THEORETICAL STUDIES CONCERNING THE INFLUENCE OF PHYSICAL AND MECHANICAL PROPERTIES OF THE SOIL IN THE PROCESS OF EPURATION AND SELF-EPURATION

CHIȚIMUȘ ALEXANDRA-DANA[1*], NEDEFF VALENTIN[1], LAZĂR GABRIEL[1], MĂCĂRESCU BOGDAN[1], MOŞNEGUȚU EMILIAN[1]

[1] *„Vasile Alecsandri" University of Bacau, 157 Calea Marasesti, RO-600115, Bacau, Romania*

Abstract: The paper describes theoretical aspects concerning the influence of physical and mechanical properties of the soil in the process of epuration and self-epuration. Soil depollution is carried out by means of long-term procedures (in the case of auto-epuration) or by way of costly procedures or methods which are, technically speaking, difficult to apply (in the case of epuration), so in order to prevent the physical pollution of the soil, we need to study the properties (physical and mechanical ones) and their influence on the soil considered as filtering material.

Keywords: soil, distribution, pollutants, filtering material, saturated area, unsaturated area.

1. INTRODUCTION

As related to human life, the soil fulfills four essential functions: biological, nourishment, ecological filter and usage as construction material [1-5].

The biological function results from the fact that soil represents the environment/location for numerous species of animals and plants. The biological cycles pass through the soil, including it as a component part for numerous ecosystems [1, 2, 6].

The nourishment/feeding function is related to the fact that the soil contains all the chemical elements necessary for living (calcium, magnesium, potassium, phosphorus, etc.). It accumulates them and then conveys them for usage to plants and animals, and it also provides the necessary water and air necessary to circulate them [4].

The function of ecological filter (Figure 1) is mainly due to the fact that the soil is a porous medium. The water first permeates the soil, which functions as a real biological filter, similar to a cleaning system, a neutralizer and converter of the pollutants included in activities. Water, in the process of its infiltration in the soil, is thus transformed so that its chemical and biological qualities will be influenced by the properties of the pedological layer [1, 5, 7, 8].

[*] Corresponding author, email dana.chitimus@ub.ro

The function of a raw material is given by its use in manufacturing (sand, calcareous crusts, clays etc.) and in various semi-industrial sub domains. The soil is also a basis for constructions, roads, dams, canals [2, 7, 9].

