ABSTRACT

This work describes the main environmental impacts form the physical point of view, generated by an improper daily deposition of Aracaju City garbage, during the last 15 years. Sandy sediments characterize the geological structure of the open landfill area, with a considerable permeability, in such a way that the Marituba Formation may be submitted to a very strong pollution process, due to the leachate migration, generated in the open landfill. The same is happening with the superficial waters in the neighborhood of this influence area. This region is very important to the tourism development of Aracaju. Based in some secondary hydrologic data a mathematical simulation was done in order to understand the pollution propagation wave of leachate concentration in the Marituba Geological Formation. There are some municipal public actions to get the remediation of this open landfill, and from the environmental point of view, the best choice for a new adequate place, to implement a sanitary landfill.

KEY WORDS: solid waste management, landfill leachate impacts, underground water pollution, environmental risks in landfill.

INTRODUCTION

Aracaju is a coastal city of the Northeast part of Brazil with approximately 470,000 inhabitants, producing 300 ton/day of garbage with about 65% of organic matter, including heavy metals, working until today, without any selective process.

A primitive garbage deposit, which is called the Terra Dura open landfill, without daily cover, is used to receive the Municipal Solid Waste of Aracaju. From the technical point of view it can not be considered a Sanitary Landfill.

Some characteristics of the open landfill have to be taking in account: first of all, there is no leachate collection and treatment, then the leachate migrates away from the landfill, causing serious pollution to the groundwater aquifer, as well as adjacent surface waters; second, there is no superficial drainage increasing the generation of leachate; third, there are no drains for collection or appropriate dispersion of the gases generated by aerobic and anaerobic biodegradation reactions and forth, there is no daily cover, causing the propagation of diseases transmitted by insets, rats etc.
This open landfill is in activity during the last 15 years without considering the main good practices of operation, in order to protect the environment and the public health.

Unhappily, this is a common situation in this country and most of the landfill; approximately 77% operates in such bad conditions, for example, without impermeable clay layers or appropriated plastics membranes, causing several risks of the natural resources contamination.

**LOCALIZATION**

The aerial photo, **Figure 1**, shows the localization of the garbage deposit. This clearly indicates the environmental fragility from several points of view: the proximity of several residential groups, due to the urban expansion of the city; located in part of the recharge zone of one important aquifer called Marituba, and is very close to important and intricate superficial water resources, between two important hydrological basins, in the Northeast direction, Rio Sergipe Basin, near Aracaju, and in Southeast direction, Rio Vaza Barris Basin, both of them, very important, including from the tourism point of view; the proximity of Aracaju Airport.

**Figure 1 – Aerial view of the open landfill**

The situation exposed above, leads the federal and local authorities to implement severe actions in order to avoid at once these prohibitive conditions from the environmental protection, and security point of views because of the serious risks involved.
The garbage deposit has being made in valleys, in a wrong way, without environmental protection technologies, for instance, impermeable layers. As can be shown in Figure 2 it is possible to see a quasi-pacific interrelationship between human being, (in the poverty line) and several kinds of animals, such as cows, horses, birds, etc.

Figure 2 – The open Landfill of Aracaju City
GEOLOGICAL AND HYDRO GEOLOGICAL CHARACTERISTICS OF THE AREA

The Figure 3 shows the topographic map and the different profiles in the main directions of larger environmental interest, including the intricate and very important net of superficial hydrological drainage system. The geological profile in direction NW-NE shows the wells which are used for the population.

Figure 3 – Topographic map showing the hydrological system.

ENVIRONMENTAL VULNERABILITY OF THE AREA

As showing in the Figures 3 and 4 the area has a high environmental vulnerability, mainly from the point of view of the superficial and underground water resources, including the recharge area of the aquifer.

The dominant semi-permeable geologic formation permits the leachate infiltration in an important aquifer and still the pollution of several superficial water resources, as estuarine rivers, streams and channels of great tourism importance.

An additional serious difficulty is that the aquifer is constituted by a not very consolidated tertiary sand rock, which has a very low capacity to attenuate the propagation of heavy metals in the porous formation.

The proximity of Aracaju Airport, is indeed a very important security problem because there are many birds in the open landfill area, mainly black vulture and in the last years, the presence of several heron is confirmed. Some accidents were reported due to the collision of these birds with some aircrafts, with the possibility of tourism active reduction.
THE OPEN LANDFILL REMEDIATION

The deposit has being disabled by judicial constraint, without the necessary providences that have to be taken to avoid the drastic effects of the pollution caused by this enormous environmental (dormant) passive, that occupies an area of 200,000 square meters.

