface monitoring was the assessment of methane retention in the cover layer determined by the difference in gas concentration before passing through the cover (auxiliary test tube) and after its passage (flow plate).

The methodology that is currently being used to monitor the gases generated at the Aterro da Muribeca involves the traditional study of the concentrations of CH_4, CO_2 and O_2 gases on the cell's surface and sub-surface, as well as in-depth monitoring of the gases. This monitoring is carried out in the borehole of the SPT test, measuring the gas concentrations simultaneously with the drilling [1]. Although of great value for the understanding of the organic matter degradation processes along the depth, this monitoring is only financially justified when SPT tests are necessary to determine other parameters. It is also important to note that during the performance of this monitoring, there is no reverse pressure gradient towards the entry of air into the garbage mass because, if this happens, the corresponding readings will not be satisfactory. Therefore, special care must be taken to make these readings reliable. One way to minimize this problem is to assess the local atmospheric pressures during the test.

2.2.1. Leachate Monitoring

The sample collection technique was based on [12] and consists of an apparently simple task. It is necessary to obtain a representative and stabilized sample of the sampled effluent and local conditions that may interfere both in the data interpretations and in the laboratory determinations themselves.

Some precautions were taken during the collection of samples of the effluent at the entrance of the Leachate Treatment System:

- The samples collected should not have large particles, or debris, or leaves.
- Samples were collected in a flask against the current.
- About 5 liters of leachate were sampled in each sampling campaign, packed in plastic barrels previously sterilized for physical-chemical analysis.
- For microbiological tests, approximately 200 milliliters were sampled in glass containers, previously sterilized. After sampling, the vials were placed in an ice bath at a temperature of approximately 4ºC.
- The periodicity of the sample depended on the type of

sampling performed.

Sampling is of fundamental importance in monitoring, not only constituting the collection of samples to be analyzed but involving the planning of sampling activities from the field to the laboratory.

For this research, the composite sampling was performed, formed by small and different rates collected over time. This type of sampling was carried out in this research to characterize the leachate in different months of the year. It is noteworthy that for each day of sampling, ten aliquots of 500 ml of leachate were collected in the interval of one hour, between 8 and 17 hours, forming, at the end of the day, a homogeneous sample of 5 liters. The samples were collected at the entrance of the Decantation Lagoon of the Leachate Treatment Station at the Aterro da Muribeca-PE, where all the leachate from the landfill is concentrated, as shown in Figure 2.

Due to the great variability of the leachate composition, the collected samples were previously analyzed with a view to their physical-chemical characterization. The following parameters were selected to characterize leachate: COD, BOD, pH, conductivity, color, turbidity, alkalinity, series of solids, ammonia nitrogen and heavy metals (Iron, Manganese, Zinc, Chrome, Copper, Lead and Nickel). The methodology adopted for physical-chemical analysis of the leachate was based on the procedures established by the Standard Methods for the Examination of Water and Wastewater [13]. Table 1 briefly presents the physical-chemical parameters analyzed for this research. All tests were performed at the Environmental Geotechnics Laboratory of the Solid Waste Group (GRS), except for heavy metal analyzes that were carried out at the Environmental and Quality Engineering Laboratory (LEAQ).

Fig 2: Leachate collection site, Aterro da Muribeca, Pernambuco, Brazil. Source: The authors.

Table 1: Parameters analyzed for the leachate characterization.

Parameters	Method Analytical	Reference (standard)
DQO (mg O_2/L)	Titration (Digestão com $K_2Cr_2O_7$)	SMEWW* 5220 C
DBO_5 (mg O_2/L)	Manometric	Adapted from SMEWW 5210
pH	Potentiometric	SMEWW 4500 B
Color (Hz)	Photocolorimetric	SMEWW 2120 C
Turbidity (NTU)	Nephelometric	SMEWW 2130 B
Conductivity (mS/cm)	Condutância elétrica	SMEWW 2510 B
Ammoniacal Nitrogen (mg/L)	Electrometric (Ion Selective Electrode - Orion Model 720)	SMEWW 4500 - NH_3 D
Total Phosphorus (mg/L)	Photocolorimetric	Spectroquant 14848 – MERCK
Sulfate (mg/L)	Photocolorimetric	Spectroquant 14791 – MERCK
Sulphide (mg/L)	Photocolorimetric	Spectroquant 14779 – MERCK
Chlorides (mg/L)	Photocolorimetric	Spectroquant 14897 – MERCK
Metals (Fe, Mn, Zn, Cr, Pb, Cd, Cu, Ni) (mg/L)	Atomic Absorption Spectrophotometry	Adapted from SMEWW

