



## Evaluation of native plant species for sustainable phytoremediation of urban environmental pollution

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### Abstract

Rapid industrialization, urbanization, pollutants emission from vehicles and waste disposal problems are creating environmental pollution in cities which is a serious ecological and public health problem. The conventional remediation technologies are costly, energy consuming and environmentally disruptive, so sustainable and eco-friendly solutions need to be developed. The implementation of green technology phytoremediation, which involves the use of plants to remove, stabilize or eliminate contaminants from soil, water and air, represents a promising solution to combat pollution in urban environments. The purpose of this study is to assess the applicability of indigenous plant species to the sustainable treatment of pollution in urban environment. Being well adapted to the local environmental conditions, native plants have climatic, ecological tolerance, they are low maintenance and have a higher survival rate, thus making them good candidates for long term remediation programmes. The study aims to evaluate the pollutant accumulation capacity, tolerances, growth performance and ecological importance of selected native species in polluted urban habitats. Special attention is given to the elimination and stabilization of heavy metals, particulates, hydrocarbons and other pollutants from urban areas. The morphological, physiological and biochemical parameters are measured for the assessment of the phytoremediation efficiency and stress tolerance. The findings also emphasize the importance of native plants for enhancing urban biodiversity, ecological balance, beauty, and mitigating urban climate effects (e.g., urban heat islands). The results will help to identify efficient native species for phytoremediation, and will guide the design of sustainable urban green infrastructure and environmental restoration plans.

**Keywords:** Phytoremediation, native plant species, urban environmental pollution, sustainable remediation, heavy metal contamination

### Introduction

Urban environments are highly polluted ecosystems, where high levels of heavy metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), excess nutrients, and microplastics from vehicular pollution, industrial effluents, construction activities, and domestic effluents are present. These pollutants accumulate in urban topsoils, road adjacent sediments, and stormwater systems that have a negative impact on human health, groundwater quality and urban biodiversity. Suitable, but energy-consuming, expensive and disruptive conventional remediation technologies like excavation, soil washing, solidification and chemical oxidation are frequently effective, but are not applicable in densely built cities with limited land availability and high social sensitivity (Di Stasio & Regni, 2025)<sup>[1]</sup>. To the contrary, the nature based approach, phytoremediation, has been proven to be a promising solution in the removal of environmental pollutants by plants and microorganisms of their rhizosphere. Phytoremediation generally can be less expensive than engineered approaches with lower secondary waste production, and can be placed in urban green spaces to offer co-benefits including air quality improvement, stormwater retention, temperature regulation, and aesthetic enhancement. In this context, sustainable phytoremediation has gained more and more attention due to the use of species native to the local climatic, edaphic and disturbance

conditions. Native species are evolutionarily adapted to local soil types, water regimes, and biotic interactions, and often perform better than many exotic plants used for remediation in polluted urban environments in terms of survival, resilience, and long term performance (Sahoo *et al.*, 2025)<sup>[2]</sup>. Additionally, planting native plants will help provide habitat for local pollinators, birds and soil microbes, which will help reach broader urban biodiversity and ecosystem service goals. The paper critically assesses the potential of locally available plant species to address various types of urban environmental pollution, examines the major selection criteria, reviews empirical evidence, and explores several possible avenues for incorporating native plant phytoremediation into sustainable urban design and green infrastructure efforts (Kazemi & Mohorko, 2025)<sup>[3]</sup>.

### Processes, mechanisms, and urban relevance of Phytoremediation

#### 1. Core phytoremediation mechanisms

The term phytoremediation is used as a general term for several processes which utilize plants to remove contaminants, either in isolation or in combination, depending upon the specific contaminant, soil characteristics, and land use application. Phytoextraction (phytoaccumulation) is the ability of plants to absorb pollutants from soil or water and sequester them in the above-ground parts of the plants (shoots and leaves), which

can then be harvested and safely disposed of or processed, for example, via phytomining; when the plant species have high shoot to root concentration ratios and high biomass. Phytostabilization (phytoimmobilization) is a process that minimizes soil erosion and leaching of contaminants and/or adsorbs, precipitates or complexes contaminants in the root zone of plants in the area where the plants are growing and is most appropriate for situations in which it is not possible to remove all the contaminants and where efforts to prevent the downward migration of contaminants to ground water or movement by wind or water are the most important considerations (Pouresmaeli *et al.*, 2025) <sup>[4]</sup>. The plants degrade organic pollutants, including PAHs, PCBs, pesticides and petroleum hydrocarbons, into less toxic or completely mineralized compounds such as carbon dioxide and water, either using enzymes they produce or microbial communities in the rhizosphere that are stimulated by root exudates (enzymes) (phytodegradation or phytodestruction). Rhizofiltration is the ability of plant roots to absorb or adsorb dissolved pollutants from contaminated water or leachate, and this method is often used in constructed wetlands or riparian buffer zones, particularly for the treatment of urban stormwater, wastewater overflow channels and contaminated surface waters. Finally, certain plants are able to absorb volatile pollutants (some organic compounds or metalloids, such as selenium) and release them to the atmosphere, in a modified form and normally in a less harmful form, thus reducing the pollutant level in the soil; this can be used as a tool in risk assessment since it can lead to the transfer of pollutants from soil to air (Geeta & Chaudhary, 2024) <sup>[5]</sup>. These mechanisms can be integrated to improve the remediation effectiveness and the resilience in complicated urban contaminant mixtures by carefully selecting mixed species plant communities with complementary traits by selecting some species producing metal extractants, some species stabilizing and metalizing, and others producing organic pollutant degraders (Di Stasio & Regni, 2025) <sup>[11]</sup>.