Its is strictly necessary the monitoring process with respect to the pollutant plume due to the leachate, through the geologic porous media, by using a detailed geologic survey, associated with the use of mathematical simulation models that will be presented in the next item.

The main intention of this action is related to the preservation of the water quality of the wells showed in Figures 3 and 4. These wells are used today as a provision part of the population of Aracaju; this aquifer is in the area of direct influence of the referred polluting source, i.e. the open landfill.

Some implemented actions to control and minimize the potential pollutant of that garbage deposit are: the bio-remediation "in loco" by using a special kind of bacteria; the leachate drainage and treatment, by using compact fluidized bed reactors; the use of monitoring wells, and still a hydraulic barrier, if necessary with the principal aim to intercept and to treat the water contaminated by the leachate that, inexorably, will affect the wells of provisioning as presented in the illustrations, Figures 3 and 4.

MATHEMATICAL MODELING OF GROUND WATER POLLUTION

A canonical analytical solution for a one-dimensional pollutant dispersion problem, as showed in Figure 5, was used to control the concentration distribution in the Marituba Geological Formation.

Physical Model: Polluted river - Leachate

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The concentration distribution as a function of x and t, is given by \( C = C(x, t) \), which is obtained from the solution of partial differential equation 1, called diffusion equation.

\[
\frac{dC}{dt} = D \left( \frac{d^2C}{dx^2} - \frac{U}{dx} \frac{dC}{dx} \right)
\]  

(1)

The derivatives in this equation are partial derivatives.

The initial and boundary conditions 2, are:

\[
C(x, 0) := 0 \quad \text{para } x > 0 \quad (2)
\]

\[
C(0, t) := C_0 \quad \text{para } t>0
\]

\[
C(∞, t) := 0 \quad \text{para } t>0
\]

The diffusion equation solution obtained by using the Laplace Transform operator is given by the equation 3:

\[
CFL := \frac{C_0}{2} \left[ 1 - \text{erf} \left( \frac{x - U \cdot t}{2 \cdot \sqrt{D \cdot t}} \right) \right] + \exp \left( \frac{U \cdot x}{D} \right) \left[ 1 - \text{erf} \left( \frac{x + U \cdot t}{2 \cdot \sqrt{D \cdot t}} \right) \right]
\]

(3)

In which \( \text{erf} c=1 - \text{erf} \)

The problem solution is presented through the three graphics showed in the Figures 6,7 and 8:

**Figure 6 – Concentration distribution versus distance, for different times.**
Figure 7 – Concentration distribution versus time, for different distances.

Figure 8 – Concentration distribution 3 D.
The solution is given in the matrix representation as:

\[
\begin{array}{cccccc}
0 & 1 & 2 & 3 & 4 & 5 \\
0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0.305 & 9.568 \times 10^{-3} & 2.092 \times 10^{-5} & 2.825 \times 10^{-9} & 1.238 \times 10^{-14} \\
2 & 0 & 0.661 & 0.176 & 0.014 & 2.944 \times 10^{-4} & 1.562 \times 10^{-6} \\
3 & 0 & 0.829 & 0.428 & 0.109 & 0.012 & 5.565 \times 10^{-4} \\
4 & 0 & 0.909 & 0.632 & 0.28 & 0.07 & 9.324 \times 10^{-3} \\
5 & 0 & 0.95 & 0.77 & 0.463 & 0.185 & 0.046 \\
6 & 0 & 0.972 & 0.858 & 0.62 & 0.333 & 0.124 \\
7 & 0 & 0.984 & 0.912 & 0.739 & 0.482 & 0.236 \\
8 & 0 & 0.991 & 0.946 & 0.825 & 0.613 & 0.366 \\
\end{array}
\]

\[
\text{CFL} = \frac{\text{gm}}{\text{liter}}
\]

The results obtained through the monitoring process in this area will be compared with those calculated by using the simulation models. The results presented comes from well known literature data.

**CONCLUSIONS**

The set of information presented demonstrates that the considered Terra Dura open landfill area, is a very vulnerable area, showing a high risk from the environmental point of view, with respect to the pollution of the hydrological superficial and underground water resources, the soil in the neighborhood, the public health of the communities and serious risks related to the airplanes flights procedures.

This severe environmental situation provokes an important set of public actions, mainly from the municipal power, in order to solve this very important problem, including the remediation of the open landfill area and the choice of new one, satisfying all environmental requisites.

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