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UNDERGROUND WATERS AND SOIL CONTAMINATION STUDIES

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ABSTRACT

Maybe the greatest problem associated to the nuclear energy is what to do with the waste generated. As example, in Portugal, two of the most important of uranium mines produced a significant amount of waste, now deposited in several storage facilities. To evaluate the impacts generated, samples of water, sediments and soils were analyzed. The space distribution of these samples revealed that the contamination is restricted in the vicinity of the mining areas, and the biggest problem happened due to the illegal use of waters for irrigation, originated from the mine effluents treatment stations [1]. In Brazil, the radioactive waste remains a problem for the authorities and population, since there is not until now a final repository to storage them. The objective of this work is to do studies with the software FRAC3DVS, which simulates the contamination of soils and underground waters due to radioactive and no radioactive sources of pollution. The obtained results show that this tool can help in environmental evaluations and decision making processes in the site selection of a radioactive waste repository.

1 – INTRODUCTION

Human activities unfortunately generate several environmental problems, which many times affect the surrounding soils and local underground waters. As example, these parameters in the city of Natal (Brazil) and the surrounding municipalities are vulnerable to a degradation process caused by urban activities. Some studies accomplished in the south area of Natal showed that in a expressive fraction of the urban area, the underground waters were polluted by nitrates, with levels much superior than the limits established by the World Health Organization – WHO [2].

The presence of cemeteries in urban areas is a risk factor to the public health, because the local underground waters can be used. The presence of pathogenic microorganisms, originated from the cemetery leachate, can produce serious problems, like the cases of typhoid fever in Berlin last century and in Paris, in the decade of 1970. A study carried out at the oldest cemeteries in Belo Horizonte, which also offer the best conditions for the pluvial water infiltration, showed that the contamination of the underground waters around these places is very significant [3].

A soil contamination caused by mercury was detected accidentally in 2002, in the municipality of Descoberto, located 300 km far from Belo Horizonte. The problem was detected during some routine maintenance works near a road. After the pollutant identification, evaluations were done to determine possible damages to the water courses responsible for public supply. The geochemistry evaluations delimited an area of larger contamination, where the value of total Hg found was higher than 8.800 ppm [4]. Several works were done to evaluate the level of contamination and to delimit the pollutant distribution in the substratum. As control measures, sedimentation boxes and tanks of physical treatment were constructed, among other actions [5].

Investigations about the water movement at the Amargosa Desert, USA, demonstrated the migration of gases containing tritium and carbon 14. In the place, there is an installation destined to storage low activity radioactive waste. Since 1976 some studies are accomplished in the area, located in the States of Nevada and California. In 1997 the place became part of the "Hydrological Program of Poisonous Substances" after the verification of high tritium concentrations in the samples of gases originated from the area that, between 1962 and 1992, received radioactive waste [6].

High arsenic levels in the underground waters used for consumption historically cause serious health problems, like Bowen's disease, to millions of people in Asia [7]. Another problematic factor for soils and underground waters is the agriculture. Aware of this situation, in 1990, the National Association for the Agricultural Development in France started to grant a title to farmers that commit to alter their fertilization way and to reduce the use of pesticides. The legislation regarding the discharge of industrial residues became more rigid [8].

In 1965, some underground nuclear tests took place in Semipalatinsk, Russia. In 2003 studies were executed to evaluate the status of the existent contamination in the soil and underground waters. Cesium 137, strontium 90, americium 241 and plutonium 239/240, among other radionuclides, were detected. The results showed the pollutants migration path in the area [9]. Other researches associated to the environmental impacts derived from the Russian nuclear park, that included the contamination of the soils, atmosphere, underground and superficial waters, demonstrated an increase in the waters pollution amount. The work considered the whole cycle of the nuclear fuel [10].

A nuclear facility located in the State of Washington – USA, operated between 1943 and 1990. After this date, efforts were made to remedy the existent contamination in the soil and underground waters in the area. The extensive contamination resulted in the inclusion of the site in the list of national priorities, in agreement with the criteria adopted by the Agency of North American Environmental Protection (EPA). The area of the place contains nine inactive nuclear, and the waste generated during the operation was stored in the roundness, resulting in a huge contamination of the soil and underground waters for cesium 137, cobalt 60 and europium 152 [11].

