Clean and green?

The power and limits of phytoremediation in cities

MANUAL April 2021

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Contents

Preface

Over the past decades, the focus on green in cities has increased. Current knowledge on biodiversity loss due to urbanisation and human activities has led to the inclusion of green infrastructure in cities. Moreover, other benefits of plants in cities, such as air quality, heat reduction, water retention and improved mental health, have aided to the multi-purpose use of plants.

At the same time, increasing soil and water pollution in urban and industrial areas has led to extensive regulations to further limit pollution. Many types of pollution can pose a threat to human health and therefore clean soil is important in cities.

For this reason, we, a multidisciplinary team of biology and plant-science students from Wageningen University, have started a project on the use of plants to clean the environment from pollutants (called *Phytoremediation*). Phytoremediation is a green method to work towards a clean and healthy environment in cities, for both humans and nature.

Following our research, we have set up an integrated database that lists plant species to clean the environment. Additionally, the database lists the practical implications and limitations of each plant species. This database is meant for city planners, property developers, designers and architects, so that they can use these plants in removing urban pollution.

For more details on our project, see our website: https://clean-and-green.webnode.com/.

Accompanying the database, this manual was set up. It offers both background information on plants in the city, phytoremediation and the database. Together, this manual and the database help designers to include nature in urban area, while giving the possibility to clean urban soil.

In the first chapter of this manual 'Green in the city', advantages of plants in urban area are explained together with different suggestions to include more green in projects. In the second chapter 'Phytoremediation', the background, advantages, limitations and implication of phytoremediation is explained in a comprehensible way. The third and last chapter includes some background information on the database and explains how to use it.

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April 20 2021

1. Green in the city

Plants in urban environments can have many advantages, ranging from mental health benefits, to reducing heat stress or flooding, increasing biodiversity and much more. This chapter will give some general background on plants in urban environment.

1.1 Background – What different forms of green in the city?

Green has many different places in urban area. Obviously, plants are used in city parks. But also, the inclusion of trees on streets, plants climbing on public buildings or small green patches in neighbourhoods offer implementation of plants in public spaces. Furthermore, green roofs have gained increased interest, because of the many advantages they offer in terms of isolation, cooling and aesthetics. And even entire buildings covered in hanging plants are starting to arise.

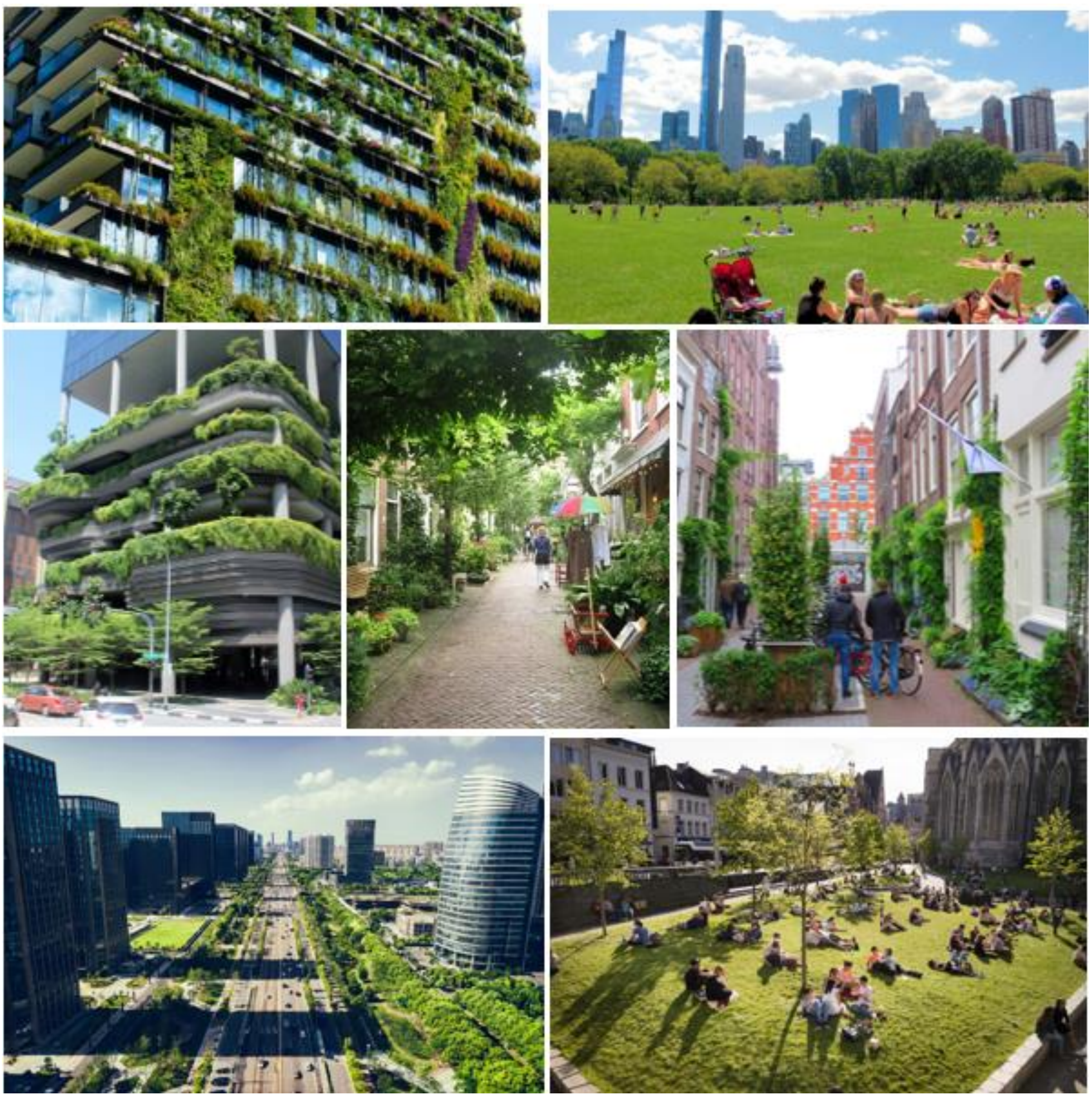


Figure 1, Different forms of green in the city ranging from green buildings, to green alongside streets and parks. [1]

