ISSN 1454 - 8003
Proceedings of 2019 International Conference on Hydraulics and Pneumatics - HERVEX
November 13-15, Băile Govora, Romania

RESEARCH ON METHODS OF DEPOLLUTION OF CONTAMINATED HEAVY METAL SOILS

Nicoleta-Alexandra VANGHELE[1], Valentin VLĂDUȚ[1], Iulian VOICEA[1], Augustina PRUTEANU[1]

[1] INMA Bucharest, vanghelelrc@gmail.com

Abstract: *Heavy metal soil contamination is a major environmental problem resulting from global industrialization in recent years. Therefore, it is very important to decontaminate soil contaminated with heavy metals, reduce the associated risks and maintain environmental health and ecological restoration. Soil contamination is the most serious because it has a significant impact on humans and all ecosystems. Metals in very small quantities are needed for all vital forms, but in large quantities they become toxic.*
This paper aims to highlight the best decontamination techniques that are efficient, not costly and environmentally friendly.

Keywords*: Heavy metals, contamination, de-pollution*

1. Introduction

Heavy metals can be grouped into essential and non-essential classes. Essential heavy metals include Co, Cr, Cu, Fe, Mn, Ni and Zn and are considered to be essential micronutrients, but become poisonous when taken in excessive amounts. Non-essential heavy metals include Pb, Cd and Hg and are highly toxic to living organisms [1].
Heavy metals are natural components of the soil; due to human activities they have increased their concentration. Sources of heavy metals from the soil include excessive application of agrochemicals, waste sludge, industrial wastewater, biosolids and manure [2]. Also, anthropic and geological activities can be sources through which heavy metals enter the soil.
In contrast toorganic contaminants, heavy metals are somewhat unique in that they are highly resistant to biologically or chemically induced degradation. Therefore, the total heavy metal content in the soil persists for a long time after it has been introduced into the soil which causes serious environmental problems, which makes the land resource unavailable and which causes risk to human health, because soil is the main resource to increase part of human food [3].Thus, remediation of soil contaminated with heavy metals is necessary to reduce the associated risks, to make the land resources available for agricultural production, to increase food security and to scale up land use problems [4].
The paper presents a short summary of some methods of decontamination of the soil contaminated with heavy metals, considered to be the most reliable in terms of costs but also without endangering the health of the population.

2. Materials and methods

Techniques for remediation of contaminated soil in heavy metals
Decontamination of soils contaminated with heavy metals is the main concern of environmental legislation. There are two approaches used to decontaminate the affected soils, namely ex-situ (fig.1) and in-situ (fig.2) [5].

Fig.1. Ex-situ decontamination [7]

Fig. 2. In-situ decontamination [7]

Ex-situ procedures involve extracting the soil and treating it in the same site or in another location where the treatment technology is available. The costs of this process depend very much on the amount of material to be evacuated and the distance to which the soil must be transported. Most ex-situ procedures are based on the same principles as in-situ procedures, their main advantages being the shorter period required for decontamination, the possibility of homogenizing the soil which results in more uniform results.
Many of the technologies applied ex-situ can be in the form of mobile installations, which can be easily transported near the contaminated site. [6]

The ex-situ methods (fig. 3) are:

- **biological** - the use of biocells in which the decontamination is carried out with the help of microorganisms, new cultures of microorganisms are added, possibly nutrients air;
- **incineration** - destruction of the pollutants by exposure to high temperatures, it is necessary to have special incendiary installations (furnaces) that must be equipped with an adequate purification and filtration system in order not to generate toxic residues;
- **thermal desorption** - is a decomposition process that involves the volatilization of pollutants by heating the substrate, purifying and filtering waste gases, it is a method that has lower installation and exploitation costs than incineration because the substrate is not burned but only heated the decontaminated space can be reused the least expensive desorption is microwave; [8]
- **treatment / filtration** stations - the contaminated material is driven in these stations where techniques (mechanical / chemical / thermal) are applied for decanting, filtering and inactivating the contaminants.

a) biolgical

b) incineration

c) thermal desorption

d) treatment / filtration

Fig. 3. The ex-situ methods

The in-situ process represents the executionof neutralization directly in the environment affected by pollution, without excavating or moving the contaminated soil.

