ACTUAL STAGE IN SOIL REMEDIATION

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Abstract: The article describes a few theoretical aspects concerning soil depollution processes. Techniques for the treatment of polluted soils have as an objective the destruction, elimination or immobilization of pollutants. The choice of the soil depollution technique or of the treatment method/type depends on the intrinsic characteristics of those techniques (on performance, installation), and on constraints specific to the site.

Keywords: soil depollution, depollution techniques, phytoremediation, in situ, ex situ.

1. INTRODUCTION

Both production activities and natural processes have affected soils in time, as a result of: mining activities, excavations, waste deposits, landslides, erosion, salinization, acidification etc.

Soil pollution is represented by [1, 2]:

- physical degradation (structure compaction or degradation);
- chemical degradation (increased contents of heavy metals, pesticides, and pH modification);
- biological degradation (with pathogenic germs).

1.1. Effects of pollution in the geological medium

The effects of pollution in the geological medium are represented by [3, 4,]:

- modifications of the physical, chemical and biological quality of the soil;
- modifications of the physical, chemical and biological quality of subterraneous waters;
- modifications of the physical, chemical and biological quality of geological formations;
- the appearance of accumulations of pollutants in the soil/ subterraneous waters/geological formations which, in their turn, become sources of pollution;
- the appearance of restrictions concerning the employment of certain categories of natural geological resources;
- the appearance of areas inside the geological environment with significant risk for the health of the environment, and access or usage restrictions or interdictions can be instituted for them;
- affecting terrestrial ecosystems.

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2. STATE OF CURRENT ACCOMPLISHMENTS AND RESEARCH CONCERNING SOIL DEPOLLUTION

The elimination of soil pollution can be achieved by means of long-term procedures (such as self-cleaning, Figure 1) or using costly methods or procedures which are difficult to apply from a technical viewpoint (in case of artificial cleaning) [1, 3, 5, 6, 7].

The strategy including measures of administering a polluted site (Figure 2) should be conceived as follows [5, 6, 7]:

- controlling polluting sources:
    - rehabilitation work (partial or total removal of the source);
    - isolation.

- limiting transfer:
    - in the soil, gases in the soil, in subterraneous and surface waters;
    - at the level of buildings.

- modifying arrangements:
    - changing use(s) (on the site or outside it);
    - changing the site's arrangement (its surface);
    - controlling activities (ignition sources).

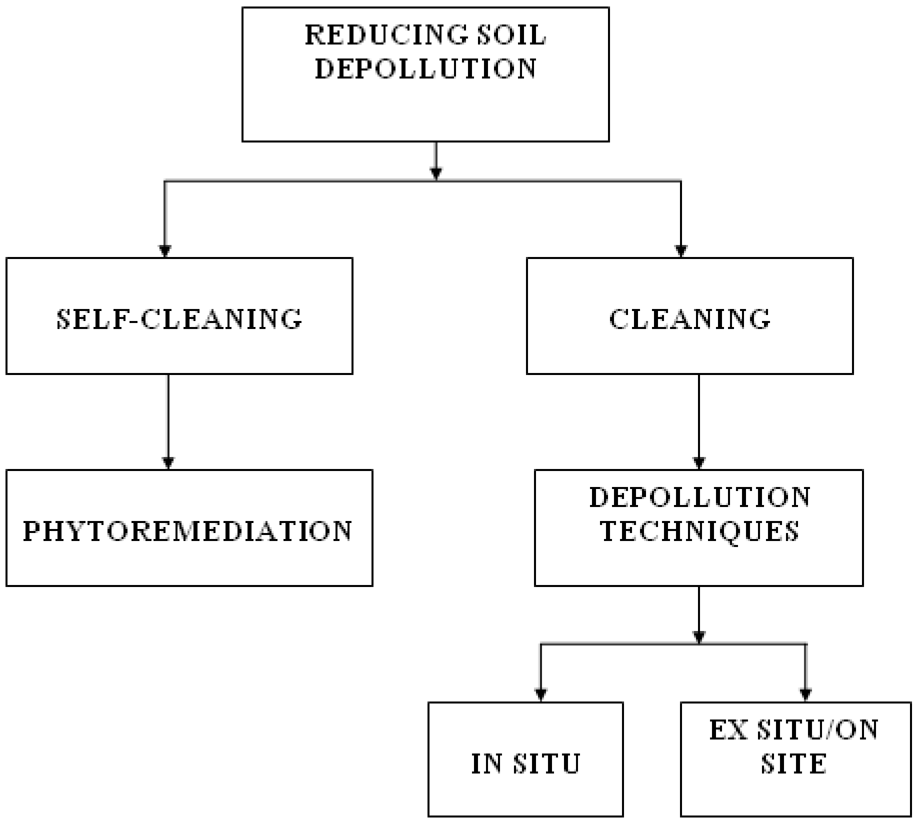

Fig. 1. Major procedures for reducing soil depollution [1, 3, 5, 6, 7].