1.2 Advantages – Why use plants in the city?

As stated, the implication of green in cities has many advantages. In this section, the most important green advantages are listed [2].

Biodiversity

Biodiversity is defined as the total variation of life. This comprises of e.g. plants, insects, small animals, wildlife, but also microbial diversity in soils and waters. Biodiversity is important for humans because of many reasons. First, biodiversity is needed for our food production via pollination, pest control, breeding and the maintenance of healthy livestock. Moreover, biodiversity is essential for medicine development, because many plants and animals offer new sources of drugs. Furthermore, biodiversity offers many other products such as textiles, wood, rubber, wool, silk, leather and more. Lastly, many other ecosystem services are provided by diverse nature such as tourism and recreation in wild nature [3].

While biodiversity has thus many advantages, increasing urbanisation and land use for agriculture has degraded and fragmented natural habits of many plants and animals. To connect these fragmented habitats and help maintain biodiversity, a major shift in the design of our cities is needed: we should start to view urban areas as potential sources of biodiversity [4]. Plants, as primary producers, are the foundation of biodiversity [5]. Hence, the implementation of green infrastructure in cities has a great potential to positively influence urban biodiversity and creating green cities will help to decrease negative effects of urban areas [6].

Aesthetics

Plants, especially flowering plants, are generally perceived as attractive by people. More biodiverse planting is generally found more beautiful than monotonous planting [7]. Moreover, plants add live and colour the grey city streets. Since we humans are by nature forest animals, our eyes are especially suitable for seeing different shades of green. For this reason, we find green environments prettier than grey ones.

Mental health

Plants have a positive effect on our mental healt. Research has shown that being around plants causes people to feel more at ease and relax [8]. This decreases anxiety and stress. Moreover, a green environment helps against depressions, while enhancing happiness and life satisfaction [8]. Besides, plants help to improve memory and attention, thereby increasing productivity [8]. Lastly, a green environment is more attractive for playing outside and sporting, which increases the level of exercise citizens get. In total, people are healthier when their environment contains more green.

Including green in cities can thus improve citizens mental health, happiness and cognitive functioning. Furthermore, citizens (especially young children) can better create a connection with nature and start to value nature better.

Land value

Generally, more green increases the value of houses in a neighbourhood. Houses with view on water, parks or public gardens are 5-15% more valuable than other houses. Moreover, green contributes to social cohesion in the neighbourhood, which again increases the quality of living and the value of the area. Besides, companies are more inclined to settle in a green environment, which increases the economic growth in the city.

Air quality

Plants positively influence air quality both indoors as outside. Especially toxic gasses like formaldehyde, benzene, and toluene are taken up by plants [9]. Also, smog has been known to decrease with the presence of plants. Besides, plants increase air humidity, which prevents people to dry out and reduces complains in airways. Overall, plants filter and improve the air around then, making them extra suitable for polluted city air.

Heat spot reduction

Cities are 2 to 10 degrees hotter than rural area, which is called the city hot spot. During hot summer days, streets, squares and buildings warm up quickly, while cooling down very slowly. This heat often causes nuisance, or even health problems.

Green areas greatly reduce this heat stress due to the evaporation of water. For example: a normal roof can get up to 70 degrees Celsius, while a green roof does not exceed 32 degrees. Moreover, trees provide welcome shade and strongly reduce heat nuisance.

Water retention

Up to 90% of the surface in cities is built on or paved. This causes all rainwater to run off into the sewage, putting immense pressure on city sewers with heavy rain. Green in parks, gardens or green, prevent flooding of cities by retention and evaporation of rainwater.

2. Phytoremediation

Phytoremediation is an umbrella term used for cleaning up the environment (soil, water and air) from contaminants such as heavy metals or mineral oils with the use of plants. Phytoremediation has been applied successfully in many cases to clean the environment. It offers a green alternative to the conventional remediation practices [10]. Cleaning soils using soil dressing or chemical extraction methods, takes a lot of effort and money [11]. While soil remediation with plants takes more time, it is also less intensive and expensive. Additionally, the use of plants to decontaminate water is even more cost-effective solution to the removal of heavy metals or cleaning of wastewater [12]. Moreover, using phytoremediation instead of conventional soil cleaning, the amount of green in cities in increased. The different advantages of more green in cities have been explained in section 1.2. Therefore, using phytoremediation combines all the positive aspects plants have in urban area.

This chapter will explain the basic mechanisms of phytoremediation, what soil contaminants it can be used for, the limitations of this technique and how to implement phytoremediation in projects.

