Environmental impact of coal-based power plants slag and ash deposits through mass transfer in subsoil

Cornelia A.Bulucea, Andreea C. Jeles, Carmen A. Bulucea

***Abstract*—** The toxins specific to slag and ash deposits through the environmental xenobiotics induce malignant tumors of high incidence rate. Within the framework of sustainable development the environmental and technical issues are linked. In line with this idea it is important to build mathematical models that reflect how the transfer into the subsoil of a toxic dose from a slag and ash deposit source on ground is realized. Identification of such a mathematical model to process the data of mass transfer type could allow relevant conclusions on the interaction polluter - geographic area. This paper presents a case study based on the scenario of the transfer of a toxic dose in the subsoil from the slag and ash deposit on the ground of Isalnita power plant located in Oltenia region, Romania. Taking into consideration the spatial distribution of soil structure in depth it is analyzed the toxic mass transfer into the subsoil based on two scenarios, namely the linear and nonlinear distribution of mass transfer. Based on linear and, respectively nonlinear mathematical models there are performed numerical simulations of toxic mass transfer into the subsoil.

***Keywords*—** mass transfer, mathematical model, slag and ash deposit, toxic, xenobiotic

I. Introduction

GENERALLY the subsoil pollution is caused either by the contamination with saline waters, gases and hydrocarbons, or because of mining and drilling processes [1-3].

It is broadly known that besides oil and natural gas, coal belongs to the group of main energy sources of the 20th and the beginning of the 21st century [1-6]. Further one could note that when it comes to coal there are two main problems: resources are limited and its use pollutes the environment. Operation of coal-based power plants determines a big amount of slag and ash, and also releases harmful flue gases. Consequently it is widely accepted that over time the coal-based power plants operation determined a hard depletion and destruction of our natural environment [4-7].

Following this worrying assertion, one could note that slag and ash deposits have a varied and complex impact on groundwater and surface waters, depending on the nature and concentration of pollutant substances [1-7]. Consequently these waters suffered alterations of physical, chemical and biological parameters.

When these changes exceed the limits established by the environment regulations and persist for longer then we have to do with pollution.

Environmental factors are altered by the slag and ash deposits through environmental xenobiotics, and induce devastating effects on living organisms, including humans. The impact on people is seen by the high incidence rate of primary malignant tumors localized in the central nervous system (malignant glioma) [8].

Standard therapy for glioblastoma multiforme (GB) is consisting of rejection surgery, radiotherapy and chemotherapy. Prognosis in patients with GB is reserved [9].

The innovative immunotherapeutic treatment of dendritic cells had not a significantly different effect compared to the treatment of bevacizumab and irinotecan based on the gain in survival [10]. GB aggressiveness can be determined by identifying resistance in vitro cell lines GB to a series of inhibitors used in cytotoxic chemotherapy [11-14]. In vitro process can directly reveal cell proliferation, on cell lines GB [14-15].

Mass transfer systems can be estimated on mathematical models that allow a high degree of generality. The mathematical models are expressed by algebraic equations, differential or logical, their form depending essentially on the real system. The mathematical models that describe the behavior of a system represent the basis of analysis and synthesis of real systems.

II. Case Study. Thermoelectric Power Plants Isalnita Branch – Slag and Ash Deposit of Isalnita Power Plant

The thermoelectric power plant Isalnita is positioned near Craiova. The group of coal-based power plants Isalnita is based on two thermoelectric units of 315 MW at Işalniţa branch.

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A thermoelectric unit is composed of two boilers Benson 510T / h, a condensing turbine Rateau-Schneider and an electric generator ALSTHOM of 300MW (see Figure 1).

Slag and ash deposit is located in a relatively secluded area but can be a potential danger of pollution of groundwater and surface water, including river Jiu (see Figure 2).

Fig. 1 Thermoelectric unit

Fig. 2 Slag and ash deposit of Isalnita power plant/Sludge of slag and ash

III. Working method. First scenario: linear mass transfer in soil

The case study is based according to the first scenario on the transfer of a toxic dose in the subsoil from a slag and ash deposit on the ground (Fig. 2, 3).