## 2. Pollution in urban environments and its problems

Remediation in urban areas is a special case. Heavy metal soils often have multiple contaminant profiles, including heavy metals associated with traffic (including brake linings and tire wear), industrial activities, and construction sources, and organic pollutants from fuel spills, industrial effluents and impervious sealed surfaces. Meanwhile, pollutant concentrations can be very unevenly distributed, increasing significantly over short distances, such as being much higher near roads, industrial areas, or stormwater discharge points. Furthermore, the feasibility of deep excavation or large scale engineered interventions is limited due to the constraints of limited space and infrastructure including densely built form, underground utility networks, and buried services (Koç *et al.*, 2026) <sup>[8]</sup>.

### Advantages of using native plant species

#### 1. Ecological and evolutionary suitability

Native species have adapted to the climatic, soil and biological conditions of the local environment; often they have several advantages over introduced (exotic) species. Native plants often have more tolerance for local and seasonal rainfall, temperature, and drought conditions, and do not need the same amount of special protection in urban situations, which makes them more cost-effective and

durable in the long term. They also demonstrate good soil compatibility, being often well adapted to local soils like red or lateritic soils in the tropics, sandy or saline soils in coastal cities, and arid soils in desert urban interfaces, thus achieving high establishment success and long-term persistence in disturbed and marginal urban soils (Acharya *et al.*, 2023) <sup>[9]</sup>.

#### 2. Pollution tolerance traits

A number of studies have shown that species found in disturbed or marginal habitats (e.g., arid habitats, soils affected by mines, roadside corridors) are remarkably tolerant to a variety of pollutants. Roadside soil adjacent to high traffic urban corridors has been found to contain higher concentrations of heavy metals than non-urban areas, and native desert grasses and shrubs can accumulate heavy metals in the soil, and in some instances, translocate them, suggesting their ability to take up and in some instances translocate traffic derived contaminants (Alzeyadi *et al.*, 2022) <sup>[10]</sup>. Native plants such as *Salsola* spp., *Aeluropus litoralis*, and *Limonium delicatulum* have been shown to stabilize or remove metal(loid)s in mine affected or metal-contaminated areas, including urban brownfields and other industrial sites degraded by metals, and thus have promise for use in metal-contaminated sites. The use of native riparian and wetland plants (including many sedges, rushes and grasses) in constructed wetlands to remove heavy metals, excess nutrients and suspended solids from urban stormwater and wastewater is another example of their value in improving water quality. The overall results confirm that native species not only meet ecological requirements for a particular area, but are also able to effectively reduce a combination of pollutants commonly associated with urban areas (Amogha *et al.*, 2023) <sup>[11]</sup>.

#### 3. Reduce maintenance and threat from invasion




In some cases, exotic remediation plants, such as some hyperaccumulator species or fast growing grasses, are seen to be superior to native plants in short-term biomass production or metal uptake, and may thus be attractive for use in rapid remediation. They also have major disadvantages, such as high water and nutrient needs, especially in non-native climate settings, which can drive up maintenance costs and strain local resources. As well, exotic species can be invasive, outcompete native plants and cause damage to native ecosystems where they are planted and in the surrounding areas. On the other hand, native species, once established, will typically need less irrigation, fertilizer and pest control, lowering long term operating expenses and the environmental impact of the remediation system. Native species are ecologically safer options for sustainable phytoremediation in urban areas as they are already part of the regional flora, and more likely to remain under cultivation instead of escaping cultivation and becoming invasive outside the target area (Boi *et al.*, 2022) <sup>[12]</sup>.

#### 4. Nature-based solutions that deliver benefits for biodiversity and ecosystem services

In addition to their remediation properties, native plants deliver a variety of co benefits that are relevant to urban ecosystems. They attract diverse pollinators, including bees and butterflies, birds and other animals, and help counter biodiversity loss and restore ecological connections in a fragmented city setting. Native vegetation can also help

reduce urban heat island effects and enhance outdoor thermal comfort for residents by providing shading and regulating temperature through water loss through evapotranspiration. Native plants also will promote soil structure, infiltration and erosion prevention, especially in compacted and degraded urban soils, where there is a risk of

runoff and waterlogging. They collectively highlight the fact that native plant phytoremediation is not only a pollution control tool but a multifunctional aspect of a sustainable urban design, encompassing environmental restoration, climate adaptation and social wellbeing (Asante-Badu *et al.*, 2024)<sup>[13]</sup>.