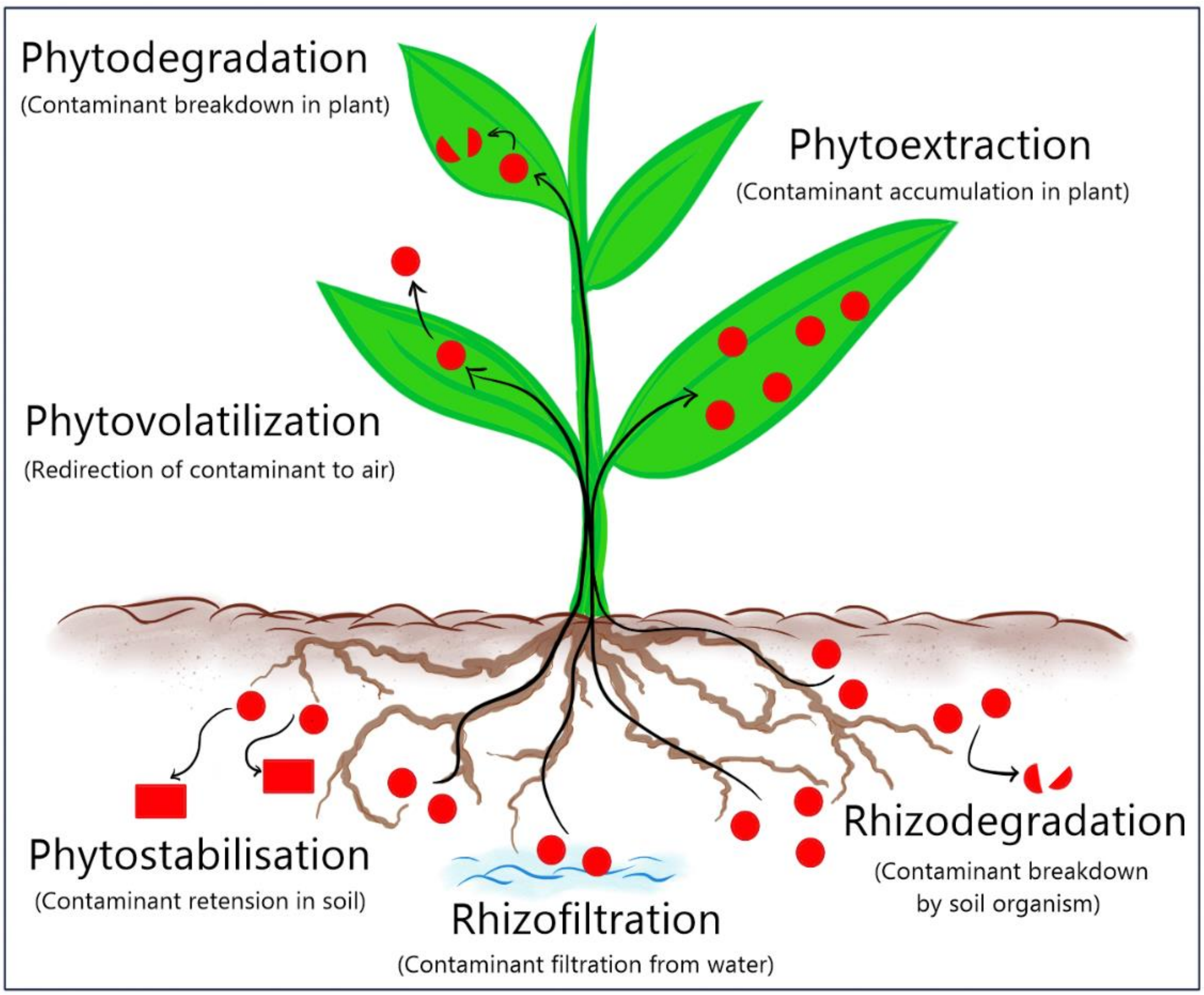
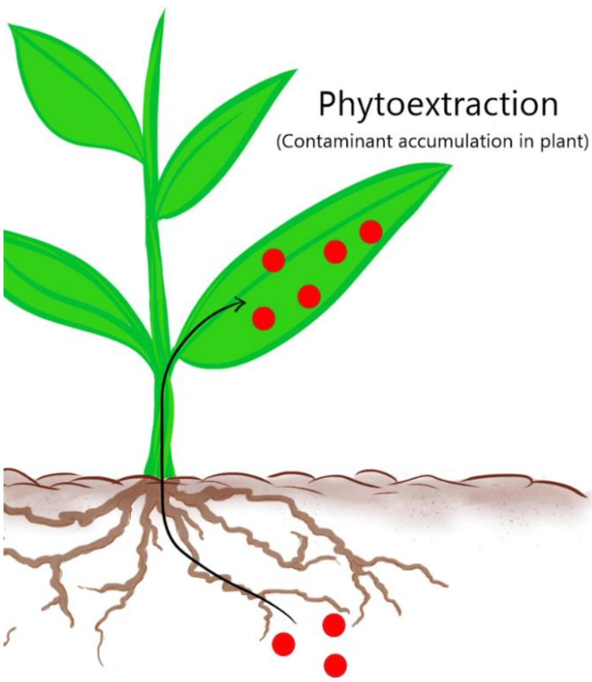


Figure 2, Different forms of phytoremediation. The contaminant (represented by the red circles) can be stabilized or broken down in the soil, accumulated or degraded inside the plant biomass, or be volatilized into the atmosphere.

2.1 Background – What is phytoremediation?

Phytoremediation is the direct or indirect use of plants to clean the environment from pollutants or immobilize them [13]. Phytoremediation can be used for different types of pollutants that are present in soil, water, or in the air. This technology is very cost-effective, socially accepted and non-invasive approach to remove contaminants from the environment [14].