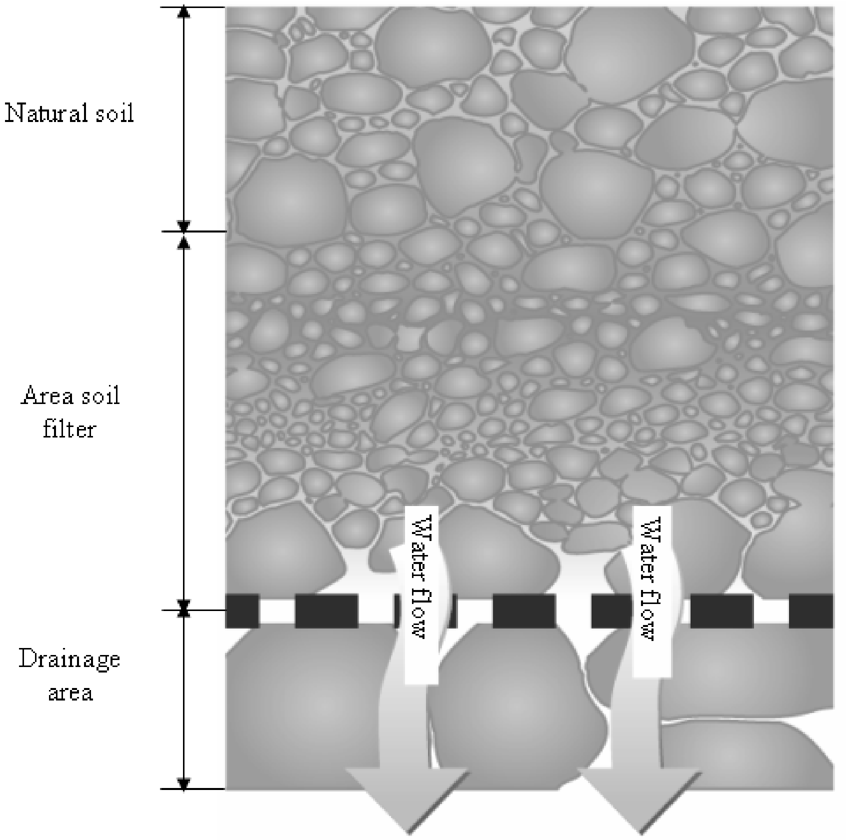


Fig. 1. Soil as natural filter [7, 10, 11].

Soil pollution (Figure 2) consists of those anthropogenic activities which usually lead to the disturbance of its normal functionality as a life sustainer and medium within various ecosystems [12-14].

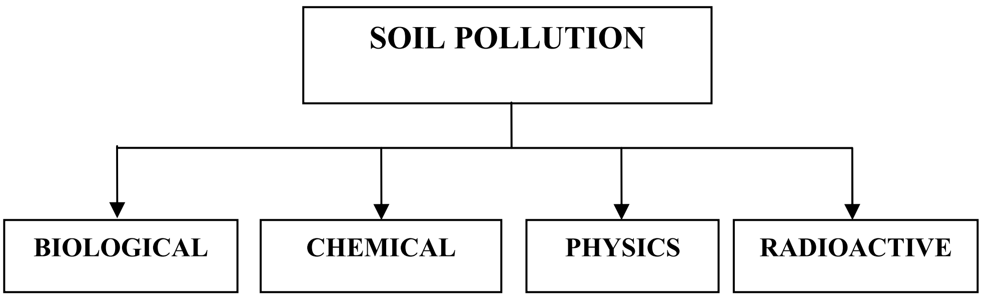


Fig. 2. Categories of soil pollution [5, 12, 14-19].

Soil is a much more complex system than water and air, so pollution affects its properties and, hence, its fertility. Further more, pollutants can pass from the soil in plants, water or air, and depollution appears as a difficult process, and even as an impossible one [8, 14, 20].

2. THE SOIL'S PROPERTIES AS FILTERING MATERIAL AND THEIR INFLUENCE ON REDUCING POLLUTION

The most important properties of the soil which affect the process of self-epuration and epuration are physical and mechanical properties, such as: texture, structure, granulometric composition, density, specific volume, porosity, pores' number, consistency, permeability, temperature.
After permeating the geological medium, pollutants go through some phenomena related to: transport, transformation, transfer, accumulation and fixation (Figure 3) [10, 13]. These phenomena also contribute to their spreading and distribution to the elements of the geological environment (soil, geological formations, and subterraneous waters) and to the chemical alteration of the geological medium [4, 21].

All these phenomena: transport, transformation, transfer, accumulation and fixation depend on [4, 5, 15, 21]:
- the properties of the pollutant;
- the properties of the soil, of the geological formations, of the subterraneous waters;
- the properties of the media with which the pollutant gets in contact (the transport medium, the receiver medium).

From the surface of the soil towards its depth two areas can be distinguished:
- the unsaturated area, in which the pores are filled partly with water and partly with air, and this fact allows the coexistence, at this level, of solid, liquid and gaseous phases;
- the saturated area, in which the pores are totally filled with water, and the dominant component of liquid flowing at this level coincides with the direction of subterraneous water flowing.

The unsaturated area (for aeration) of the aquifers is the location where intense phenomena of subterraneous water-transfer take place, mainly vertically [infiltration (Ir), evapotranspiration (Er)], shown in Figure 4 [21-24].
The characteristics of this area determine the moving speed of pollutants from the surface sources (concentrated/diffuse) towards aquifers where the moving speeds increase significantly [19, 21, 22, 24].