2 - MATERIALS AND METHODS

Significant contributions to understand the groundwater flow and solute transport in fractured porous media have evolved due to the urgent need to safely dispose the radioactive waste. However, the problem of contaminant migration in fractured media that are relatively porous is still a challenge. Recent field studies have shown that vertical fractures can be present to significant depths in the underlying aquifer.

A number of mathematical models describing groundwater flow and solute transport in fractured porous media have been developed. One classical approach is to view a fractured porous medium as a single continuum or equivalent porous medium in which the point-to-point spatial variations in the hydrogeological properties of the rock mass are averaged over a representative elementary volume in order to define bulk macroscopic values. This idea generated some studies to verify the applicability of this approach in the context of groundwater flow and dissolved solute transport in fractured geologic materials under saturated conditions [12].

In this work the software FRAC3DVS will be used. This is an numerical model that solves the three-dimensional variably-saturated groundwater flow and solute transport equations in non-fractured or discretely-fractured media and which was developed by researchers from the University of Waterloo and the Université Laval [13]. This program simulates the pollutants flow and transport in underground waters, in porous or discreetly fractured means, through the finite elements method. The porous way is represented by blocks, while the fractures are by lines (vertical and/or horizontal). The software considers the flow and transport mechanisms through both means - fractured and in the block of the main matrix that configures the mean.

The main parameters requested by the program are related to the source of contamination and the hydrogeological characterization of the site to be modeled, including the fractures. The cases simulated consider only theoretical examples.

3 - RESULTS

In all the cases simulated, the structural and conceptual model was defined as being composed by one free aquifer in a saturated matrix, whose dimensions will be mentioned case by case. Figures 1, 2 and 3 show the obtained results for a case where a source spreads its contamination plume in the soil. On the left side, the figure shows the configuration ten days after the contamination, and the right side presents the scenario after a hundred days. In spite of being a three-dimensional software, FRAC3DVS shows the results for a pair of axis. So it is possible to visualize the results in the axis XY, XZ and YZ, but not in three axis in the same figure. The operator defines the geometry assumed for the simulations. In this case, the dimensions of the matrix are 10 x 1 x10 meters, being XZ the soil's surface.

For this particular simulation, it was assumed that there is dissolution of the immiscible phase (that can be liquid or solid) into the groundwater until all dissolvable material is exhausted. When all the material associated with a node has dissolved, the node reverts back to unconstrained conditions. In all cases in this work, the contamination unit is kg/m^3. The results can show any slice of the matrix, according to the user. As example, figures 2 and 3 show the slices at position 4.8 (in both cases, range goes from 0 to 10). It is valid to observe here that the original figures generated by the software are colored, but due to their large memory size, they will be present here as black and white.

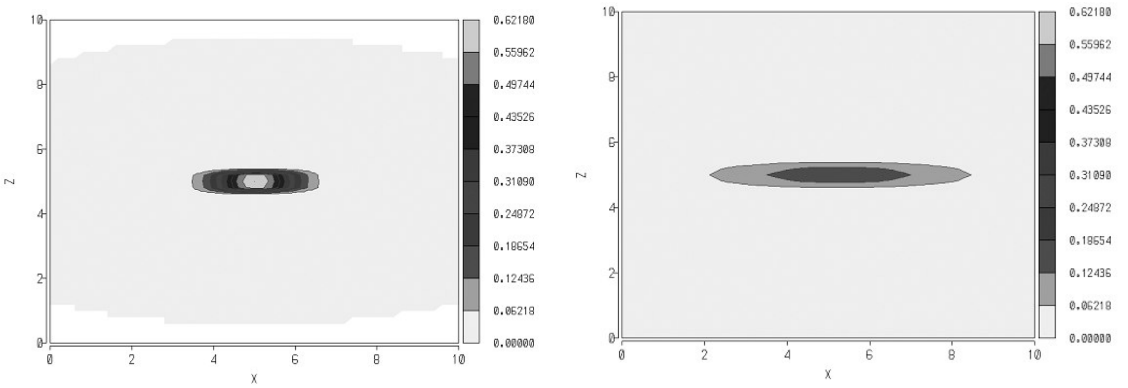

Figure 1 – Simulations: ten and a hundred days after the contamination. XZ plan.