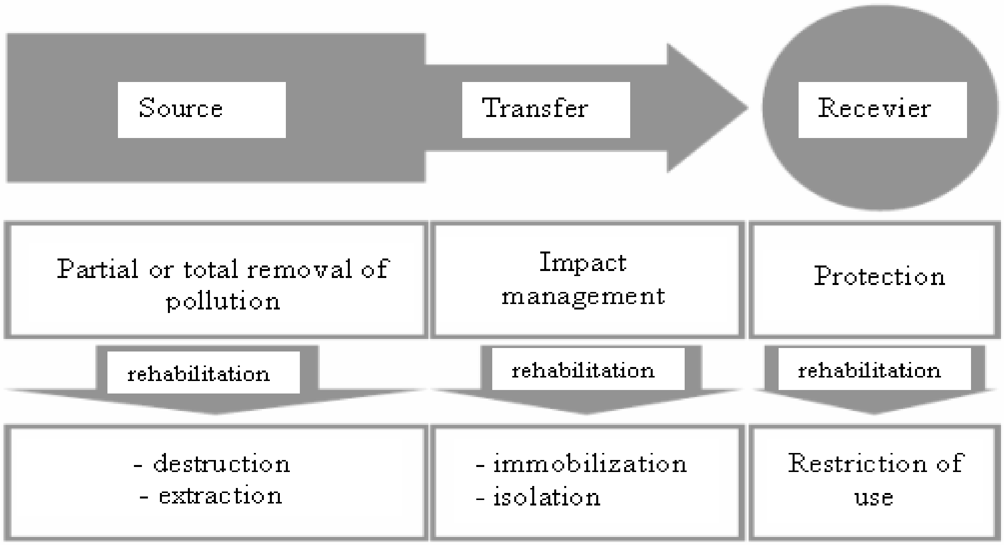

Fig. 2. Strategy concerning measures for managing a polluted site [5, 6, 7].

2.1. Phytoremediation

Phytoremediation (Figure 3) can be achieved using various mechanisms. It can be divided in two categories [3, 5, 6, 7, 8]:

- active remediation which actually destroys pollution;
- passive remediation which can only stabilize pollution.

Depollution procedures using plants can be of four types [1, 3, 4, 5, 6, 7, 8]:

a) Phyto-stabilization is a technique which uses plants with strong/well developed roots so as to reduce the mobility of pollutants in the soil [8, 15, 18, 19].

The roots fix pollutants, limiting their horizontal and vertical movement. This technique is used as a first measure in case of soils polluted because of [3, 4, 6, 7]:

- metals;
- pesticides;
- solvents;
- explosives;
- oil and derivatives.

The plants mentioned above are part of the family graminaceae (wheat, rye, millet, buckwheat etc.).

b) Phyto-extraction is a soil decontamination method from heavy metals (copper, silver, gold, mercury, cadmium, lead). It is based on the cultivation of plants, having the characteristics of tolerance and accumulation of heavy metals in their harvestable part. These accumulating plants are capable, by way of their adapted physiology, to accumulate up to 1 % of the pollutant, as compared to their dry matter/substance [3, 5, 8].

Plants will be chosen depending on the nature of the pollutant, the climate and biomass, so that a great quantity of pollutants can be accumulated/stored. Oftentimes, the soil is contaminated by numerous metals, and this requires the cultivation of more plants [2, 3].

Once they are harvested, these plants are incinerated and the ashes are stored in a secure place. The crop can be renewed until the acceptable concentration of metals in the soil is reached [2, 8].