3. Results and Discussion

3.1 Characterization of Biogas and its impacts

[1] Made the assessment of CH_4 through the relationship between the concentration of CH_4 inside the plate (C) and the average concentration of the gas under the cover (Co), that is, through the C/Co ratio. Considering that the final concentration of gases inside the plate is the maximum that percolates through the roof, this relationship can be used as an indication of CH_4 retention in the soil. It was observed that the final C/Co ratio of CH_4 was minimal in the P-4 test (0.40) and maximum in the P-7 test (0.96), that is, there was a 60% retention in the initial concentration of the CH_4 in the P-4 test and only 4% at point P-7. It is worth remembering that the P-7 test showed atypical pressure behavior, and, for this reason, the minimum gas retention was found. In this way, it can be said that the higher the rate of percolation of the gas in the soil, the lower its retention. The author also evaluated the emission of gases for one of the garbage cells of Aterro da Muribeca. Table 1 shows the results of monitoring CO_2, CO and H_2S gases carried out in the test campaign. Despite the analyzes being made on a single occasion, the values found show consistency among themselves and with the concentrations seen in the literature.

According to [14], the maximum allowed tolerance limit, of the exposure of man to hydrogen sulfide, must not exceed 8 ppm or 12 mg/m^3 up to 48 hours a week. H_2S is a colorless gas, heavier than air, with an unpleasant odor of rotten eggs. Your physical state can be liquid under pressure. In addition, it is a strong acid with high corrosive power. It is a highly toxic and irritating gas, which acts on the nervous system, eyes and respiratory tract. Intoxication by the substance can be acute, subacute, and chronic, depending on the concentration of the gas in the air, the duration, the frequency of exposure and individual susceptibility. As it is a volatile gas, the main route of penetration is respiratory. Experiments with laboratory animals have shown absorption through the skin; however, in man, absorption by this route is discussed. At the level of the pulmonary alveoli, H_2S is solubilized in the surfactant liquid that covers the surface of cells, occurring a reaction with basic compounds present in the tissue. During solubilization hydrolysis occurs. The ionized form (H^+) is acidic, while the molecular form (H_2S) is fat-soluble and easily crosses the alveolocapillary membrane, which has a lipid composition. From that point, H_2S reaches the bloodstream, spreading throughout the body, producing systemic effects, such as at the level of the central nervous system: excitation followed by depression, particularly in the respiratory center: weakness, headache, nausea, vomiting, hyperexcitability, hallucinations, amnesia, irritability, delirium, drowsiness, weakness, convulsions and death (Table 2).

Table 2: Parameters analyzed for the leachate characterization. Source: NR-15.

H_2S concentration (ppm)	Exposure time	Effects
0,0005 - 0,13	1 minute	Odor perception
10-21	6 - 7 hours	eye irritation
50 – 100	4 hours	conjunctivitis
150 – 200	2 - 15 minutes	loss of smell
200 – 300	20 minutes	unconsciousness, hypotension, pulmonary edema, convulsion, dizziness and disorientation
900	1 minute	unconsciousness and death
1.800 - 3.700	Instants	death

The loss of smell results from the interaction of H_2S with zinc (Zn), which is important in the reactions of perception of smell. Olfactory fatigue occurs in 2 to 15 minutes, in concentrations above 100 ppm. Thus, the odor of H_2S is not a safe parameter to assess dangerous concentrations. The irritating action of H_2S on the skin and gastrointestinal mucosa results from the formation of sodium sulfide, resulting in itching (itching), burning and hyperemia (redness). Conjunctivitis, photophobia, tearing and opacification of the cornea appear in the eyes. In the digestive system, H_2S irritates the gastrointestinal mucosa and produces nausea and vomiting. The biotransformation of H_2S occurs very quickly and involves, in part, oxidation reactions by oxygenated hemoglobin and liver enzymes, forming sulfates and thiosulfates that are eliminated by urine and feces. When this detoxification mechanism is insufficient, as in exposure to extremely high concentrations, above 700 ppm, H_2S is eliminated unchanged in the exhaled air. As for impacts on the environment, hydrogen sulfide can cause acid rain through the reaction of hydrogen sulfide with oxygen.

Based on the [1], it is observed that the total H_2S retention in a soil thickness of only 0.25 m (test P-3) is of great interest to the context. It is also observed that, under the cover layer, there is a high concentration of hydrogen sulfide, meaning that this being in the open could have a great impact on human health, especially those who are exposed directly to garbage for a long time. In the case of landfills, the contact of the collectors with the waste may have a real impact in short periods of time. As for Carbon Monoxide, NR-15 states that the maximum permitted tolerance limit for human exposure should not exceed 39 ppm or 43 mg/m^3. [1] it is observed that carbon monoxide would not represent, at least in cell 08, such an accentuated exposure when compared to hydrogen sulfide.