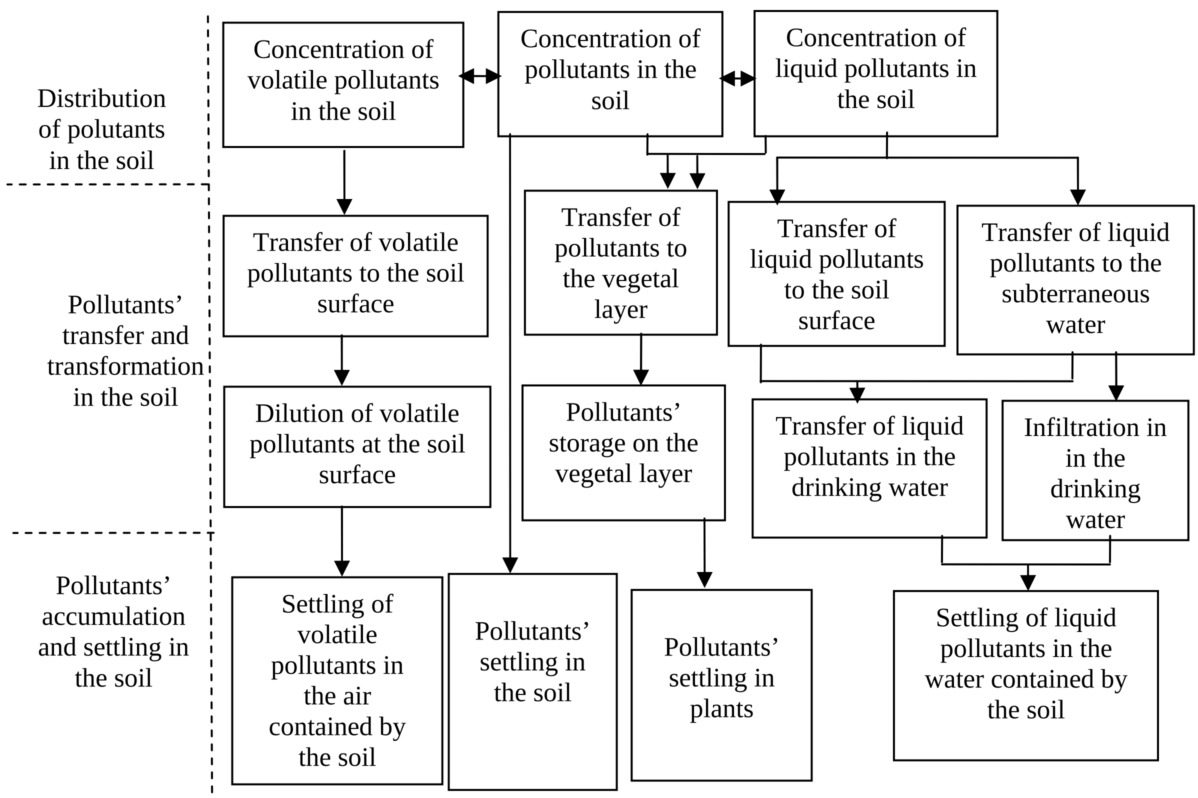


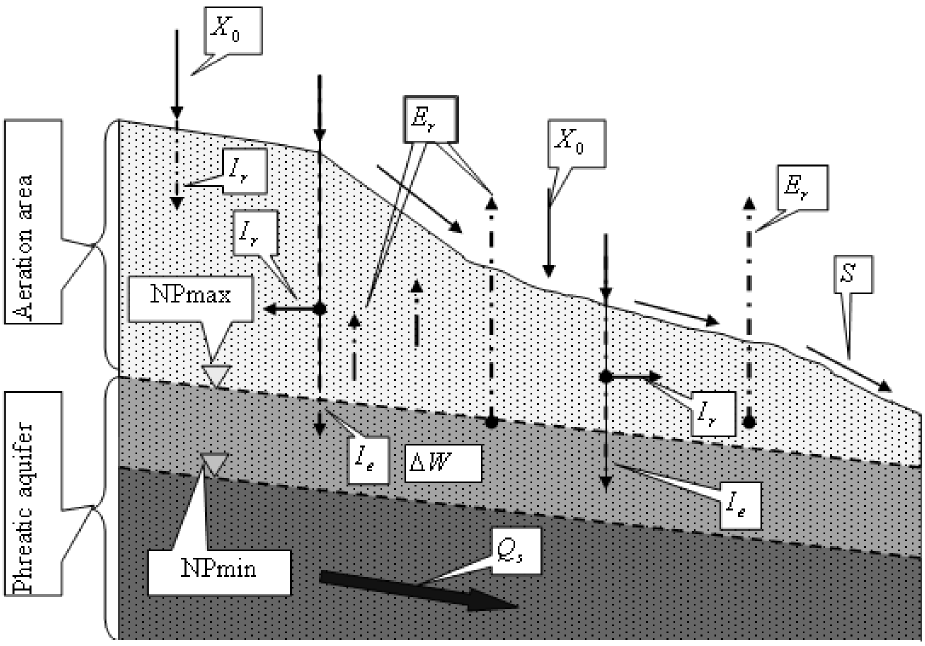
Fig. 3. Scheme of pollutants' activity in the soil [7, 10, 11, 13].

The saturated area is a strong filter for the access of pollutants in the subterraneous area and that is why knowledge of its characteristics is necessary [8, 19, 21, 24]:

- thickness;
- mineral matrix:
  - granulosity;
  - porosity;
  - permeability;

- fluids present in the unsaturated area:
  - gases;
  - miscible fluids;
  - immiscible fluids: lighter than water or heavier than water;

- interaction between fluids - aqueous land:
  - humidity/saturation degree;
  - interfacial tension;
  - capillary pressure.



X_0 – precipitations; S – leakage surface;
$Np_{max/min}$ - percolation level maximum/minimum; E_r – evapotranspiration;
I – infiltration ; Q_s – leakage subterraneous.

Fig. 4. Components of water balance for the unsaturated area (for aeration) and phreatic aquifer [11, 21, 23-25, 28].

The thickness of the unsaturated area, if it is sufficiently big and made up of lands with fine-grain structure and low permeability, with significant humidity scarcity, can ensure the reduction of vulnerability to pollution in case of aquifers [11, 19, 21].

The characteristics of the mineral matrix are synthesized in the value of the permeability coefficient, and for its evaluation it is necessary to parameterize the characteristics of the porous space, features determined by the land granulosity [25].

2.1. Major properties influencing the epuration and auto-epuration process

Permeability is an intrinsic characteristic of geological formations depending on the **size and shape** of the cavities in which the fluids can move. The bigger the pores' diameter is, the lower the environment's resistance to the fluids' flow is, and the permeability of geological formations is higher [5, 10, 11, 23].
Permeability is quantified by means of the permeability coefficient (Figure 5) [7, 19, 26].

The value of the permeability coefficient (K) depends on the pores' width. The finer the sediments' granulosity is and, as a consequence, the pores' width gets lower, the contact surface between the fluids and the solid particles increases, as well as the resistance to flowing, while permeability decreases [7, 19, 26-28].

