Circular Economy Lab & Observatory

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SOIL CONTAMINATION

Methods of soil remediation from industrial contaminants and possible use of phytoremediation or other bioremediation technologies in those processes

Croatia-4.2

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We tend to forget that soil is the largest living system known to man.

We have perceived it as just a place for growing plants while applying herbicides and fertilizers for an excessively long amount of time.

Strictly speaking, soil is a biologically active natural medium for the growth of land plants composed of mineral and organic material, water, and numerous life forms.

Why is soil important for the Earth? (graph by Marina Janković)

It secures plant roots, filters rainwater and protects groundwater, provides materials, shows past environmental conditions, and is a biological habitat.

Whether it stems from the use of agricultural chemicals, improperly disposed waste, or industrial contaminants, on which we will be focusing further in the text, soil can become contaminated.

Fundamentally, any substance that transcends its naturally occurring levels in the soil and poses a vital risk primarily for humans, but also animals and plants, is considered a soil contaminant. Living in a modern world, the idea of industrial contamination is no stranger to us. Nevertheless, it should be explained more thoroughly to raise awareness and because it has become one of the biggest threats to soil quality, which impacts numerous life forms and agriculture.

Our ticket to purifying soil is soil remediation. By definition, soil remediation is a way of revitalizing and returning soil to its ecological stability after degradation. The most common soil remediation techniques include soil washing (using liquid chemicals to scrub contaminated soil and then separating clean soil from contaminated soil), thermal remediation (vaporizing the contaminants), and bioremediation (using living organisms to remove contaminants).

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[1] While observing the bioremediation techniques of soil remediation, which proved to be more sustainable and less expensive than other remediation techniques, it is interesting to notice how nature can heal nature with the natural ability of various organisms to absorb and degrade.


Growing industrial activity (https://unsplash.com/photos/6xeDIZgoPaw)

As it happens, bioremediation uses a great many techniques with plenty of organisms.

Some of the techniques are bioaugmentation (adding bacterial cultures or other cultured microorganisms to accelerate the degradation of contaminants), bioventing (adding air/oxygen to soils to increase the growth rate of microorganisms), biostimulation (adding nutrients like phosphorus and nitrogen to speed up the growth of existing microorganisms to remove contaminants), and phytoremediation (planting certain plants to absorb contaminants).

[2] Taking into account the profitability and other innumerable advantages of bioremediation and the danger of growing industrial contamination of soil, it would be smart to explore the options of bioremediation and phytoremediation techniques on industrially contaminated soil, push for actually using them, and educate people who are still not aware of the information previously mentioned.

How should this information be used and put into practice? How could contaminated soil be purified using phytoremediation and other bioremediation techniques? [1-2]

Since the 19th century, the world's ever-increasing industrial activity has generated a significant amount of industrial waste. The exact term "industrial waste" represents waste that was created as a result of manufacturing or industrial activities. Industrial waste contains poisonous chemicals and heavy metals, which eventually make their way into the food chain. It can be found in all three aggregate states of matter: solid, liquid, and gas. The most prominent gases include sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon dioxide (CO_2), and carbon monoxide (CO).

They are produced by combustion in industry (in factories, warehouses, etc.), by automobiles, and by other machines that function based on the principle of burning fossil fuels.

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Most of previously mentioned gases react with water in the atmosphere, creating sulphurous, nitric, and carbonic acids, therefore lowering the pH value of rain and creating acid rains. Acid rains, aside from destroying forests, polluting water and presenting a risk for humans and animals, destroy the quality of soil. They change the pH balance of soil, consequently increasing the quantity of H+ ions (creating acidic soil).

One of our group members professionally taking a sample of soil in the centre of Zagreb (photo by Uma Fazlić)

Because of that, important mineral substances such as potassium, calcium, magnesium, and so on are washed out from the soil. This is dangerous for forests because trees begin to lack calcium, which is crucial for building their cells.

On the other hand, acids directly damage plant roots, and they can reach leaves or needles of plants through water, thus damaging their tissues.

Those damaged plants create an even bigger problem because harmful substances also affect animals and humans through food chains.

The contaminants travel via various food chains, through all fragments of the biosphere, and affect not only animals and plants, but also most of the food produce we consume every day. Other types of industrial waste include chemical and solid waste, which can be hazardous (have a harmful effect on the environment and human health) or non-hazardous. The most frequent sources of chemical waste are power plants, warehouses, factories, etc. Chemical waste includes solvents (acetone, alcohol, ...), oil, cleaning fluids and bleaching chemicals, dyes, corrosives (various acids), reactive substances (oxidizers, sulphides, and explosives), etc.

Regarding solid waste, mining and smelting industries create mud and debris with a high concentration of mercury, and thermal power stations create ash. Other types of solid waste are plastics, cardboard, packaging materials, wood, and scrap metal.

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Of all the industrial contaminants, heavy metals probably pose the biggest danger. Heavy metals are metals with a density greater than 5 g/cm^3.