Nowadays, more than 320 heavy metal-accumulating plants are registered and classified as follows [2, 5]:

- of type I, those accumulating metals such as Al, Ag, As, Be, Cr, Cu, Mn, Hg, Mo, Pb, Pd, Pt, Se, Zn, for instance, sun flower, fern, willow, Indian mustard, osier;
- of type II, which accumulates Ni, such as: water fern, Indian mustard, sun flower;

- of type III, which accumulates radio nuclides, hydrocarbons and organic solvents, such as: oat, cabbage, Indian mustard, hyacinth, osier, lettuce, red beet, sycamore maple, coconut tree, pine tree, white clover, corn, juniper tree.

c) Rizo-degradation is more often used for treating pollution with hydrocarbons. It is achieved by plants and especially by rizo-carpic micro-organisms (which live in plants – like reed, banana tree) [4, 6, 7].

d) Phyto-volatilization consists in utilizing plants (such as poplar) in order to extract and volatilize certain inorganic (Hg) or organic compounds (TCE – trichloroethane) through their parts above the ground [2, 7].

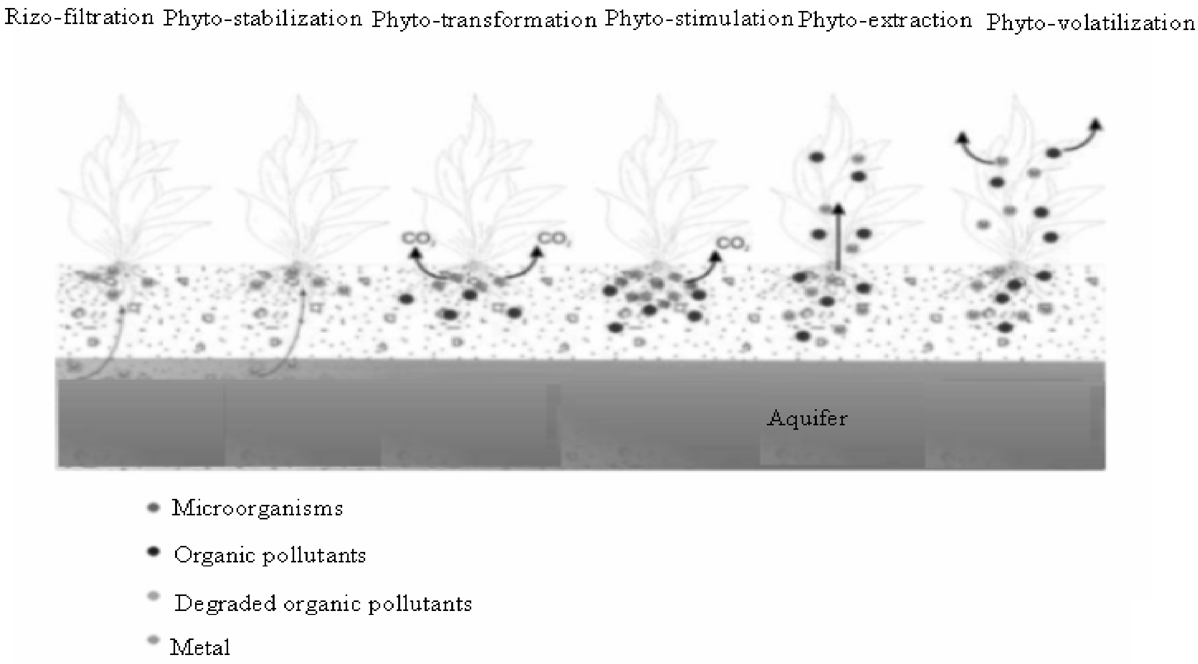

Fig. 3. Phytoremediation scheme [3, 5, 6, 7, 8].

2.2. Artificial soil depollution

Procedures for artificial soil cleaning are also called draining procedures and they consist in sanitation and pH correction etc. Draining procedures are performed using mobile equipment corresponding to each type of pollution [2, 3, 9, 10, 11, 12].

2.2.1. Classification of depollution techniques

Depollution techniques can be classified according to [2, 3, 10, 12]:

- the nature of procedures used;
- the location where the treatment takes place;
- the transformation of pollutants.

Depollution techniques can be classified depending on the nature of procedures employed, as follows [3, 4, 13, 14, 15]:

- physical procedures, which consist in the extraction of the pollutant from the contaminated environment;
- biological procedures, which make use of microorganisms' actions (bacteria, fungi) in order to eliminate organic or mineral pollutants present in soil, silt, sediments or liquid effluents;
- thermal procedures, in which heat is used so as to neutralize the pollutant (for example, by incineration), to isolate it (thermal desorption, thermolysis etc.), or to make it inert (e.g. vitrification).
- chemical or electrochemical procedures using the chemical properties of pollutants in order to make them inert (e.g. precipitation), to destroy (e.g. oxidation), or to separate from the polluted environment (e.g. surfactants) with the help of adapted reactions.