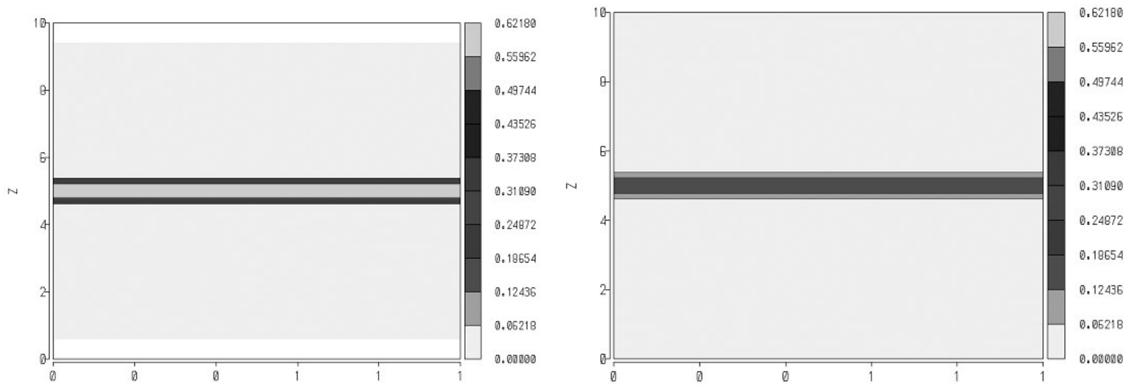

Figure 2 – Simulations: ten and a hundred days after the contamination - YZ plan.

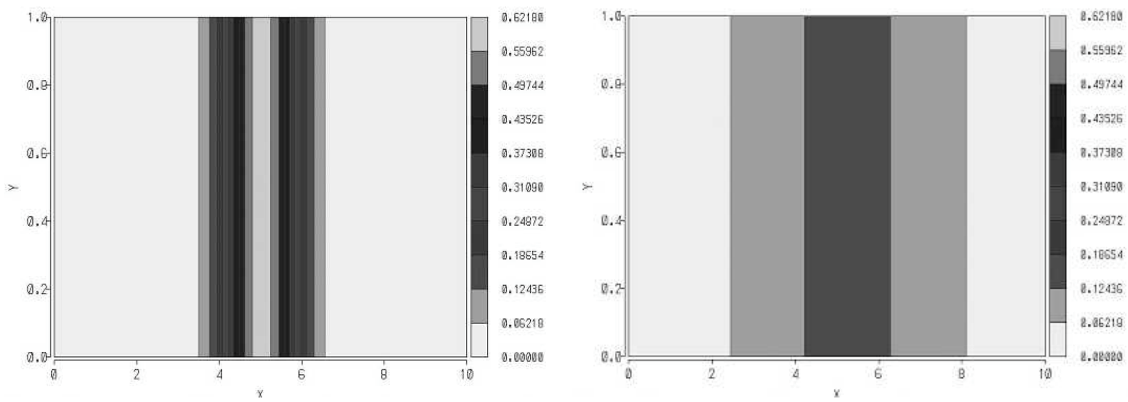

Figure 3 – Simulations: ten and a hundred days after the contamination. XY plan.

In another simulation, a contamination plume located along the Z axis moves from the left to the right. In figure 4 it is possible to visualize the movement of the plume. In this case, the dimensions of the matrix simulated are 60 x 5 x 1 (meters).

Also, one parameter was altered to check its effects in the results, which can be seen in figure 5. For the two simulations showed below, all the parameters are the same, except the hydraulic head that was increased. The results show that when the hydraulic head is increased, the plume moves faster in the soil (dimensions of the matrix: 60 x 1 x 1).

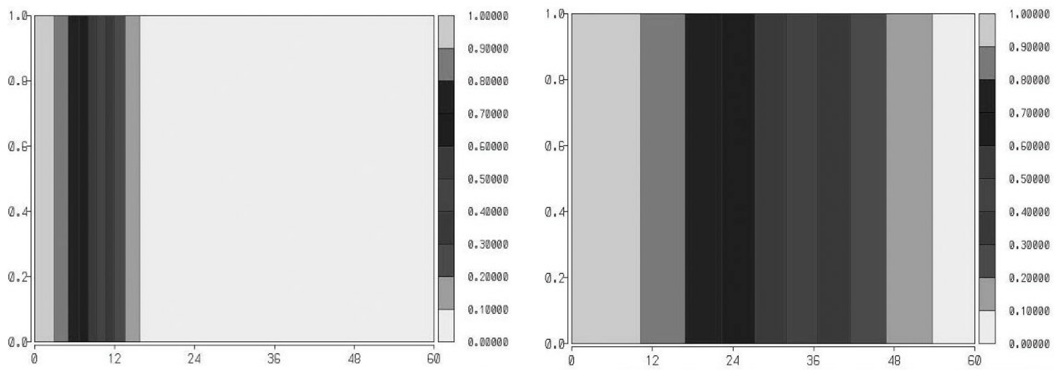

Figure 4 – Simulations: one and five years after the contamination. View of the XZ plan.