Hydrogen sulfide and carbon monoxide are considered by NR-15 as the maximum degree of unhealthiness. As for Carbon Dioxide, NR-15 states that the maximum permitted tolerance limit for human exposure should not exceed 3900 ppm or 7020 mg / m^3 (up to 48 hours per week), not being a potential risk to human health, but largely responsible for the greenhouse effect. For Methane, NR-15 considers gas as a simple asphyxiant for confined environments, but its impacts refer to the risk of explosion that this can cause due to the lack of gas drainage in covered landfills, in addition to being a gas inducing the major greenhouse effect.

3.2. Characterization of Leachate Samples and their impacts

In this step, the characterization of the leachate from Aterro da Muribeca was performed, obtaining a range of values (minimum and maximum) for all parameters obtained. The results of the leachate characterization carried out through sampling composed in the period in which the leachate was more concentrated are shown in Table 3. It should be noted that during the collection period, most of the landfill waste was old (t > 5 years), with only a small fraction of new waste. The maximum pH range was between 8.2 and 8.7, which may indicate a landfill leachate in the methanogenic phase, as observed by several authors [15,16]. In this phase, there is the decomposition of acid fermentation products that are converted into methane (CH_4), humic substances and water [17]. With this pH range, the low concentration of heavy metals present in the leachate from Aterro da Muribeca can be justified since the high pH reduces the availability of contaminants [18]. According to data from the survey carried out by [19], this pH range is within the most likely range for Brazilian landfills.

Table 3: Characterization of leachate from Aterro da Muribeca.

Parameters	Aug/07	Sep/07	Nov/08	Dec/08	Nov/09	Dec/09	Maximum Range
pH	8,46	8,58	8,70	8,63	8,21	8,36	8,21 - 8,70
DBO_5 (mg/L)	2.320	2.430	3.185	3.190	1.140	500	500 - 3.190
DQO (mg/L)	3.307	3.467	4.293	4.735	3.600	3.800	3.307 - 4.735
DBO_5/DQO	0,70	0,70	0,74	0,67	0,32	0,13	0,13 - 0,74
Color (Hz)	8.683	8.645	10.550	10.355	8.850	8.830	8.645 - 10.550
Turbidity (NTU)	193,3	163,2	137	188	106,8	80,3	80,3 - 193,3
Conductivity (mS/cm)	18,24	20,63	21,33	19,40	24,16	24,73	18,24 - 24,73
Ammoniacal Nitrogen (mg/L)	1.708	1.446	1.532	1.125	2.900	2.050	1.125 - 2.900
Total Phosphorus (mg/L)	14,62	8,25	13,75	11,5	9,75	NA**	8,25 - 14,62
Sulfates (mg/L)	764	967	880	662	NA**	NA**	662 - 967

Sulfides (mg/L)	1,05	1,26	1,06	1,23	0,37	0,65	0,37 - 1,26
Chlorides (mg/L)	227	245	760	NA**	230	140	140 - 760
Fe (mg/L)	5,78	7,23	9,21	6,46	7,22	4,45	4,45 - 9,21
Mn (mg/L)	0,22	0,22	0,31	0,26	NA**	NA**	0,22 - 0,31
Zn (mg/L)	1,03	1,97	1,37	0,79	1,20	NA**	0,79 - 1,97
Cr (mg/L)	0,16	0,26	0,33	NA**	0,10	0,28	0,10 - 0,33
Cu (mg/L)	0,2	0,7	0,12	ND*	NA**	NA**	0,12 - 0,7
Pb (mg/L)	ND*	ND*	0,1	NA**	NA**	NA**	ND - 0,1
Ni (mg/L)	0,14	0,22	0,30	0,12	NA**	NA**	0,12 - 0,30