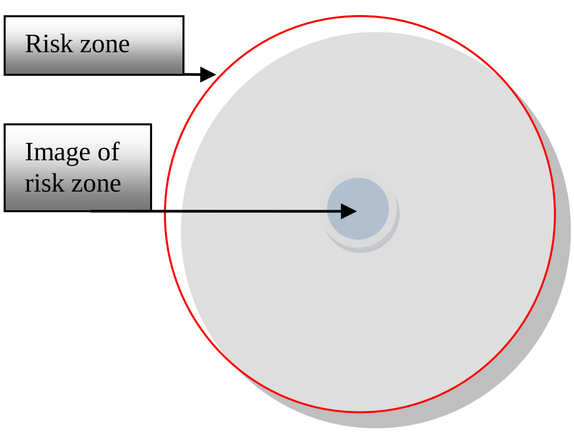

Fig. 3 Positioning Risk Zone Image/ Risk Zone

An analysis in depth of soil structure highlights a complex structure thereof.

So if in the first part (a depth of approx. 1 m) we are dealing with hum ground, still we have further a shift to materials of gravel type, and ends usually with materials of sandy type (Fig. 4).

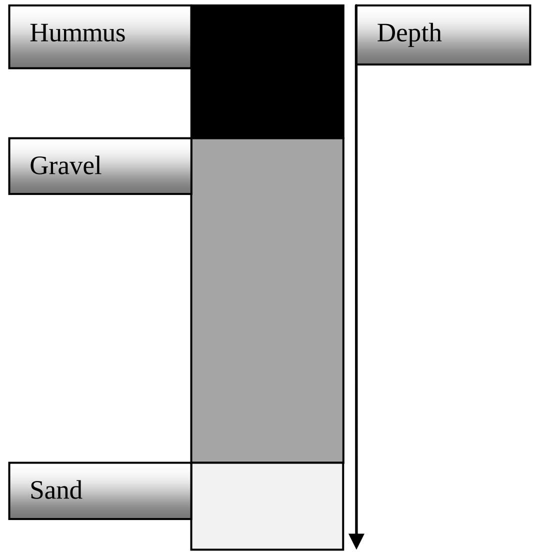

Fig. 4 Spatial distribution of soil structure in depth

This type of analysis of soil depth is specific to Oltenia region of Romania.

In each of these situations, specified materials show a different pollutant drag under continuous gravitational effect.

To obtain a simplification of the model, we work with an average of toxic drag.

At first glance based on the analysis of Fig. 4 it would seem that it is sufficient to determine the linear distance between the point of infiltration of toxic and the point measurement in soil depth.

By working on a simplifying assumption one consider that the toxic distribution in depth into the soil is linear. In this case the mathematical model of D dose distribution in depth, relative to the initial dose D_0 of contact with the pollutant at ground surface is linear, according to the following relation:

$$D = D_0 - x(D_0 - D_A)/x_A \quad (1)$$

where: D is the current toxic dose at depth x;
D_0 is the initial dose at contact surface;
D_A is the maximum acceptable dose (corresponding to the depth x_A).

In relative units the expression of the pattern becomes:

$$d = 1 - x(1 - D_A/D_0)/x_A \quad (2)$$

where d is the current relative dose at the depth x.

In order to perform the simulation we used a specific tool to data analysis namely the StatSoft 701. It runs well on a platform based on Intel i3 generation. How to work with this utility requires a great experience in the use of such programs on modern PC platforms running under Windows 8.

In Fig. 5, 6 and 7 there are represented on ordinate the relative values of toxic dose depending on the depth values x represented on abscissa for linear distribution.

According to Fig. 5 on the surface of contact (*x=0*) the toxic dose value is $D = D_0$. Relative dose decreases linearly with the depth *x*. At the depth $x_A = 50$ the value of mass transfer is $D_A/D_0=0.4$.