Depollution techniques can be classified depending on the location of the cleaning process (Figure 4) as follows [4, 5, 9, 10, 11, 16, 17]:

- treatment outside the site, which involves the excavation of the polluted environment and its evacuation in an adapted treatment /cleaning centre (for instance, an incinerator, a storing centre etc.);
- on-site wastewater treatment, which involves the excavation of the soil and treatment on the same site;
- in situ treatment corresponds to treatment without excavation, and in this case the pollutant is either extracted, or decomposed or fixed in the soil;
- isolation consists in blocking/ limiting the pollutants' migration.

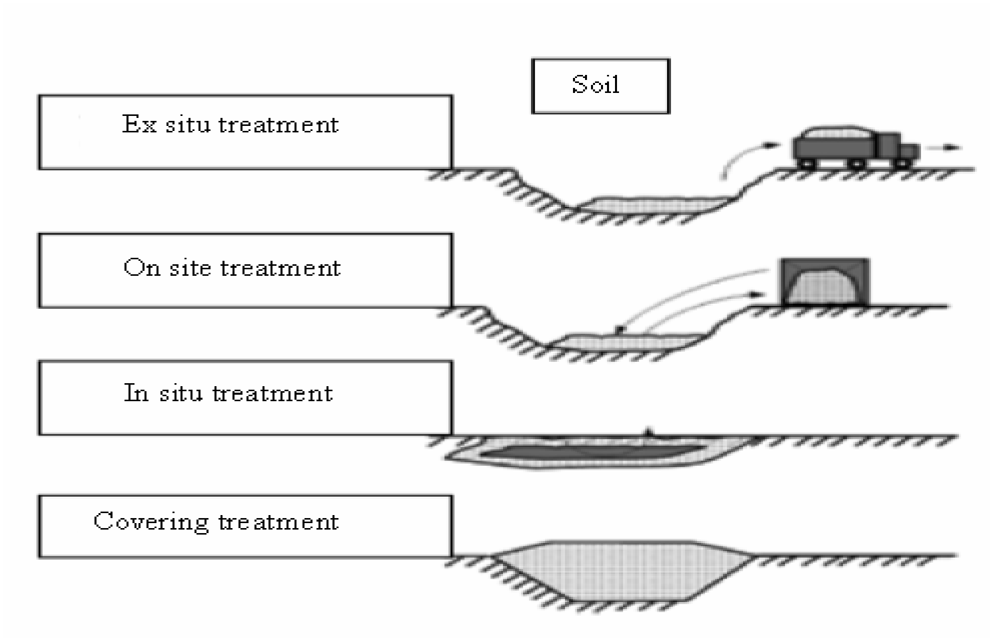

Fig. 4. Soil depollution techniques depending on the location of the treatment [4, 5, 9, 10, 11, 16, 17].

Table 1. Applicability of in situ vs. on site/ex situ treatment [2, 3, 9, 10, 12].

Technology	Site characteristics	Applicability technology
Ex situ/on site	Expanding pollution	Limited vertical and horizontal
	Soil characteristics	Very heterogeneous, preferential leakage
	Surface structures	The site is not crowded
	Proximity receptor	In close proximity there are no sensitive receptors (problem during soil excavation)
	Decontamination constraints	Require quick remediation
In situ	Expanding pollution	Significant vertical and horizontal extension
	Soil characteristics	Uniform, moderately permeable to permeable
	Surface structures	Structures present in the area of pollution
	Proximity receptor	The presence of sensitive receptors in close proximity
	Decontamination constraints	Immediate remediation is not required

Depollution techniques can be classified on the basis of pollutants' transformation in two main types [2, 5, 7, 10, 11, 12]:

- pollutant immobilization, which consists of the alteration of pollutants' mobility and/or toxicity by way of two types of processes:

• modifying the pollutant's properties (changing its behavior, its toxicity), acting on the level of oxide-reduction, complexation, precipitation;

• modifying the receiving environment: reducing permeability and porosity:

  · by means of solidification/stabilization;
  · by means of isolation.

- pollutant destruction (total or partial destruction) by means of chemical, thermal, physical and biological procedures.

After a previous selection of the depollution techniques which can be applied on the site, the choice and adjustment of the depollution technique(s) will be carried out depending on more criteria that are specific to that site.