*ND: Not detected; **NA: Not Analyzed

According to [20], the results of the algae toxicity test suggests that the concentration of ammonia is the most important factor in the toxicity of the landfill leachate. For the leachate under study, a maximum concentration range between 1,125 and 2,900 mg / L was obtained, which according to [19], is characterized in the maximum range of Brazilian landfills. On the other hand, according to [21], through calculations using mathematical regression applied to physical-chemical and toxicological parameters, they obtained confirmation that alkalinity and ammonia may be the main contributors to the toxicity attributed to the leachate. Thus, it is necessary that the pH and alkalinity of the leachate that will be released in the receiving body, be controlled, so as not to create favorable conditions for the emergence of toxic ammonia. In the specific case of the leachate from the Aterro da Muribeca, the concentrations of ammoniacal nitrogen varying between 1,125 and 2,900 mg/L, with a high alkalinity value and a pH of 8.6 can indicate that the ammoniacal nitrogen is in the ionized form NH_4^+. However, [22]. Explains that in an alkaline environment, there is a possibility of an increase in the concentration of the non-ionized form (NH_3), which is toxic. According to [23], the high amount of ammoniacal nitrogen in the leachate can be caused by the high concentration of nitrogen in the humic substance. These substances contain aliphatic and aromatic components with primary phenolic and carboxylic functional groups, where the carboxylic group is about 60 to 90% of the entire functional group [24]. According to [25], values of non-ionized ammonia above 0.20 mg/L are already sufficient to induce chronic toxicity and lead to decreased growth and fish tolerance to diseases. Ammonia levels between 0.70 and 2.40 mg/L can be lethal to fish, when exposed for a short period. Continuous or frequent exposure to toxic ammonia concentrations above 0.02 mg/L can cause intense irritation and inflammation in the gills. Even in the absence of detectable levels of total ammonia in the water, a large increase in the pH of the water during periods of intense photosynthesis impairs the excretion of ammonia. Such a condition invariably results in the fish being self-intoxicated by the ammonia generated in their own metabolic processes. Nitrogen in the form of ammonia is one of the main obstacles to the intensive development of fish [25]. According to [20], the results of the algae toxicity test suggest that the concentration of ammonia is the major factor that governs the toxicity of the landfill leachate [26]. studied the nitrogen cycle in fish tanks covered with aquatic macrophytes and found that, quantitatively, the most important source of nitrogen for protein synthesis was ammonia assimilated by plankton. The assimilation of nitrogenous compounds by phytoplankton can cause uncontrolled growth in this community, causing algal blooms in the environment [27]. Observed that ammonia, whose concentration values ranged between 0.77 and 1.58 mg/L, favored the growth of algae, since nitrogen compounds are essential nutrients for primary productivity. [28]. stated that a concentration of 0.30 mg/L of nitrogen is sufficient to promote algae bloom. High concentrations of the ammonium ion can strongly influence the dynamics of oxygen dissolved in the medium, since to oxidize 1.0 mg of the ammonium ion, approximately 4.3 mg of oxygen are needed, which, in turn, influences the community of fish, because, at basic pH, the ammonium ion is transformed into ammonia (free, gaseous NH_3), which can be toxic to these organisms [29].

The true or real color of the leachate is related to the dissolved solids and colloids, more specifically to the presence of humic and fulvic substances. [23]. observed that over time the molecules and aromatic components of humic substances also increase, that is, as the leachate gets older, the color tends to become more concentrated. According to Table 1, of the leachate characterization, no significant change in leachate color has yet been noticed after the landfill closure. The most likely concentration range found for the color varied between 8,645 and 10,550 Hz, which may indicate a leachate quite concentrated in humic and fulvic substances. Humic substances (HS) are included as potential polluters, since they are composed of dissolved organic mixtures that occur in nature, which plays an important role in the chemical and biochemical pollution of natural soils and waters. They can be derived from some organic materials (including plants and animal remains, microfauna residues, pesticides, etc.), affecting the behavior of some pollutants in natural environments, such as toxicity and speciation of heavy metals, solubilization and adsorption of hydrophobic pollutants [23]. SHs do not exhibit defined physical and chemical characteristics, have high molecular mass, and cause dark coloring in soils and waters [30].

Some researchers [31]. indicate that humic substances constitute an important group of the leachate's organic matter. [23]. Observed that, over time, the molecular particles and aromatic components of humic substances also increase. Such humic substances are responsible for the brown color found in the leachate [17]. In aquatic environments, humic substances can be compared with humic substances of natural organic matter (NOM). They are refractory anionic macromolecules of moderate (1,000 Da - fulvic acids) to high (10,000 Da - humic acids) molecular weight, where fulvic acid may be responsible for the mobility of the pollutant. [32]. in their studies, analyzed the distribution of molecular weights in stabilized and intermediate leachate. These studies indicated that most of the compounds responsible for COD were found below 1000 Da: 74% for stabilized and 64% for medium or intermediate leachate.

Turbidity is related to suspended solids that cause diffusion and absorption of light, caused by platelets, bacteria, clays and silts in suspension, sources of pollution that release fine material and others. It is due to the presence of colloidal, suspended, organic or inorganic particles and other microscopic organisms [33]. According to Table 3, of the leachate characterization, turbidity varied between 80.3 and

193.3 UNT, presenting a very turbid effluent when compared to sewage.

The electrical conductivity of a material is determined by the presence of dissolved substances that dissociate into anions and cations depending on the temperature. Metal ions generally combine with non-metallic compounds (acids or bases) called ligands. In a landfill, the most common binders are certain anions (chlorides, phosphates, sulfates), nitrogen, humic acids and amino acids [34]. In the leachate samples analyzed, the maximum range obtained was 18.24 and 24.73 mS/cm at the entrance of the leachate treatment system at the Aterro da Muribeca for different periods.