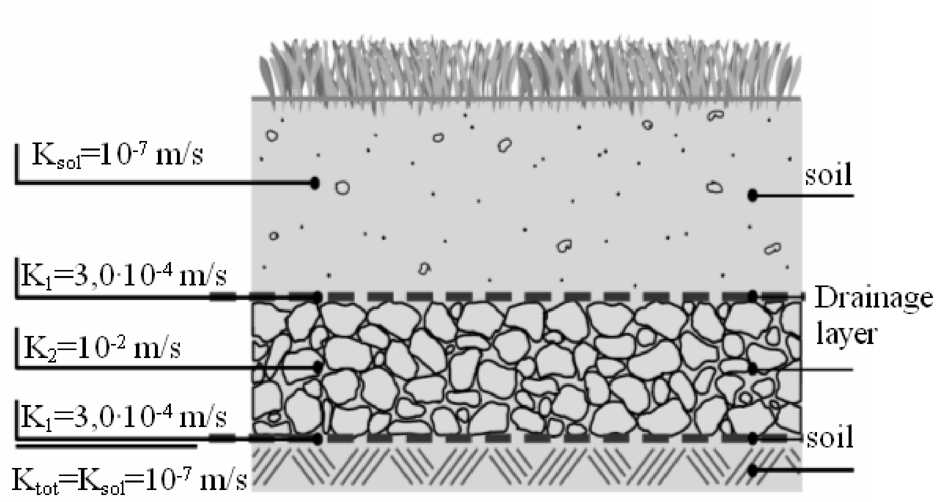


Fig. 5. The characteristics of soil and drainage systems (K_{tot} is determined by the soil layer which is the least permeable) [7, 19, 26, 27].

Apparent density is one of the main indicators of structure of the soil and, at the same time, one of the main determining factors of the soil's physical properties (Figure 6). High apparent densities signify the reduction of water-retaining capacity, of permeability and aeration [3, 16, 19].

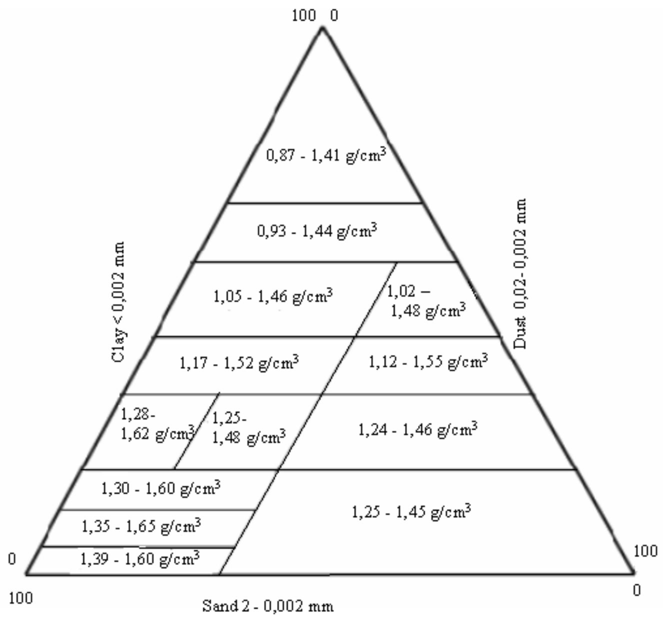


Fig. 6. Frequent values of apparent density [3, 19].

Total porosity offers important information related to numerous characteristics of the soil. High values of porosity indicate a high water-retaining capacity, high permeability and satisfying aeration, while sometimes indicating low values of bearing. As in the case of apparent density, the interpretation of the total porosity value is only performed only in correlation with soil texture (Figure 7). At the same absolute value of total porosity, a sandy soil can have quite favorable physical features, whereas in case of a clayey soil these characteristics can be less favorable [11, 16, 19, 26]. Draining porosity constitutes an important factor so as to assess the draining capacity of soil with excess of humidity [3, 7, 11].