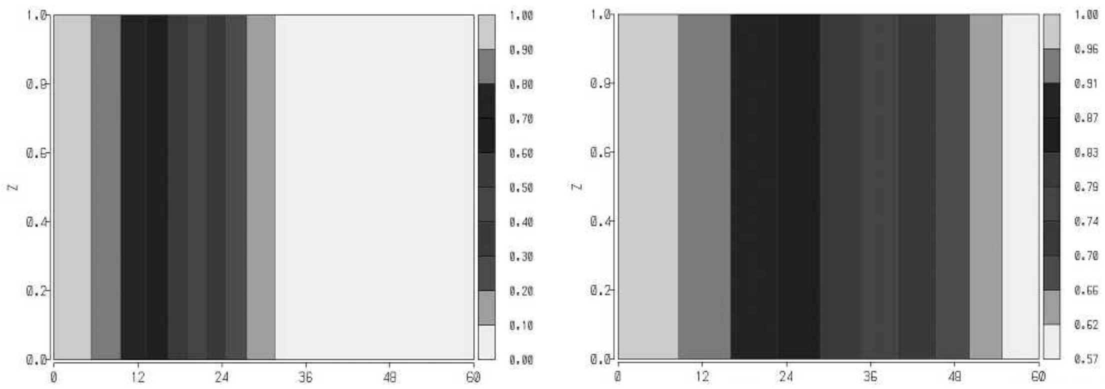

Figure 5 – Simulations showing the effect when the hydraulic conductivity is increased.

It is also possible to simulate a radioactive source, being necessary to provide some data associated to the radionuclide, like its decay constant and the free-solution diffusion coefficient. Figure 6 shows the scenarios for a contamination after 500 and 5000 years, due to a uranium source. The migration of the plume is present in this modeling.

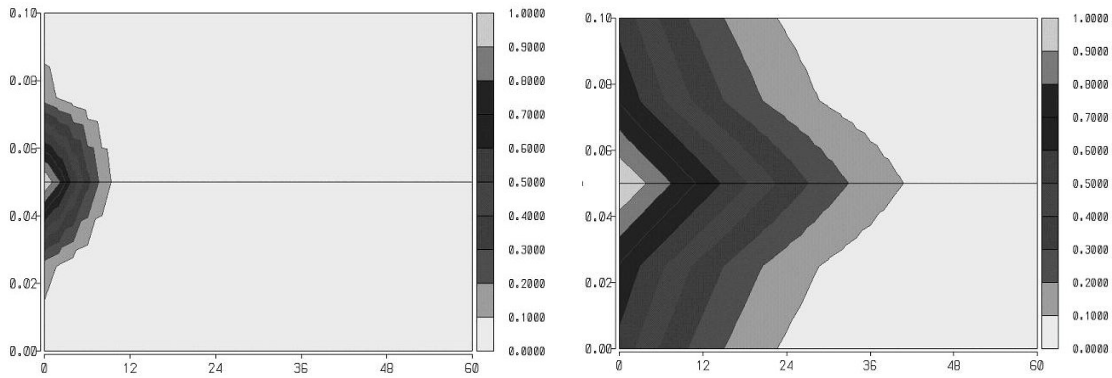

Figure 6 – Simulations 500 and 5000 years after the contamination due to a uranium source.

4 - CONCLUSIONS

The contamination of soils and underground waters are only one of the several damages linked to many human activities. If the site is vulnerable to the pollution, the contamination can become a serious problem to human health and to the environment.

The use of softwares to evaluate these impacts are important tools that help the decision making process. These preliminary studies using FRAC3DVS encourage the authors to keep studying this question. Although it is very difficult to obtain many necessary parameters every time hydrogeological data are needed, it is possible to analyze the contamination spread. Further studies will be done to keep testing the software. This task is included in the RMBN project - Repository for Radioactive Waste with Low and Medium Levels of Radiation.

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