All life forms are affected by the presence of metals depending on the dose and chemical form. It should be noted that, in general, metals are essential for the growth of all types of organisms, from bacteria to even humans, but they are required in low concentrations and can damage biological systems. The measured levels of some heavy metals in the samples are shown in Table 3. Among the values of heavy metals presented, it is observed that most of these are well below the maximum values allowed for the discharge of effluents in receiving bodies, except for the iron content that is above the standard of discharge by the [35], confirming the statements of [36], that the concentration of heavy metals in landfill leachate, in the fermentation stage, should have low levels of heavy metals due to metallic solubilization and complexation of volatile fatty acids, and the risks of environmental contamination are more due to processes accumulation [15]. According to [37], the concentration of heavy metals in landfill leachate in the acidic stage will typically be higher when compared to the fermentation stage due to metallic solubilization and complexation of volatile fatty acids. Aromatic compounds as well as humic and fulvic acids can also complex metals, such as copper, cadmium, lead, iron, nickel, manganese, cobalt, and zinc. A significant portion of solid waste is classified as hazardous and can have harmful effects on human health and the environment. Heavy metals such as lead, cadmium, and mercury, are incorporated into the biological chain, having a bio accumulative effect and can cause various diseases such as saturnism and nervous system disorders, among others.

3.3 Toxicological Aspects

According to [38], about 1% of urban waste consists of solid urban waste containing toxic elements. These residues come from fluorescent lamps, thermometers, cans of insecticides, batteries, batteries, paint cans, among other products that the population throws in the trash, because they do not know that they are hazardous waste containing heavy metals or toxic elements or do not have alternative to dispose of this waste. The cells and batteries contain in their composition metals considered dangerous to human health and the environment such as mercury, lead, copper, zinc, cadmium, manganese, nickel, and lithium. Among these metals, the ones that present the greatest health risk are lead, mercury and cadmium, where they are toxic and reactive, in addition to bioaccumulating in human organisms.

Despite containing numerous toxic substances in its composition, leachate is commonly dumped into aquatic ecosystems. Thus, the performance of toxicity tests with organisms of different trophic levels in the aquatic chain [8] - such as algae (*Chlorella vulgaris* and *Scenedesmus sp*.), Microcrustaceans (*Daphnia pulex* and *Daphnia magna*) and fish (*Salmo gairdneri*) - becomes an important instrument for determining the toxicity of this effluent to aquatic organisms [39, 40, 41].

The use of toxicity tests to assess waste disposal sites has shown that a complete assessment must be carried out with different organisms such as algae, microcrustaceans, fish, earthworms, bacteria and vegetables [42]. This assessment can be performed both on soil samples from the disposal areas and on samples of leachate residues [43, 44, 45].

Since solid waste contains a wide variety of substances, there may be a risk of human intoxication through the air, water, soil or through the food chain from the ingestion of vegetables and animals - aquatic and terrestrial - used as food, which have been contaminated by substances that can be bioaccumulated, such as heavy metals and polycyclic aromatic hydrocarbons [46].

Human contamination can occur by eating meat or milk from animals that feed on contaminated plants found in waste areas or even by eating these plants themselves [46]. Aquatic fauna and flora can accumulate chemical substances, if the water courses in which they are present have been contaminated by waste coming from disposal areas, as well as vegetation irrigated with contaminated water originating from waste disposal areas can also cause problems health care for men [47].

The health problems observed in populations living in the vicinity of the urban waste disposal area can be aggravated, taking into account that many of these people live in precarious housing (often without adequate water supply and sanitation) combined with a population which does not have adequate medical care and has a low cultural and educational level, contributing to the protection and hygiene measures not being adopted, favoring exposure to chemical substances and biological agents from waste disposal areas [47]. In addition to these factors, patients with chronic diseases, women, the elderly, and children are vulnerable groups that can have their health more easily affected.

The health effects caused by exposure to various chemical substances from waste disposal sites occur in several ways and affect different target organs, depending on the type of substance involved, the route of exposure and the dose received [48].

Liver and kidney functions are often affected when many chemicals reach toxic levels in the body, as both organs are involved in the metabolism and excretion of substances. For the liver, the damage is often non-specific. For example, cirrhosis is often associated with alcohol consumption, but the disease can also be caused by exposure to chlorinated hydrocarbons. The excretory function of the kidneys can predispose this organ to a greater intensity of exposure to chemical species. Mercury and chloroform are examples of chemical species that can cause kidney damage [48].

[49/ mention that the health effects prevalent in low exposure situations are generally nonspecific. In situations of moderate exposure, hematological abnormalities are frequent and at high exposure, skin problems, disorders in the central nervous system, liver and reproductive system are often observed.

The skin and the central nervous system are often affected in cases of direct contact with chemical species from waste disposal areas. Effects on the hepatic, renal and reproductive systems are observed in chronic exposures to low doses of chemical substances through ingestion. Both dysfunctions in the central nervous system and in the reproductive system have been seen in many exposure circumstances, both in high and low doses, as well as in a wide variety of chemicals. However, respiratory, gastrointestinal, and cardiovascular disorders were mostly observed in situations of exposure to low doses [49].