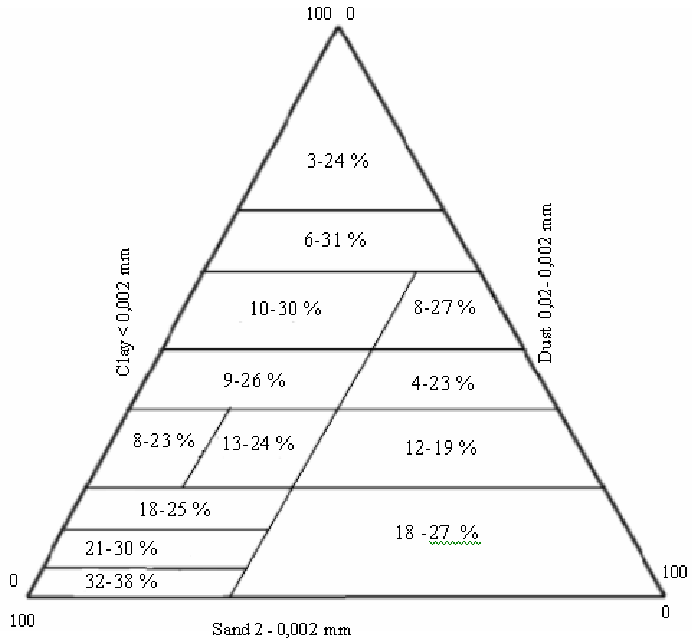


Fig. 7. Frequent values of drained porosity [3, 11].

Contraction is the soil's property to diminish its volume due to reducing the water quantity in the soil. In Figure 8 a group of curves is represented, showing both the influence of the clay contents and that of the apparent density on the contraction index. We observe higher values of the contraction index, at the same texture, for higher apparent densities [3, 16, 19].

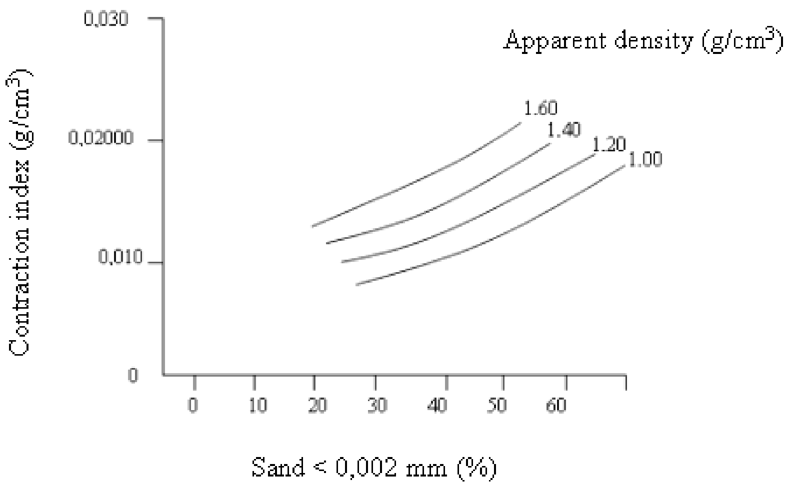


Fig. 8. The variation of the contraction index depending on the clay contents and apparent density [3, 9, 19].

3. CONCLUSIONS

For certain pollutants, soil represents a transport medium, and for other pollutants it represents a storing tank.

The distribution of the pollutant in the soil depends on the properties of the pollutant, the soil's properties, of the geological formations, of the subterraneous waters, and on the properties of the media it comes in contact with.
The saturated area of the soil is a powerful filter for the access of the pollutants in the subterraneous areas and that is why it is necessary to acquire knowledge about its characteristics.

Soil depollution is made by means of long-term procedures (in the case of auto-epuration) or by means of costly methods which are, technically speaking, difficult to apply (in the case of epuration), therefore in order to prevent the physical pollution of the soil, we need to study the properties (physical and mechanical ones) and their impact on the soil regarded as filtering material.

ACKNOWLEDGMENTS

The present research was performed in the frame of the BRAIN project: "Doctoral scholarships, an investment in intelligence", financed by the European Social Found and Romanian Government.