By applying this method, the simultaneous depollution of soil and groundwater is sought and is generally applied in areas where there are constructions and no excavation operations are possible. In-situ treatment is applied until the limits set in the regulatory acts are reached (specific legislation, environmental authorization / agreement) [7].The most well-known in-situ techniques presented in Figure 4 (a-g) are:

• **isolation of the area with screens / hydraulic insulation** - the isolation of the area contaminated by impermeable screens (covering, creating a wall or insulating layer) does not have the role of decontamination only of prevention, isolation and limitation of pollution, and hydraulic insulation builds an extraction well In front of the pollutant front, from which the polluted water is pumped (which can be purified or transported), an injection well, located upstream of the polluted area, can be built in order to increase the hydraulic gradient;

• **decontamination screens / reactive permeable barriers** - isolation of the contaminated area by impermeable screens with gates / treatment areas, isolation of the contaminated area or substrate by insulating walls that treat / inactivate pollutants;

• **systems pump and treat / volatilize** - the contaminated water is pumped from the underground and treated to the surface using procedures appropriate to the type of pollutant, the purified water can be re-injected into the aquifer to increase the efficiency of the method and reduce the decontamination time, the design of the pump system must be it ensures high pumping rates and possibly re-injection (for rapid decontamination). The method cannot be applied to all types of pollutants. A variant of the type of pumping and treatment is the volatilization method used to extract volatile pollutants (e.g. benzene, toluene, xylene, ammonia) from the water, the exhaust air must often be filtered prior to discharge;

• **SVE systems - underground vapor extraction** - reduce the concentration of volatile compounds absorbed underground, apply a negative pressure underground to have a suction force that collects vapors by suction. A typical EVS system comprises: extraction / suction wells, vacuum pump (for vapor extraction), pipeline treatment system + particle filter [9];

• **air bubbling, steam injection** - a technique that aims to reduce the concentration of volatile contaminants by injecting air into the contaminated substrate;

• **thermal remediation** - thermal remediation theology from the range of EVS techniques (combined with them) is performed almost complete decontamination 95-99%, the efficiency of the decontamination operation increases due to the fact that the weakly volatile compounds, compounds with high boiling temperature are mobilized [10];

• **chemical methods** - it involves immobilizing the polluting compounds at the site of contamination by oxidizing or reducing them into more stable, non-toxic forms, usually using the injection of strong oxidants (hydrogen peroxide, ozone, peroxone, potassium permanganate, oxygen) or some reducing substances (sulfites, sulfur dioxide),but washing techniques can also be used (mobilization and extraction of NAPL - liquids not immiscible with water). Chemical methods include, among other things, soil washing, for less harmful washes, organic acids and chelating agents are often suggested as alternatives to the use of straight mineral acid [4], the most commonly used and studied chelating agents are: EDTA (acid) ethylenediaminetetraacetic), NTA (nitrilotriacetic acid) and DTPA (diethylenetriaminepentaacetic acid) due to their reduced efficiency and cost;

• **stabilization and solidification** - Stabilization - addition of aggregate materials to pollutants to produce more stable compounds and Solidification - addition of aggregate materials to pollutants to increase their stability and isolation in solid products (eg not to be mobilized by water from rain) cement is usually used in different combinations, it is an expensive method, applicable only to certain contaminating products, it requires a complex technique, the durability of insulation is uncertain and the toxic products are not destroyed or extracted but stabilized / cemented at the site of contamination [11];

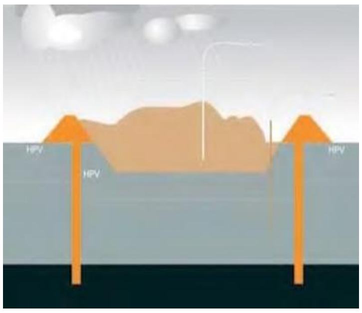
• **bioremediation techniques** - Biotechnology consisting of the use of living organisms and their metabolic peculiarities - or of some natural processes in the action of removing contaminants from the environment. Oxygen and nutrients are usually injected to accelerate the metabolic capacity of microorganisms, fungi, bacteria to produce enzymes that will enzymatically break down contaminating materials into subcompounds with reduced toxicity.

Bioremediation is a modern technology for treating pollutants that uses biological factors (microorganisms) to transform certain chemicals into less harmful / dangerous final forms, ideally to CO_2 and H_2O, which are non-toxic and released into the environment without altering substantially the balance of ecosystems. Bioremediation is based on the ability of some chemical compounds to be biodegraded.

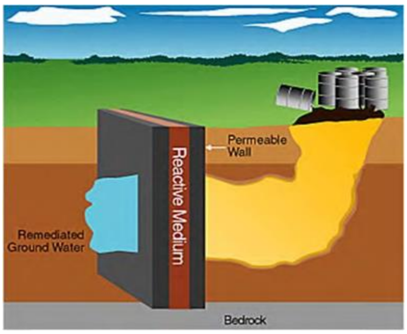
Classification of decontamination biotechnologies:

• Bioremediation - Bioremediation
• Mycoremediation - Mycoremediation
• Phytoremediation – Phytoremediation [12].