According to [17], the impacts that heavy metals can have on the human body are:

- Cadmium (Cd): Hypertension, kidney problems, destruction of red blood cells.
- Chromium (Cr): The hexavalent form causes cancer.
- Nickel (Ni): Induction of nasal, lung and larynx cancer.
- Zinc (Zn): Vomiting, dehydration, nausea, fainting...
- Mercury (Hg): Neurological problems, paralysis, blindness...

The severity and immediate manifestation of the effects are related to the dose and route of exposure. Ingestion is the route in which contamination episodes occur with more severe consequences for the health of the populations, especially in cases where the food has been directly or indirectly contaminated. The intake of contaminated water is still an important route, but the clinical manifestations were only apparent in situations of exposure to extremely high doses of the substance. In low-dose situations, many exposed individuals were asymptomatic or showed only transient subclinical manifestations [49].

With regard to air contamination, the main complaints from populations neighboring these areas refer to respiratory disorders, not only due to the suspended dust, but also due to the burning of residues and the unpleasant smell and irritating effect of some volatile substances, which cause headache. and nausea. Air contamination can also be responsible for vision problems, such as irritation and inflammation of the ocular mucosa [50]. Not to mention the possibility that the suspended dust contains heavy metals associated with clays with marked adsorption characteristics, such as montmorillonite.

Health problems reported in populations found in the vicinity of urban waste deposits refer to intestinal disorders, worms, skin allergies, respiratory problems, conjunctivitis, etc. [47]. However, a high incidence of cancer among residents in the vicinity of a municipal solid waste landfill was found in studies [51, 52].

4. Conclusions

According to the referred research, it is concluded that:

For the test carried out in the place with the lowest soil thickness (25 cm), a total retention in the passage of hydrogen sulfide (H_2S) was verified. This fact allows us to conclude that, although the 25 cm cover layer is inefficient to avoid CH_4 pollution, it works as a satisfactory barrier to minimize local pollution from H_2S.

Based on the biogas tests carried out, it is observed that the gases emanating from the landfill would be more harmful in confined environments, and not in dispersed environments such as Aterro da Muribeca. However, for those who operate the landfill, PPE should be used to avoid headaches and eye irritation. In addition, the exposed mass of garbage must be covered to retain hydrogen sulfide. Already under the cover layer there is a high concentration of hydrogen sulfide, meaning that this being in the open could have a great impact on human health, especially those who are exposed directly to garbage for a long time. In the case of dumps, the contact of the collectors with the residues can promote real impacts in short periods of time.

According to the characterization of the residues, it was observed that the raw leachate in contact with soil or water can have numerous impacts on human health. The ingestion, for example, of fish contaminated by raw leachate or improperly discharged into rivers, becomes a route in which episodes of contamination occur with more severe consequences for the health of the populations.

Ingestion of contaminated water is still an important route, but the clinical manifestations may be apparent only in situations of exposure to extremely high doses of the substance, such as direct ingestion of leachate. In low-dose situations, many exposed individuals may be asymptomatic or show only transient subclinical manifestations.

5. References

1. Maciel FJ. Estudo da geração, percolação e emissão de gases no aterro de resíduos sólidos urbanos da Muribeca. Recife. f. Dissertação (Mestrado) - Universidade Federal de Pernambuco, 2003.
2. Lins Eam. A utilização da Capacidade de Campo na Estimativa do Percolado Gerado no Aterro da Muribeca. Recife. Dissertação de Mestrado. Universidade Federal de Pernambuco. Departamento de Engenharia Civil, 2003.
3. D'almeida, Maria Luiza Otero, Vilhena André (Coord.). Lixo municipal: manual de gerenciamento integrado. 2. ed. São Paulo: Instituto de Pesquisas Tecnológicas – IPT/ Compromisso Empresarial para Reciclagem – Cempre. 2000; 6:295-313.
4. Azevedo FG. Estudos das condições ambientais para a produção de biogás a partir de glicerol co-produto do biodiesel. Dissertação (Mestrado), Universidade Federal de Pernambuco, CTG. Programa de Pós-Graduação em Engenharia Química, 2010, 88.
5. Capelo Neto J. Estudo Quanti-Qualitativo do Percolado Gerado no Aterro Sanitário Oeste, em Caucaia, Ceará. Fortaleza, f. Dissertação (Mestrado) - Universidade Federal do Ceará, 1989.
6. Gerland GA, Mosher DC. Efeitos Nocivos da Percolação em Aterros de Lixo Executados Inadequadamente. *Revista de Limpeza Pública*. Ed. Ano I, outubro. 1975; 3:23-31,
7. LU JCS, Eichenberg B, Stearns RJ. Leachate from Municipal Landfills, Production and Management. Pollution Technology Review. New Jersey: Noyes Publications, n, 1981, 119.
8. Bernard C. Estimation of the hazard of landfills through toxicity testing of leachates. I. Determination of leachate toxicity with a battery of acute tests. *Chemosphere*, v. 1996; 33:2303-2307.
9. Giordano G. Análise e formulação de processos para tratamento dos chorumes gerados em aterros de resíduos sólidos urbanos. Tese de Doutorado - Departamento de Ciência dos Materiais e Metalurgia, Pontifícia Universidade Católica do Rio de Janeiro, Rio de Janeiro-RJ, 2003, 257.
10. Lisk DJ. Environmental Effects of Landfills. *The Science of the Total Environmental*, v. 1991; 100:415-468.
11. Giusquiani PL, Marucchini C, Businelli M. Chemical properties of soils amended with compost of urban waste. Plaint soil, v. 1998; 109:73-78.
12. Companhia ambiental do estado de são paulo - cetesb. Guia nacional de coleta e preservação de amostras.