REFERENCES

[1] Berthelin, J., Leyval, C., Toutain, F., Biologie des sols. Role des organismes dans l'alteration et l'humification. Pedologie, 2. Constituants et proprietes du sol. Masson, France, 1994.
[2] Blaga, Gh., Rusu, I., Udrescu, S., Vasile, D., Pedologie, Editura didactica si Pedagogica, R.A., Bucuresti, 1996.
[3] Canarache, A., Fizica solurilor agricole, Editura Ceres, Bucuresti, 1990.
[4] Jigau, Gh., Lupascu, Gh., Pedologie generala, Editura Junimea, Iasi, 1998.
[5] Killham, K., Soil Ecology, Cambridge University Press, U.K., 1994.
[6] Papacostea, P., Biologia solului, Editura Stiintifica si Enciclopedica, Bucuresti, 1976.
[7] Rattan, L., Manoj, K., Principles of soil physics, Ohio University, 2005.
[8] http://www.bettersoils.com (18.08.2010).
[9] Lungu, I., Stanciu, A., Fundatii - Fizica si mecanica pamanturilor, Editura Tehnica, Bucuresti, 2006.
[10] Pansu, M., Handbook of Soil Analysis, Springer-Verlag, 2003.
[11] http://soils.usda.gov/technical/manual/download.html (05.08.2010).
[12] Chen, J., Chen, Z., Soil degradation: a global problem endangering sustainable development, Journal of Geographical Sciences, 2002.
[13] Neag, Gh., Depoluarea solurilor si apelor subterane, Editura Casa Cartii de Stiinta, Cluj-Napoca, 1997.
[14] Van, L., George, W., European soil resources. Current status of soil degradation, causes, impacts and need for action. Council of Europe Press. Nature and Environment, No 71, Strasbourg, France, 2005.
[15] Florea, N., Degradarea, protectia si ameliorarea solurilor si terenurilor, Bucuresti, 2003.
[16] Nedeff, V., Macarescu, B., Virgil, G., Ingineria si protectia mediului in industrie, Editura Tehnica - Info, Chisinau, 2003.
[17] Rauta, C., Carstea, S., Prevenirea si combaterea poluarii solului, Bucuresti, Editura Ceres, 1993, pag.55-60.
[18] Rojanschi, V., Bran, F., Diaconu, Gh., Protectia si ingineria mediului, Ed. Economica, Bucuresti, 2002.
[19] http://www.sites-pollues.ecologie.gouv.fr. (17.07.2010).
[20] Cameron, K., Beare, M., McLaren, R.., Selecting physical, chemical biological indicators of soil quality for degraded or polluted soil. Trans World Cong. Soil Sci. Montpellier, Symp. 37, 1998.
[21] Viman, V., Mihaly, L., Vatca, Gh., Varga, C., Mathematical Modelling of Pollutants Dispersion in Soil, American Journal of Envioronmental Sciences, 2005.
[22] Bear, J., Dynamics of fluid in porous media, American Elsevier Enviromental Science, 2000.
[23] Meyera, C., Geraldo, L., Polluant dispersion in wetland systems: Mathematical modelling and numerical simulation, Soil Science Society of America, 2006.
[24] Viotti, P., Mantovani, V., Modelli numerici per la simulazione del trasporto di contaminanti nella zona satura e non satura, edizioni Osservatorio Siti Contaminati, 2005, pag 71-109.

[25] BRGM, Guide sur le comportement des polluants dans le sol et les nappes, Eds. BRGM, 2001.
[26] Unsal, E., Dane, H., Equivalent Soil Pore Geometry to Determine Effective Water Permeability, Vadose Zone Journal, 5(4), 2006, p. 1278-1280.
[27] Molfetta, D., Ingegneria degli Acquiferi, Editura Politeko, 2002.
[28] Spitz, K., Moreno, L., A practical guide to ground water and solute transport modeling, John Wiley and Sons, 1996.