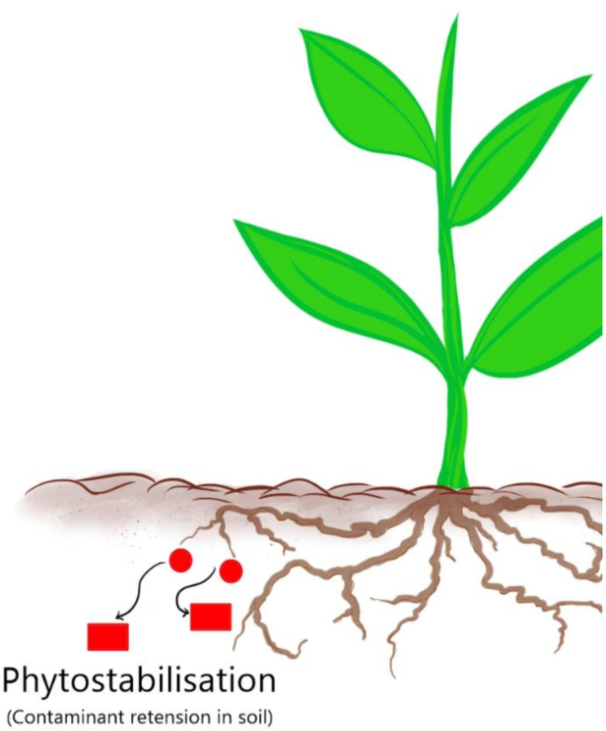
2.1.1 Phytoextraction – Accumulation of heavy metals

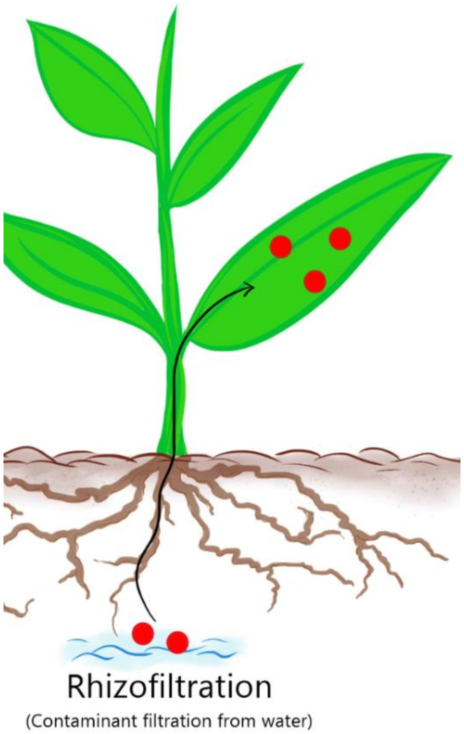
Phytoextraction is the term used for plants that extract inorganic contamination from the soil. This technique is mainly used for the removal of heavy metals. The metals accumulate in the plant tissue, meaning that these plants need to be removed frequently and carefully, taking out the complete plant (roots and all).

Though this method thus requires more management, it is still financially more attractive than conventional methods to remove this polluted soil. The effectivity of this method strongly depends on the soil and plant properties.

2.1.2 Phytostabilization & Phytoimmobilization - Contaminant retention

Both phytostabilization and phytoimmobilization limit the availability of heavy metals in the soil. This means that the pollution cannot leak out of the soil and remains where it is. In this manner, the toxins cannot enter nature or other areas surrounding the polluted area. This way the hazard of the contaminant is strongly reduced.



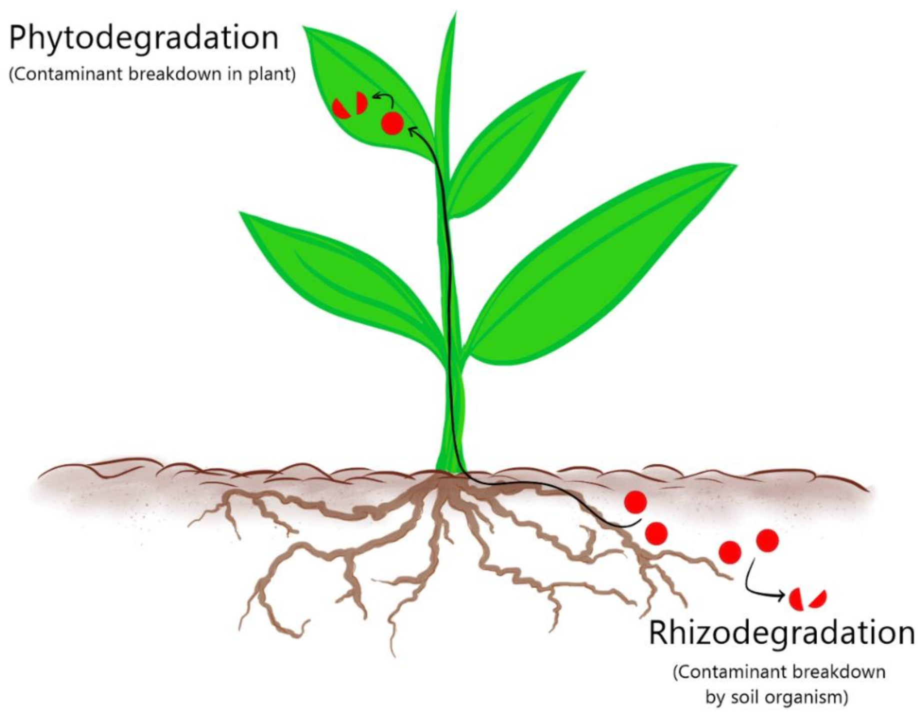


2.1.3 Rhizofiltration - Water remediation

Rhizofiltration is used in aquatic environments to clean both surface water, groundwater and wastewater. Phytoremediation via filtration can primarily clean heavy metals, which are accumulated in the plant tissue. Therefore, these plants need to be replaced at regular intervals and the waste must be dealt with carefully. However, using phytofiltration with floating baskets on which plants are bound, they can easily be taken out and replaced. This system can be used easily in ponds and channels.