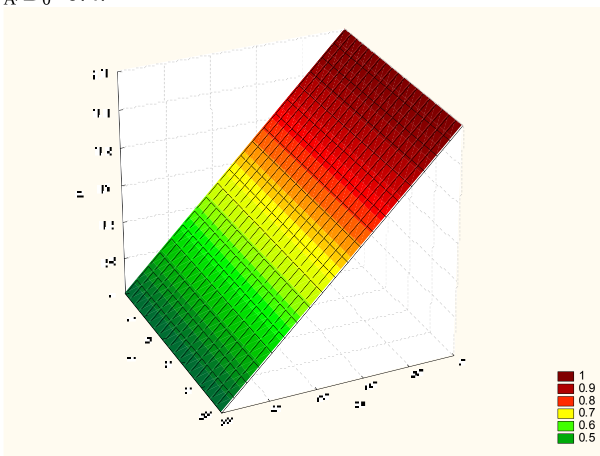

Fig. 5 Linear distribution of mass transfer at $D_A/D_0=0.4$; $x_A=50$

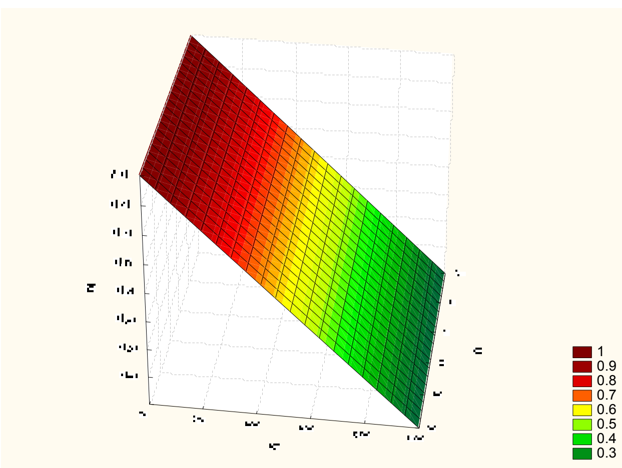

Fig. 6 Linear distribution of mass transfer at $D_A/D_0=0.2$; $x_A=50$

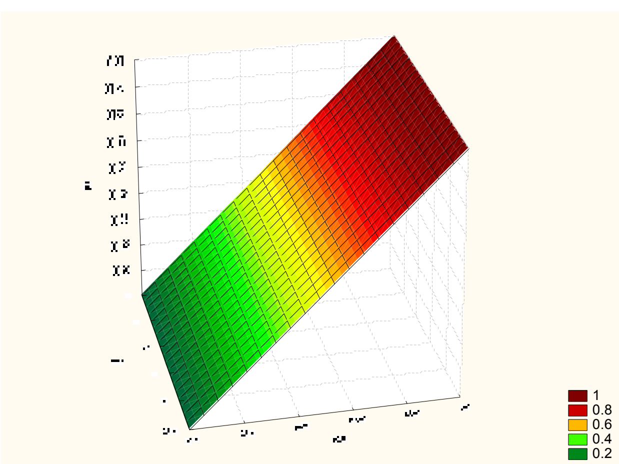

Fig. 7 Linear distribution of mass transfer at $D_A/D_0=0.1$; $x_A=50$

According to Fig. 6 on the surface of contact (*x=0*) the toxic dose value is $D = D_0$. Relative dose decreases linearly with the depth *x*. At the depth $x_A = 50$ the value of mass transfer is $D_A/D_0=0.2$.

According to Fig. 7 on the surface of contact (*x=0*) the toxic dose value is $D = D_0$. Relative dose decreases linearly with the depth *x*. At the depth $x_A = 50$ the value of mass transfer is $D_A/D_0=0.1$.

IV. Working method. Second scenario: nonlinear mass transfer in soil

This case study is also based on a scenario of the transfer of a toxic dose in the subsoil from a warehouse source type of slag and ash on the ground (Fig. 2, 3, 4). In this case the materials specified in Fig. 4 shows a different drag of toxic under continuous gravitational effect. Relative to the reference surface , we are dealing with a different route of mass transfer. Based on a nonlinear model described by a nonlinear equation, as below, one could carry out the mathematical modeling and computer simulation:

$$D = D_0 - (D_0 - D_A)\cdot(x/x_A)^2 \qquad (3)$$

In relative units the pattern expression becomes:

$$d = 1 - (1 - D_A/D_0)\cdot(x/x_A)^2 \qquad (4)$$

As previously we run with the tool StatSoft 701 which is specific to data analysis.

In Figures 8, 9 and 10 there are represented on ordinate the relative values of toxic dose depending on the depth values x represented on abscissa for nonlinear distribution.