The table below (Table 2) presents a synthesis of the depollution techniques which are most commonly used in the present [2, 5, 3, 9, 10, 12, 17].

Table 2. Soil depollution technologies [2, 5, 3, 9, 10, 12, 17].

Soil depollution techniques	**Ex situ or on site**	**In situ**
Pollution by evacuation of physical methods	Separation	Venting
	Soil washing	Dual phase extraction
		In situ barbotage (or in situ air injection)
		Soil excavation
Pollution by stop of physical methods	Landfill	Isolation and sealing capsules
	Solidification/stabilization	Vertical isolation
		Solidification/stabilization in situ
Chemical methods	-	Soil flushing
		In situ chemical oxidation
Thermal methods	Incineration	In situ desorption
	Thermal desorption	
Biological methods	Biopile	Enhanced biodegradation
	Composting	Bioventing
	Land farming	Biosparging
		Phytoremediation
		Enhanced natural attenuation

As a first step, the previous selection of the depollution techniques will allow to make up a list of techniques which can be applied on the site. Tables 3 and 4 present the matrices with possibilities to apply rehabilitation methods on the type of targeted environment, both for organic and inorganic pollutants, depending on each type of environment [2, 3, 4, 5, 11, 12].

Table 3. Matrix with rehabilitation possibilities for organic pollutants [2, 3, 4, 5, 11, 12].

Rehabilitation potential	**Environment to**	**VOC**	**Halogenated hydrocarbons**	**Non-halogenated hydrocarbons**	**HAP**	**PCB**	**Dioxins and furans**	**Pesticides and herbicides**
Excavation and burial	S	+	+	+	+	+	+	+
Natuaral atenuation	W	+	+	+	+	-	-	+
Chemical Oxidation	S, W	+	+	+	+	-	-	+
Chemical washing	S	+	+	+	+	-	-	-
Changes in surface	S	-	-	-	-	-	-	-
Washing	S	-	+	+	+	+	-	+
Incineration	S	+	+	+	+	+	-	+

„+” is envisaged; „-” not envisaged; S –unsaturated zone; W – saturated zone.

Table 4. Matrix with rehabilitation possibilities for inorganic pollutants [2, 3, 4, 5, 11, 12].

Rehabilitation potential	**Environment to**	**Heavy metals**	**Non-ferrous**	**Asbestos**	**Cyanide**	**Explosives**
Excavation and burial	S	+	+	+	+	+
Natuaral atenuation	W	+	+	-	-	+
Chemical Oxidation	S, W	-	+	-	-	-
Chemical washing	S	+	-	-	-	-
Changes in surface	S	+	+	-	-	-
Washing	S	+	+	-	+	-
Incineration	S	+	+	+	+	+

„+” is envisaged; „-” not envisaged; S –unsaturated zone; W – saturated zone.

After the preliminary selection of applicable techniques, the comparison of these techniques (by way of a cost – advantages balance sheet) is carried out by means of preliminary studies, taking into account the following criteria [1, 2, 3, 6, 7, 18, 19]:

- technical criteria;
- economic criteria;
- environmental criteria.

3. CONCLUSIONS

Phytoremediation has numerous positive features, both from the point of view of environmental protection and from an economic viewpoint. It allows the conservation/preservation of nature and it also permits to carry out agricultural activities after depollution. Economically speaking, it is more advantageous than other methods.

Phytoremediation requires at least 10 years in order to depollute a contaminated soil. The investment is small, but the long-term blocking of the land can cause an economic problem. Some pollutants can migrate before they degrade.

Artificial methods for soil depollution are difficult to apply and very costly (costs vary between €/t 15 ÷ 1500), but they there is the advantage that the soil depollution period is shorter (from an hour to two years).

The cleaning efficiency/capacity in case of self-cleaning processes climbs up to 70 %, while in case of artificial depollution procedures it varies between 50 and 99 %.

As a consequence, it is very difficult to associate a certain technology with one type of pollution. Moreover, in order to respond to the temporal, spatial or efficiency demands, the treatment type often constitutes a combination of various techniques.

In order to carry out soil depollution processes in the future, the following elements should be considered:

- tests for orientation and evaluation which allow the evaluation of applicability conditions depending on the site's state, and the effectiveness of meeting the rehabilitation objectives;
- more detailed studies concerning: the pollutants' properties, the limitation of pollutants' transfer, the site's properties and its uses.

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