Coming mostly from industry, mining, and agriculture, they accumulate in the soil and are then transferred to plants through the vascular system with water. [3]

Even though both plants and humans need them for several organs, they can become toxic when their concentration exceeds recommended levels (which are usually very low).

Soil polluted by industrial activities (https://www.megapixl.com/effects-of-heavy-metal-poisoning-or-chemicals-and-heavy-metals-in-soil-fromindustrial-stock-photo-44026752)

Heavy metals negatively impact the number of microorganisms and thus, altering the microbial community, influence important microbial processes (for example, the process of enzyme synthetization). They have a more negative effect on plant growth than other environmental stresses and reduce the possibility of harvest production.

To prove the effects industrial contamination has on the pH balance of soil we decided to test and compare the pH balance of two soil samples in our school lab.

One sample was taken in the school backyard (in the centre of Zagreb, where acid rains were known to be a problem) and the other near Duga Resa (in a more rural area). Our hypothesis was that the pH balance of the soil collected in Zagreb will be lower than the pH balance of the soil collected in Duga Resa. [3]

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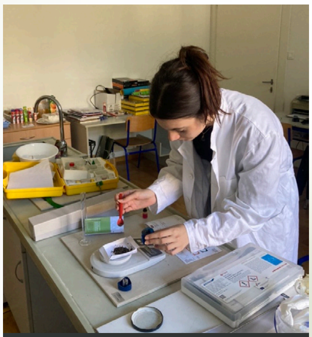
To our surprise, both the soil from the city of Zagreb and from the rural Duga Resa were relatively acidic and had almost the same pH value (pH=6.72). That was contradictory to our hypothesis and it showed that acid rains, which are transported by clouds, pollute massive areas, even the untouched nature not close to any big industrial complex. This relatively small experiment simply described the danger of industrial contamination – we can't control the way its spreading.

Bioremediation is one of the most profitable and sustainable ways of soil remediation. It is highly efficient, requires minimal use of chemicals and it can even have the possibility to recover the metal pollutants so that they can be reused, hopefully for some non-polluting purpose. Bioremediation is conducted by using bacteria, fungi (mycoremediation) or plants (phytoremediation) to clean the soil from contaminants.

In the method of phytoremediation, plant roots, in addition to absorbing water and minerals they require, absorb pollutants (heavy metals, solvents, corrosives, etc.). These contaminants would usually damage most plants, but when absorbed by plants used in phytoremediation processes, they are instead only chemically broken up into harmless compounds without causing damage to either the plant or the environment.



One of our group members measuring the pH balance of soil samples (photo by Blaž Škrgatić)

Phytoremediation also proves more advantageous than other techniques because it is very effective at healing large areas of contaminated soil, and the plants necessary for it are also significantly cheaper to both set up and maintain.

Furthermore, over 400 plant species that can effectively remediate the soil have already been discovered and each species specialises in countering different contaminants. Based on the literature from 1995 until 2009, it can be stated that the most frequently citedspecies in phytoremediation studies were Brassica juncea, Brassica napus, and Zea mays.

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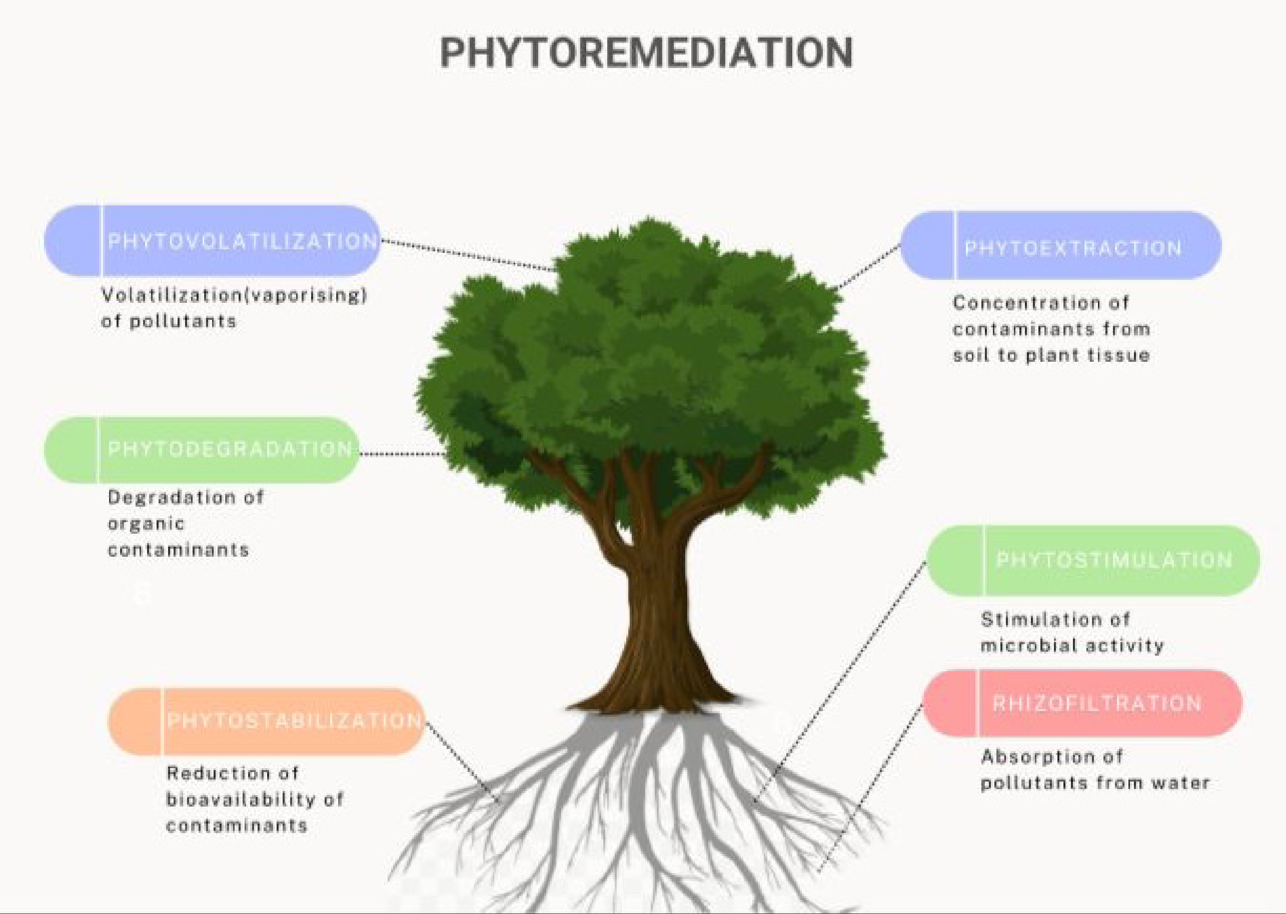