Águas, Sedimento, Comunidades Aquáticas e Efluentes Líquidos. Brasília, DF, 2011.
13. Apha. Standard Methods for the examination of water and wastewater. American Public Health Association, American Water Works Association, Water Environmental Federation, 20th ed. Washington, 1998.
14. Brasil. Ministério do Trabalho e Emprego. NR 15 Atividades e Operações Insalubres. Brasília: Ministério do Trabalho e Emprego, 2014.
15. Ehrig HJ. Quality and Quantity of Sanitary Landfill Leachate. *Waste Management & Research* I, 1989, 53-68.
16. Firmo ALB. Análise comportamental de parâmetros físico-químicos e geração de gás numa célula experimental no Aterro da Muribeca-Pe. Monografia de Conclusão de Curso - Departamento de Engenharia Química, Universidade Federal de Pernambuco, Recife-PE, 2006, 70.
17. Segato LM, Silva CL. Caracterização do Lixiviado do Aterro Sanitário de Bauru. In: XXVII Congresso Interamericano de Engenharia Sanitária e Ambiental, Porto Alegre – RS, 2000.
18. Mendez R, Lema JM, Blazquez R, Pan M, Forjan, M. Characterization, digestibility and anaerobic treatment of leachates from old and young landfills, *Water Sci. Technol*. v. 1989; 21:145-155.
19. Souto GDB, Povinelli J. Características do lixiviado de aterros sanitários no Brasil. In: 24º Congresso Brasileiro de Engenharia Sanitária e Ambiental, Belo Horizonte-MG, 2007.
20. Cheung KC, Chu LM, Wong MH. Ammonia stripping as a pretreatment for landfill leachate. *Water, air and soil pollution*, v. 1997; 94:209-221.
21. Clément B, Merlin G. The contribution of ammonia and alkalinity to landfill leachate toxicity to duckweed. *The Science of the Total Environmental*, v. 1995; 170:71-79.
22. Esteves FA. Fundamentos da limnologia. 2. ed. Rio de Janeiro: Interciência, 1998, 602p.
23. Kang K, Shin HS, Park H. Characterization of Humic Substances Present in Landfill Leachates with Different Landfill Age and Its Implications. *Water Research*. v. 2002; 36:4023-4042.
24. Hong S, Elimelech M. Chemical and physical aspects of natural organic matter (NOM) fouling of nanofiltration membranes. *Journal of Membrane Science*, v. 1997; 132:159-181.
25. Kubitza F. Qualidade da água na produção de peixes. 3. ed. Jundiaí: Degaspari. 1999, 97.
26. Oláh J, e Szabó P. Nitrogen cycle in a macrophyte covered fish pond. Aquacultura hungarica (szarvas), v. 1986; 5:165-177.
27. Xavier MB, Mainardes-Pinto CSR, Takino M. Euglena sanguinea Ehrenberg bloom in a fish-breeding tank (Pindamonhangaba, São Paulo, Brazil). Algological Studies, Stuttgart, v. 1991; 62:133-142.
28. Branco SM. Hidrobiologia aplicada à engenharia sanitária. 3. ed. São Paulo: CETESB/ASCETESB, 1986, 640.
29. Trussel RP. The percent un-ionized ammonia in aqueous ammonia solutions at different pH level and temperatures. *J. Fish. Res. Board Can*., v. 1972; 29:10.
30. Kurniawan TA, Chan GYS, LO W, Babel S. (2006a) Physico-chemical treatment techniques for wastewater laden with heavy metals. *Chemical Engineering Journal*, n. 2006; 118:83-98.
31. Chian ESK, DeWALLE FB. Evaluation of leachate treatment, US EPA, Cincinnati, Ohio, 1977, 77.
32. Trebouet D, Schlumpf JP, Jaouen P, Quéménéour F. Stabilized landfill leachate treatment by combined physic-chemical-nanofiltration process. *Environmental Technology*, v. 2001; 20:587-596.
33. Sawyer CN, Mccarty PL, Parkin GF. Chemistry for environmental engineering and science. 5. ed. New York: McGraw-Hill, 2003, 752.
34. Castilhos Junior AB. Principais processos de degradação de resíduos sólidos urbanos. In: CASTILHOS JUNIOR, A.B. (Org.). Resíduos sólidos urbanos: aterro sustentável para municípios de pequeno porte. Rio de Janeiro: Rima/ABES, 2003, 143-197.
35. Brasil. Conselho Nacional do Meio Ambiente (CONAMA). Resolução nº 430, de 13 de maio de 2011. Dispõe sobre as condições e padrões de lançamento de efluentes, complementa e altera a Resolução no, de 17 de março de 2005, do Conselho, 2011, 357.
36. Santana-Silva FM, Santos RFV, Lins EAM, Lins CMM, Jucá JFT. Avaliação do método de precipitação química utilizando hidróxido de cálcio no tratamento do liviado do Aterro da Muribeca-PE. In: 25º Congresso Brasileiro de Engenharia Sanitária e Ambiental, Recife – PE, 2009.
37. Harmsen J. Identification of organic compounds in leachate from a wast tip. *Water Research*, v. 1983; 17:699-705.
38. IPT-Instituto De Pesquisas Tecnológicas. lIXO municipal: Manual de gerenciamento integrado. São Paulo: Instituto de Pesquisas Tecnológicas / Cempre, 2018, 316.
39. Atwater JW. Experiments using Daphnia to measure landfill leachate toxicity. *Water Research*. 1983; 17:1855-1861.
40. Cameron RD, Koch FA. Toxicity of landfill leachates. *Journal of Water Pollution Control Federation*. 1980; 52:760-769.
41. Enserink EL, Maas-Diepeveen JL, Van Leeuwen CJ. Combined effects of metals: An ecotoxicological evaluation. *Water Research*. 1991; 25:679-687.
42. Miller N. Locally available adsorbing materials, sediment sealing and flocculants for chemical remediation of lake and stream water. *Analytical & Environmental Consultants*, 2005, 82.
43. Coya B, Marañón E, Sastre H. Ecotoxicity assessment of slag generated in the process of recycling lead from waste batteries. *Resources Conservation & Recycling*. 2000; 29:291-300.
44. Hauser B, Schrader G, Bahadir M. Comparison of acute toxicity and genotoxic concentrations of single compounds and waste elutriates using the Microtox/Mutatox test system. *Ecotoxicology and Environmental Safety*. 1997; 38:227-231.
45. Matthews JE, Hastings L. Evaluation of toxicity test procedures for screening treatability potential of waste in soil. Toxicity Assessment: An International Quarterly. 1987; 02:265-281.
46. Chaney RL. Food chain pathways for toxic metals and toxic organics in wastes. In: Environment and Solid Wastes − Characterization, Treatment, and Disposal (C.W. Francis & S.I. Auerbach, eds.), USA: Butterworths Publishers, 1983, 179-208,
47. Sissino CLS. Destino Dos Resíduos Sólidos Urbanos E