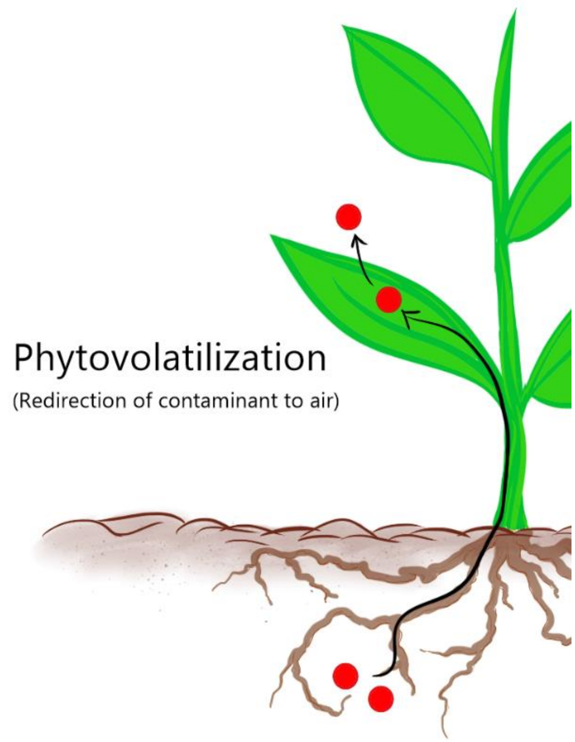
2.1.4 Phytodegradation & Rhizodegradation - Break down of pollution

Phyto- and rhizodegradation are the only methods of phytoremediation that actually break down organic contaminants, like PAHs, from the environment. In phytoremediation, plants take up this contamination in their tissue and break them down in (harmless?) compounds. In rhizodegradation, the compounds are broken down by microorganisms surrounding the plant roots, helped by the positive influence of plants. These methods a very promising techniques, for the contaminants are broken down and no special care is needed for the plants. However, plant growth is inhibited by the contaminants because it takes plants energy to break down these toxins. Additionally, this method does not work for heavy metals, because these cannot be broken down.



2.1.5 Phytovolatisation - Redirection to the air

The last method of phytoremediation, phytovolatisation, releases contaminants from the soil or water to the air. Plants take up the contamination from the soil or the water, transports it to the leaves and releases them into the air. The concentration of the contaminants in the air is far less than in the soil, which strongly limits the hazard of the toxins. This method can be used for both organic (chlorinated solvents), and some inorganic compounds (Se, Hg, and As).



2.2 Background – What is soil contamination?

Humans have a major impact on their environment. With the increasing growth of the human population and industrial activity, water and soil pollution has increased [15]. The most common pollutants in soil and water are heavy metals, polycyclic aromatic hydrocarbons (PAHs), and chlorinated hydrocarbons (CHC) [16]. From this list, heavy metals are the only non-organic pollutants.

The next sections will shortly explain each pollutant and why we need to remove them.

2.2.1 Heavy metals

Heavy metals are non-organic pollutants, which means they cannot be broken down and often remain in the environment for years [17]. Examples of heavy metals are arsenic (As), cadmium (Cd), copper (Cu), mercury (Hg), lead (Pb) and zinc (Zn). These heavy metals are toxic for plants and animals at low concentration [17][18].

Heavy metals, can be taken up by plants and in this way enter and accumulate in the food web [17][19], killing both plants and animals [20]. Besides, heavy metals like cadmium or lead could be taken up by crops [21], for instance, in city vegetable gardens. Thus, these contaminations pose a serious threat to human health [22].

Therefore, these pollutants need to be removed from open soil or waters that can come into contact with humans or other animals. Furthermore, soil on which (edible) plants are grown must not contain heavy metals. To remove them, phytoextraction or rhizofiltration can be used. Besides, metals can be stabilised in the ground by phytostabilisation, making them less hazardous.

2.2.2 Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons, or PAHs for short, are a group of organic molecules, only consisting of carbons and hydrogen atoms, that form coupled aromatic rings. PAHs have both natural and anthropogenic sources. Examples of anthropogenic activity causing PAHs to release into the environment are the petrochemical industry, fossil fuel combustion and vehicle emissions [23]. PAHs are a major pollutant of urban areas and have been linked to increased risks of cancer development as well as cardiovascular disease [24].

This kind of pollutant is difficult to tackle, because it does not dissolve in water. Therefore, a combination of different techniques is proposed, such as volatilization, photochemical degradation, microbial degradation and phytoremediation. The addition of phytoremediation (phytodegradation) to microbial degradation (rhizodegradation), is that plants enhance the number and activity of soil microorganisms, that help to break down the pollutant [25]. Combining these methods, resulted in 40% - 50% more PAHs removed in comparison to individual techniques.