Stages of phytoremediation (mindmap by Uma Fazlić)

Brassica juncea (commonly known as brown mustard) has proven especially important because of its ability to remove very high amounts of cadmium (Cd) from soil.

Furthermore, it can also efficiently remove lead (Pb), selenium (Se), and zinc (Zn) from the soil. The first recorded case of the use of bioremediation occurred in 1974 when a type of bacteria called Pseudomonas putida was used to degrade petroleum. By 1991 about 70 types of bacteria were already discovered to have the ability to degrade petroleum and through the next two decades that number was doubled. [4]

Between other methods of soil remediation such as previously mentioned soil washing and thermal remediation, bioremediation is the direction in which we, as a society, should be putting our focus. Though it is relatively slow and requires patience, the advantages we described outweigh the disadvantages. [4]

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The beauty of what soil can provide us with (photo by Uma Fazlić)

In conclusion, we can say that soil is not only probably the most important medium for agriculture, but also a home for many plants, animals, fungi, and other organisms. Not only does it help with plant growth, but it also protects and supplies them with water and required nutrients.

However, soil cannot fulfill its many purposes properly if it gets polluted. One of the greatest sources of soil pollution is industry.

Because of industrial activities and the neglective behavior of industrial complexes, soil absorbs all industrial contaminants which then affect all living creatures in that area. Industries pollute the Earth in all three aggregate states: solid, liquid and gas. Gases are a bigger and more serious threat because they pollute air. By polluting air, those gases rise in the atmosphere, mixing with clouds and end finally making acid rain.

As we previously said, acid rain ruins the quality of soil, damages plants and indirectly poisons animals and humans. Liquid contaminants are chemicals like oil, acetone, alcohol, etc., and they usually find their way into various bodies of water, of which we don't have enough to be further contaminating. Solid contaminants are mostly plastic, cardboard, heavy metals, and others.

Even though plants, animals, and humans need some of the heavy metals for normal functioning, bigger concentrations of those metals can be extremely dangerous for living organisms. Nevertheless, humans have found methods that can help remediate contaminated areas of soil. The method of soil remediation which we consider to be the best (regarding safety, cost, and pollution) is bioremediation. As previously stated, it requires minimal use of chemicals; it is highly profitable and sustainable.

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The power of bioremediation (https://www.megapixl.com/environment-change-illustration-53950309)

Bioremediation can function with fungi (mycoremediation) or plants (phytoremediation). When using bioremediation, the metals that polluted the soil can be removed from the soil without causing additional damage to the ecosystem. Some of the downsides of bioremediation are that, if the soil is extremely polluted, it could not be enough to conduct the process only once, making it time-consuming, sometimes taking several years for a relatively small piece of land. Also, it requires patience, and since soil is being contaminated so rapidly, it may not be enough for a visible immediate effect.

But it is, without doubt, proven to work. Finally, it is especially important that all of us protect our dear planet Earth since we, as humans, destroy it the most.

Given our current situation with global warming, bioremediation can only have positive outcomes and help the Earth. By protecting our soil, whose purposes we so often neglect, we protect ourselves, since so many things the biosphere (meaning all life on Earth) needs (minerals, nutrients, vitamins, etc.) can be found in it.

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