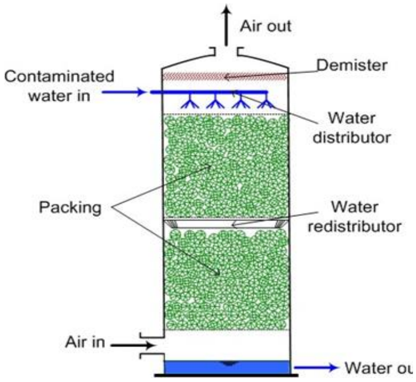
ISSN 1454 - 8003
Proceedings of 2019 International Conference on Hydraulics and Pneumatics - HERVEX
November 13-15, Băile Govora, Romania



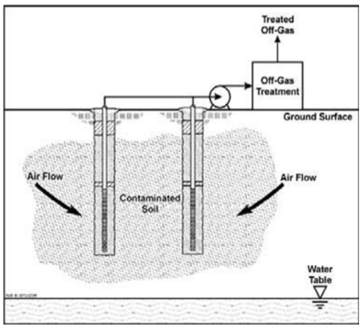
a) Isolation with screens



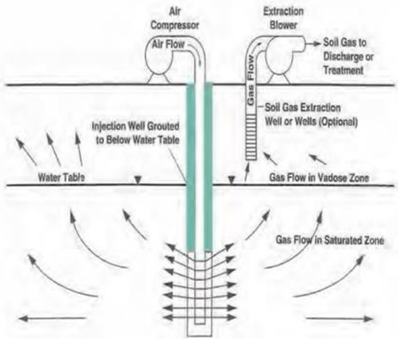
b) decontamination screens / reactive permeable barriers



c) systems pump and treat / volatilize

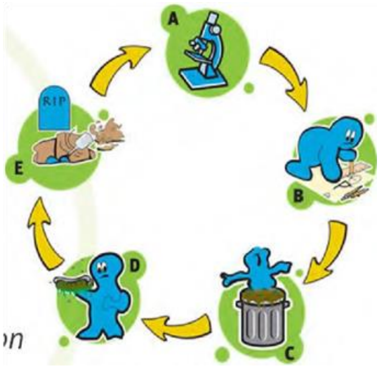


d) EVS - underground vapor extraction systems



e) air bubbling, steam injection

f) chemical methods



g) bioremediation

Fig. 4. The in-situ methods

3. Results

The remediation techniques currently available for metal-contaminated soil have different advantages and disadvantages. The applicability of these individual techniques in a specific soil remediation project is mainly determined by the geography of the place of contamination, the characteristics of the contamination, the objective of the remediation, the cost efficiency, the financial budget, the availability of the implementation, the time requirement, etc. [14].

All of these factors need to be considered and evaluated comprehensively to select the best techniques for a particular soil remediation project. Integrated uses of two or more available soil remediation techniques may be required at different stages and locations of a project. For example, chemical stabilization can be performed at severely contaminated sites to reduce the bioavailability and toxicity of heavy metals in high concentration in the soil and to allow plants to

settle, followed by phytoremediation to gradually restore the ecosystem functions of the contaminated soil.
Table 1 presents the mechanisms, advantages, disadvantages and the state of application of the remediation techniques available for soils contaminated with heavy metals.

Table 1: Mechanisms, advantages, disadvantages and application status of remediation techniques available for heavy metal contaminated soils [15]

Remediation technique	**Applicability**	**Working mechanisms**	**Advantages**	**Disadvantages**	**Application status**
Surface capping	In-situ, high contamination	Physical containment	Easy to install, low in cost, high security	Limited to small areas and certain geographic locations, loss of land cropping function	Widely practiced
Encapsulation	In-situ, high contamination	Physical containment and isolation	High security, fast to install	Limited to small, shallow contamination areas, high cost, loss of land cropping function	Remediation of radionuclide and mixed waste contamination
Electrokinetics	In-situ, fine soil, moderate to high contamination	Contaminant removal by electricity	Contaminant removal, minimal soil disturbance	Time consuming, low efficiency, best for fine-textured soils with low permeability	Under development with pilot demonstrations
Soil flushing	In-situ, coarse soil, moderate to high contamination	Contaminant removal by chemical solutions	Contaminant removal, minimal soil disturbance, low cost, simple to install	Best for coarse-textured soils with high permeability, potential groundwater pollution	Limited number of applications to mixed waste remediation
Immobilization /stabilization	In-situ, high contamination	Contaminant deactivation by physiochemical transformation	Affordable, easy to implement, immediate effects	Metal-specific, temporary effectiveness, contaminants remaining in soil	Temporary remediation, not officially approved
Phytoremediation	In-situ, low to moderate contamination	Contaminant removal and/or stabilization by plants	High public acceptance, low cost, easy to implement, suitable for large, low contamination areas	Limited to shallow contamination, metal-specific, time-consuming, low efficiency	Under development with pilot demonstrations
Bioremediation	In-situ, low to moderate contamination	Contaminant transformation by	Low cost, simple to implement,	Low efficiency, merely supplemental to	Not practiced for heavy