2.2.3 Chlorinated hydrocarbons (CHC)

Chlorinated hydrocarbons (CHCs), or organochlorides (OC), are a large group of organic compounds that contain at least one atom of chlorine. Because this is such a large group of compounds they range in applications, properties and environmental impacts. Also many toxic pesticides, like DDT, that have a negative effect on insect biodiversity, fall under this category (Rosner & Markowitz, 2013).

Most CHCs are present deep in the soil where plant roots cannot reach them. These contaminants are not possible to remove with plants. However, superficial CHCs, like pesticides, can be taken up by plants. These CHCs accumulate in plant roots and plants used for this purpose need to be harvested and replaced. Besides, volatile CHCs like carbon tetrachloride (CT) and trichloroethylene (TCE) can be taken up by poplar trees and broken down [26]. Additionally, polychlorinated biphenyls (PCBs), CHC pollutants that are very persistent in the environment and widely used, can be degraded in the soil with stimulation from plants. For PCBs a combination of phytoremediation with other (bio)remediation techniques is possible [26].

In conclusion, remediation of CHCs is strongly depended on the specific CHC. When CHC contamination is present, the exact pollutant needs to be identified and the depth of pollution. Thereafter, the possibility of using phytoremediation needs to be determined and a combination of plants and other remediation techniques can be applied.

2.3 Implementation – What to consider before using phytoremediation?

The main issue with phytoremediation is that the usability and efficiency depend on the type of pollutant, soil properties or water characteristics and removal rate of the plant [27][28]. Moreover, phytoremediation can take a long time. This section explains the four major drawbacks of phytoremediation: time, soil composition, waste treatment and toxicity.

2.3.1 Time

Generally, phytoremediation can take years to fully work. Therefore, this method should not be seen as a quick solution, but a long-term project to improve the soil quality in an area. The exact time needed to completely clean soil depends on many factors, mainly the pollutant and soil properties. For example, degradation of organic pollutants takes two to ten years, the for extraction of NaCl takes between three and ten years [29]; for heavy metals it is estimated to take from decades to centuries [30]. This is, of course, a problem for sites that need to be remediated over a short time span, but there is a lot of opportunity in phytoremediation for sites that have low contamination levels or are used for long term purposes such as parks or company premises. As an example, see the long-term project in De Ceuvel under section 2.4.4.

2.3.3 Soil composition

The feasibility of phytoremediation is strongly depended on soil composition (e.g. pH, soil age, contamination concentration, moist) [27] or water characteristics. Therefore, soil research needs to be done to determine whether it is possible to use plants for remediation. To determine whether the soil is suitable, you can make use of the 'Cleaning the soil with nature' report [27].

The most important soil characteristic is mobility of pollutant (especially heavy metals) in the soil also influences the efficiency of phytoremediation: plants are not always able to uptake metals present on the soil [31]. This problem can be solved by mobilizing the contaminants with chelators such as EDTA, EGTA and organic acids, increasing the availability to plants [32]. However, these chemicals can cause leaching in ground waters decrease break-down of the pollutant [33] and are therefore banned in most European countries [34]. A better way to improve the availability of pollutants and enhance phytoremediation is the use of microorganisms in the soil in combinations with plants.

Additionally, it is important to know the depth of the contamination, for plants need to be able to reach the contamination. Pollution deeper than a meter cannot be remediated using herbs or grass. Even more, pollution deeper than 5 meter can hardly be remediated with plants at all.

Concludingly, soil needs to be investigated before starting a project using phytoremediation and a combination of remediation techniques can enhance the effectiveness of remediation.

2.3.4 Waste treatment

When using phytoremediation methods that accumulate pollutants, mainly heavy metals, in plant tissue (phytoextraction and rhizofiltration), extra care needs to be taken when handling the contaminated plant biomass. It is recommended to use gloves and protective clothes when removing plants. Thereafter, contaminated plant waste should be stored until a definitive place is found. During storage plant waste can be shredded, composted or burned to limit the volume of the waste.

Options to use this plant debris is to burn the biomass as a source of energy [35], and thereafter recover the metals from the ashes. This is called *phytominging*. For example, Ni, Zn, and Cu can be recovered from waste ash and can be used for different purposes. Ash obtained from the burning of this polluted biomass can contain significantly more metals than minerals that are mined for this purpose. Therefore, this waste stream may be a great source of metals [36]. However, the amount of biomass is not high enough and the extraction system has not yet been optimized to make profit. Still, phytomining is the only way to get rid of the heavy metals. Additionally, working together with multiple locations can increase the biomass until a workable amount of plant material is gathered.

Thus, when using phytoremediation for accumulation of heavy metals, it is important to consider waste treatment and management practices beforehand.

2.4 Example: De Ceuvel - Amsterdam

De Ceuvel is an example of urban implementation of phytoremediation [37]. De Ceuvel lies in Amsterdam (Korte Papaverweg 2-6, Amsterdam) and is a former shipyard that was heavily polluted. This land could not be used before being cleaned. Therefore, a project was set up to redevelop De Ceuvel. The design comprises of a self-sustaining working area for innovation combined with a phytoremediating parc that cleans the soil. The goal of the project is to have an open and sustainable working space that leaves the ground in 10 years cleaner than it was. The project has now run for seven and a half years and it is possible to reflect on implementation and concerns in urban phytoremediation.

2.4.1 Pollution & remediation

The soil in De Ceuvel is polluted with a variety of heavy metals (e.g. zinc, lead, copper, cadmium and nickel) and PAHs (E.g., tar). This pollution is distributed very unequally, making the application of different plant species very site specific. The pH of the soil was generally neutral to slightly basic, meaning that heavy metal bioavailability is poor, but plants can grow easily.