Industriais No Estado Do Rio De Janeiro: Avaliação Da Toxicidade Dos Resíduos E Suas Implicações Para O Ambiente E Para A Saúde Humana. Tese de Doutorado – Escola Nacional de Saúde Pública, Fundação Oswaldo Cruz, Rio de Janeiro – RJ, 2002, 102.

48. Koning H, Cantanhede A, Benavides L. Hazardous Waste and Health in Latin America and the Caribbean. Washington D.C.: OPAS/ CEPIS, 1994.
49. Buffer PA, Crane M, Key MM. Possibilities of detecting health effects by studies of population exposed to chemicals from waste disposal sites. *Environmental Health Perspectives*. 1985; 62:423-456.
50. Acurio G, Rossin A, Teixeira PF, Zepeda F. Diagnóstico de la Situación del Manejo de Residuos Sólidos Municipales en América Latina y el Caribe. Washington D.C.: BIRD/OPAS, 1997.
51. Goldberg MS, AL-Homsi N, Goulet L, Riberdy H. Incidence of cancer among persons living near a municipal solid waste landfill site in Montreal, Québec. *Archives of Environmental Health*. 1995; 50:416-424.
52. Goldberg MS, Siemiatyck J, Dewar R, Désy M, Riberdy H. Risks of developing cancer relative to living near a municipal solid waste landfill site in Montreal, Québec. *Archives of Environmental Health*. 1999; 54:291-296.