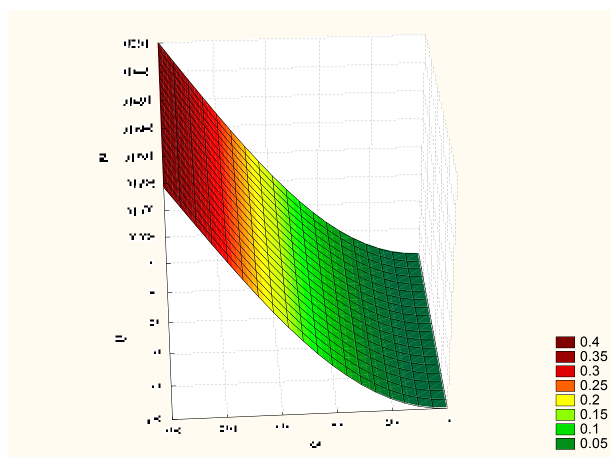

Fig. 8 Nonlinear distribution of mass transfer at $D_A/D_0=0.4$; $x_A=50$

According to Fig.8 on the surface of contact (*x=0*) the toxic dose value is $D = D_0$. Relative dose decreases non-linear with the depth *x*. At the depth $x_A = 50$ the value of mass transfer is $D_A/D_0=0.4$.

According to Fig.9 on the surface of contact (*x=0*) the toxic dose value is $D = D_0$. Relative dose decreases non-linear with the depth *x*. At the depth $x_A = 50$ the value of mass transfer is $D_A/D_0=0.2$.

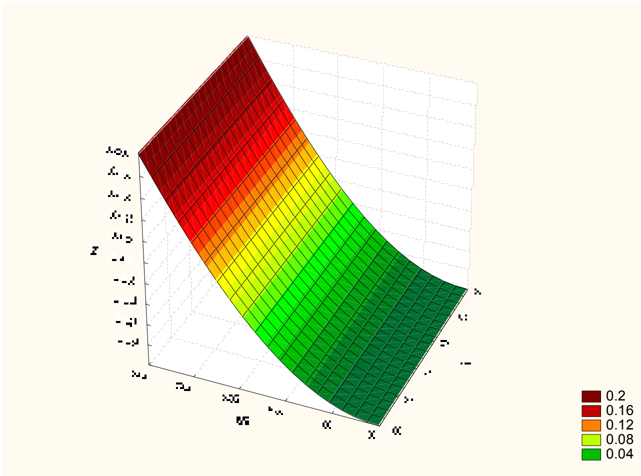

Fig. 9 Nonlinear distribution of mass transfer at $D_A/D_0=0.2$; $x_A=50$

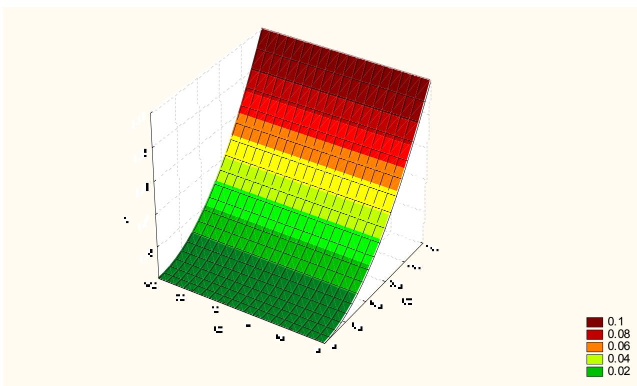

Fig. 10 Nonlinear distribution of mass transfer at $D_A/D_0=0.1$; $_A=50$

According to Fig.10 on the surface of contact ($x=0$) the toxic dose value is $D = D_0$. Relative dose decreases non-linear with the depth x. At the depth $x_A = 50$ the value of mass transfer is $D_A/D_0=0.1$.

V. Discussion and Conclusions

Deposits of slag and ash produced by coal power plants induce in living organisms, including the human the specific environmental xenobiotics. As a consequence this impact is leading to a high incidence rate of malignant tumors.

It is important to identify specific mathematical models with a polluter environmental contamination in a well defined geographical area.

For deposits of slag and ash, defining mass transfer of a toxic dose in the subsoil can be done by identifying / construction of a specific mathematical model. A mathematical pattern of mass transfer permits a dimensional calibration of slag and ash deposits. Linear mathematical model may be imposed for relatively small-scale work. For large-scale work is needed the transition to nonlinear mathematical models that can be described by differential equations.

Mathematical modeling is just a milestone to be followed by the numerical simulation of specific phenomena.

The case study carried out in this paper is based on the scenario of the transfer of a toxic dose in the subsoil from the slag and ash deposit on the ground of Isalnita power plant located in Oltenia region, Romania. Taking into consideration the spatial distribution of soil structure in depth it is analyzed the toxic mass transfer into the subsoil based on two scenarios, namely the linear and nonlinear distribution of mass transfer. Based on linear and, respectively nonlinear mathematical models there are performed numerical simulations of toxic mass transfer into the subsoil.

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