Three phytoremediation methods have been applied to clean De Ceuvel: phytoextraction and phytodegradation combined with rhizodegradation. The first method is applied for the heavy metal extraction, while the second two are used for the breakdown of PAHs. Additionally, large water tubs are present for each building that filter the grey water from the building's sinks with the use of phytofiltration.

2.4.2 Design

The first design of plants in De Ceuvel was made based on phytoremediation theory and literature, combined with aesthetics and biodiversity. However, plants developed poorly because the soil was too dry, too fertile, and too little attention was paid to the plant's required location. Later, the design was left to be more natural, using a combination of plants that showed to work well and plants that spontaneously grew on the side (weeds like ground elder, cleavers and stinging nettle). Though this design is somewhat less park-like, it is far more functional. Moreover, analysis of the spontaneous occurring weeds did show that they take up metals as well, although they are no hyperaccumulators. This emphasizes the need to combine all aspects of plants (including requirements) for a successful design.

2.4.3 Time & cost

Five years after the start of the project, soil measurements showed no change in heavy metal pollution. However, the PAHs were degraded to just 70% of the original level, indicating that the removal of organic pollutants is easier then removing heavy metals.

There was little money to spend when setting up the project. Plants used were planted as young trees or seeds, costing a total of 200 euros a year. The location is managed by volunteers, resulting in 700 euros a year. Lastly, the soil was frequently tested, costing 600 euros a year. Concludingly, for small site remediation like De Ceuvel, phytoremediation can be cheap (1500 euros a year), excluding design costs and trees.

2.4.4 Biodiversity

No research has been done on the effect of phytoremediation on the biodiversity of De Ceuvel. However, a lot of species (both plant and animal) have been observed. The phytoremediative forest does not only contain a lot of different plants but also harbours many earth worms, woodlice, bees, different insects, birds, and even a hedgehog. Generally, the animals do not seem to be bothered by the pollution, but no data is available to accurately assess this. Thus, although biodiversity seems to be thriving, it remains unclear what the exact effect of phytoremediation is on the biodiversity.

2.4.5 Waste management

Plants grown on polluted ground are separated from the other green waste and stored in large bags outside – sheltered from rain. It is unclear how this waste should be treated, and therefore the plant material is shredded and stored until it becomes clear how to deal with it. The quantities of the waste are too small to use for phytomining and coorporation with other phytoremediative projects is needed.

2.4.6 Toxicity

Many plants in De Ceuvel are considered toxic due to the accumulated heavily metals in them. For this reason, De Ceuvel has elevated the path through the phytoremediative garden to separate visitors and workers from both the polluted soils and the polluted plants. The plants are not eaten and only come into contact with humans when the plants are replaced.

2.4.7 Concluding remarks

In conclusion, De Ceuvel shows how phytoremediation can be implemented in urban areas without a danger to humans and with a potentially positive effect on biodiversity. Again, the site-specificity is emphasized, even within a certain area. De Ceuvel also shows that PAHs can be remediated using phytoremediative parcs. However, this example also illustrated the difficulty in removing heavy metals: they need to be bioavailable, and their removal takes a lot of time. Concludingly, for every site, a plan can be made to improve soil and biodiversity, but not always to completely clean the soil.

3. The database

To help implementing phytoremediation in urban area, the database is available via http://www.clean-and-green.webnode.com.

This online database is accessible for all and consists of four parts: 1. A general explanation of phytoremediation and its use (like given in chapter 2); 2. An overview of all plants on general location with visual aid (photographs) and options to dive deeper into the plant; 3. An extensive filter which allows users to select their requirements and conditions and offers a list of plants that are suitable for their situation; 4. An option to share experiences with different pollutants or plants on an interactive platform with room for commenting and questions.

3.1 Background – The database set up

The database consists of a list of plant species, of which most are native. The database is divided into three sections: terrestrial, semi-aquatic and aquatic plants. For each species the following information is available:

- General information
    - Plant name (Scientific, English and Dutch)
    - Plant type (Tree, shrub, forb, grass)
- Phytoremediation
    - Contaminant (the contamination the plant can remove, e.g. cadmium)
    - Contamination type (e.g. heavy metal, PAH)
    - Method of phytoremediation (e.g. absorption, break down, stabilisation, …)
    - Removal rate (cleaning efficiency)
- General characteristics
    - Plant family
    - Rarity (is the plant common in the Netherlands)
    - Habitat type (the area where a certain species lives naturally, e.g. heathland, forest, grassland)
    - Life span (annual, biennial, perennial)
    - Plant size (hight*width)
    - Flowering period
    - Flower colour
    - Nectar production (indication of attractiveness to insects)
    - Host plant (which insects live from this plant)
    - Root system & rooting depth (taproot or fibrous roots + depth of function)
- Environment
    - Soil type (soils the plant can grow on, e.g. sand, clay)
    - Light (sunny or shady environment)
    - Nutrients (does the plant need fertilization)
    - Water (does the plant need watering or a wet area)
    - Native to the Netherlands
- Ecosystems services (e.g. shade, food, aesthetics, bio-based materials, pollination)
- Toxicity (for humans and animals/environment)
- Maintenance (need for pruning, mowing, replacing)
- Limitations (issues concerning plant maintenance or usage)

3.2 Implementation – How to use the database?

The online database can be used in one of four ways: 1. Learning more about phytoremediation and its implementation; 2. General orientation for plants with phytoremediative properties per location with the interactive database; 3. Filtering the database list for specific requirements; 4. Using the interactive platform to share experiences with different pollutants or plants or ask questions.