		microorganisms	minimal soil disturbance	principal remediation techniques	metal remediation
Vitrification	n-situ and ex-situ, high contamination	Contaminant deactivation by thermally vitrifying soil	High efficiency	High cost, limited to small soil area/volume, treated land and soil losing environmental functions	Regularly practiced
Solidification	In-situ and ex-situ, high contamination	Contaminant deactivation by physically solidifying soil	Fast to implement, high efficiency	High cost, treated land and soil losing environmental functions	Regularly practiced
Landfilling	Ex-situ, high contamination	Physical containment and isolation	Immediate cleanup, high security	High cost, requiring additional land for waste storage	Widely practiced
Soil washing	Ex-situ, moderate to high contamination	Contaminant removal by mechanical separation and chemical extraction	High efficiency, fast effects	Extreme soil disturbance	Regularly practiced

4. Conclusions

Following the research conducted over the years in different countries and on different soil types, it has been found that no decontamination method can be declared as the most effective.
To determine the appropriate decontamination method, account must be taken of the geographical location, the degree and characteristics of heavy metal soil pollution, the costs of decontamination, the time allotted for decontamination, the qualification of the decontamination personnel and other factors that may change from a project to another.

Acknowledgement

This work was supported by a grant of the Romanian Research and Innovation Ministry, through Programme 1 – Development of the national research-development system, subprogramme 1.2 – Institutional performance – Projects for financing excellence in RDI, contract no. 16PFE.

References

[1] Sandeep, G., K.R. Vijayalatha, and T. Anitha. “Heavy metals and its impact in vegetable crops.” *Int. J. Chem. Stud.* 7, no. 1 (2019): 1612–1621.
[2] Maimon, A., J. Khairiah, R. Ahmad Mahir, A. Aminah, and B.S. Ismail. “Comparative accumulation of heavy metals in selected vegetables, their availability and correlation in lithogenic and nonlithogenic fractions of soils from some agricultural areas in Malaysia.” *Adv. Environ. Biol.* 3 (2009): 314–321.
[3] Khalid, S., M. Shahid, N.K. Niazi, B. Murtaza, I. Bibi, and C. Dumat. “A comparison of technologies for remediation of heavy metal contaminated soils.” *J. Geochem. Explor.* 182 (2017):247–268.
[4] Wuana, R.A., and F.E. Okieimen. “Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation.” *ISRN Ecol*. (2011): Article ID 402647.

[5] Zhou, Q.X., and Y.F. Song. “Remediation of contaminated soils: principles and methods.” *Sci. Press* 7 (2004): 345–346.
[6] www.scribd.ro- Marian Pen -Jun23,2015.
[7] http://silvic.usv.ro/cursuri/reed.pdf.
[8] Nistor, S., B. Nistor, and D. Strat. “Decontamination through thermal decoration of waste polluted with hydrocarbons in the Suplacu de Barcau (Bihor County) petroliferous area.”/”Decontaminarea prin desorbtie termica a deseurilor poluate cu hidrocarburi in arealul petrolifer Suplacu de Barcau (Jud. Bihor).” Paper presented at INCD ECOIND SIMI 2011 - International Symposium “The Environment and Industry”, Bucharest, Romania, November 16-18, 2011.
[9] https://ro.scribd.com/document/343183285/Metode-Si-Tehnologii-de-Remediere-a-Solurilor-Poluate.
[10]https://rtpime.files.wordpress.com/2010/03/cap-5.pdf.
[11] Simule, Codruța Violeta, and M. Dobrin. “Remedial measures for the contaminated site Post Rât – Turda."/”Măsuri de Remediere a Sitului Contaminat Posta Rât – Turda.” *ProEnvironment* 3, no. 5 (2010): 163 – 169.
[12] Malschi, Dana. *Biotechnologies and the depollution of ecological systems*./ *Biotehnologii si depoluarea sistemelor ecologice*. Online handbook. Cluj-Napoca, Bioflux Publishing House, 2014.
[13]https://images2.bizoo.eu/image/img360/sale/2012/4/12/Statie-de-desorbtie-termica-SDT-30_9145851_1334662132.jpg.
[14] USEPA. “Superfund Remedial Investigation/Feasibility Study (Site Characterization).” U.S. Environmental Protection Agency, Washington, DC, 2017. Accessed January 31, 2018. https://www.epa.gov/superfund/superfund-remedial-investigationfeasibility-study-site-characterization.
[15] Liu, Lianwen, Wei Li, Weiping Song, and Mingxin Guo. “Remediation techniques for heavy metal-contaminated soils: Principles and applicability.” *Science of the Total Environment* 633 (August 2018): 206-219.