3.2.1 Background on phytoremediation

The information available in this manual can also be found on the website. General background on phytoremediation, the limitations and how to implement it, are given under 'Phytoremediation' [38].

3.2.2 Interactive database

For general orientation on phytoremediation and plants in urban area, the first option of the database should be used. This platform allows the user to select an area (water, water border, park, public location, residential area, gardens) and get a visual overview of all plants that are usable in that area.

Figure 3, Starting page of the interactive database. Selection of an area (in this case water) brings you to a visual overview of all plants in that area.

Following, each plant can be selected to learn more about the plant profile listing the specifics of each plant species. Also, the practical implementation and limitations of each plant are indicated here.

Figure 4, Selection of plant within certain location. Clicking on the plant (in this case Plantus aquarius) brings you to the plant profile with all available information.

3.2.3 Filters

When the specific project requirements are clear, the user should use the second option of the database: to filter the complete list of plants on different criteria. After selection of all relevant criteria for a project, a list of plants is given that are suitable for that project.

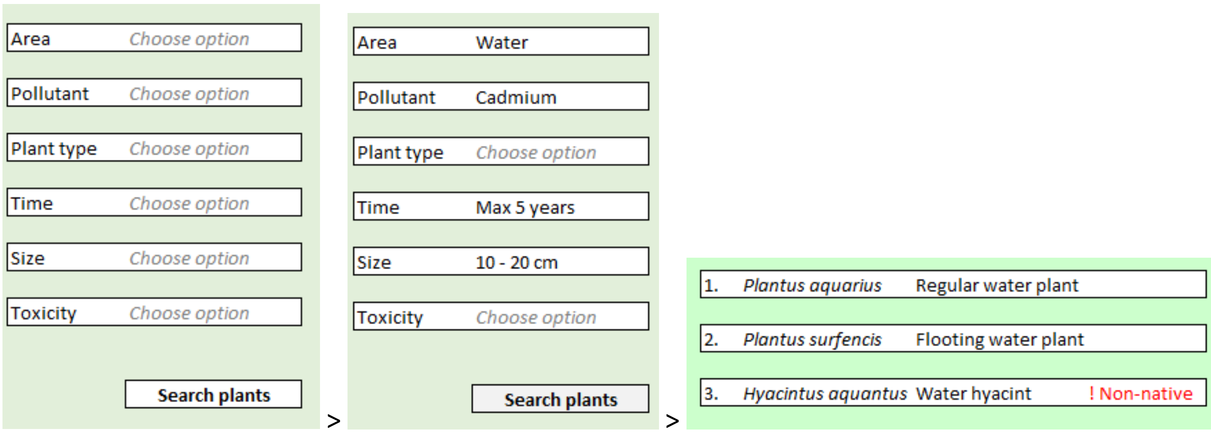


Figure 5, Selection of project specific criteria results in a list of plants suitable for the project.

For each plant, selecting the plant will redirect the user to the profile page of that plant species. This page is the same as the one from the interactive database.

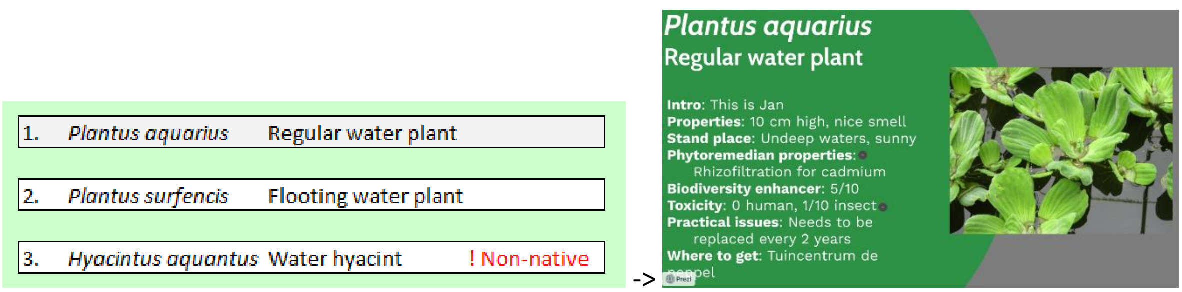


Figure 6, Selection of plant within certain location. Clicking on the plant (in this case Plantus aquarius) brings you to the plant profile with all available information.

3.2.4 Platform

The last way to use the database is via the interactive platform where everyone can share their experience with phytoremediation or ask questions about it. This platform will be in the form of posts like social media platforms. Additionally, filtering on post keywords is also possible. Useful information from the platform can be incorporated in the database list or background information. This allows a continues update of the database.

Final remarks

We hope this manual has increased your knowledge on plants in urban area and on phytoremediation. Moreover, we hope both the database and this manual have been useful for you to better include plants in your design for multiple purposes.

If you have questions, want to give your opinion on either the database or this manual, or if you want to participate in this ongoing project, do not hesitate to contact us.

Lastly, feel free to share your experience with plants or phytoremediation with us, so we can incorporate your story in this project.

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https://www.rainproof.nl/groen-secret-village
https://www.newyork.nl/gratis-in-new-york/central-park/

[2] Read more about the advantages of green in the city on: https://www.wur.nl/en/show-longread/Seven-Reasons-to-Invest-in-a-Green-City.htm

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