Characteristic	Ecological & Evolutionary Suitability	Pollution Tolerance Traits	Reduced Maintenance & Invasion Threat	Biodiversity & Ecosystem Services
 <b>Adaptation</b>	Adapted to local conditions	Tolerant to pollutants	Less irrigation and fertilizer	Attracts pollinators and wildlife
 <b>Rainfall/Drought</b>	Tolerant to local rainfall	Accumulates heavy metals	Less pest control	Reduces urban heat island effect
 <b>Soil Compatibility</b>	Well-adapted to local soils	Stabilizes or removes metal(loid)s	Ecologically safer	Promotes soil structure and infiltration
 <b>Cost-Effectiveness</b>	More cost-effective in the long term	Improves water quality	Sustainable phytoremediation	Multifunctional aspect of sustainable urban design

**Fig 1:** Advantages of Native Plant Species

### Evaluation criteria for selecting native species

There are criteria to consider when deciding on which native species to use.

#### 1. Tolerating the pollutants and survival ability

The first is that the plant is not severely toxic (e.g., chlorosis, necrosis, stunted growth) in the presence of the target pollutants. For example, species that are used for roadside remediation should be capable of coping with higher concentrations of traffic-related metals, such as lead, zinc, cadmium, and others, as well as physical stresses like road side compaction and dust. Species are often screened for tolerance using laboratory and field trials that measure growth parameters (shoot height, biomass, leaf area), physiological parameters (photosynthetic rate, chlorophyll content) and stress related markers (malondialdehyde, activity of antioxidant enzymes) (Hou *et al.*, 2022)<sup>[14]</sup>.

#### 2. Capacity for accumulation and efficiency in remediation

In phytoextraction, the plant performance is assessed by a number of key metrics. The bioaccumulation factor (BAF) relates the concentration of a pollutant in a plant to the concentration in the soil, and indicates the efficiency with which a plant can absorb pollutants from the environment. The translocation factor (TF) is the ratio of metal content of shoots to metal content of the roots, indicating the ability of plants to translocate bound-up metals to the above-ground parts, which are usually harvested. The phytoextractor species with high BAF and TF values for the relevant metal are usually selected so as to extract the maximum amount of contaminant from the site by removing the plants periodically (Geeta & Chaudhary, 2024)<sup>[5]</sup>. For phytostabilization, however, plants with deep root zone metal retention and low translocation to the shoots would have better characteristics, as they would trap the metal in or near the roots and reduce the possible pathway of metal uptake into the food chain or human exposure.

#### 3. Growth rate, biomass and harvestability

The remediation time can be greatly reduced and more contaminant per unit area per year can be removed by fast growing species with high biomass production. The grasses, willows, poplars and a few shrubs are commonly used in phytoremediation trials as being rapid-growing and good metal sorters. In urban areas, however, height or boisterous growth may not be compatible with infrastructure, sightlines or maintenance requirements so local design criteria must be considered (Asante-Badu *et al.*, 2024)<sup>[13]</sup>.

### Case examples of native-plant phytoremediation in urban contexts

#### 1. Native plants along highways and roadsides

In arid and semi arid cities, study has shown that planting native grasses and shrubs along roadways can help decrease the level of metals in the soil that surrounds the highway. In contrast, desert plants like *Pennisetum divisum* or *Tetraena qatarensis* demonstrated high metal absorption and tolerance, which can make them a good choice for stability and/or extraction of traffic related metals. Native plantings of *Salvia mellifera* (black sage), *Salvia apiana* (white sage), *Eschscholzia californica* (California poppy), and other native grasses are installed along roadways to restore nature, while also acting as a filter to reduce pollutants in road runoff (Hou *et al.*, 2022)<sup>[14]</sup>.

#### 2. Native plants of soils impacted by mining and brownfields

Studies of native vegetation in mine-affected soils have found several species that are tolerant of the metals and can be adapted to urban brownfields conditions. Saline or metal rich soil colonizers such as *Salsola* spp., *Aeluropus litoralis*, and *Limonium delicatulum* have been shown to have the capacity to sequester and/or accumulate metal(loid)s including zinc, copper, and arsenic. Native species can be used to stabilize the soils, deter dust and over time decrease the bioavailability of metals on urban brownfields which are

defined as former industrial sites, landfills, and contaminated construction lots (Pouresmaiehi *et al.*, 2025) [4].

### 3. Native plant constructed wetlands and bioswales

Native riparian and wetland plants are increasingly used in constructed wetlands and bioswales for the treatment of urban stormwater and wastewater effluents. These systems may feature native sedges, rushes, grasses and small shrubs that act to trap suspended solids, bind heavy metals, and facilitate microbial breakdown of organic pollutants. Native plant wetlands or riparian buffers have been established in many cities within parks, along drainage channels, and at the edge of stormwater retention ponds, improving water quality as well as providing habitat for aquatic and semi aquatic species (Samir *et al.*, 2023) [6].

#### Implementation in sustainable urban green infrastructure

The use of native plant phytoremediation is most effective when integrated within a larger urban planning and urban green infrastructure framework—rather than as a stand-alone restoration method. Roadside green belts and bioswales planted with native grasses and shrubs are one such potential pathway of integration that filters and captures pollutants from the roadway, including hydrocarbons and heavy metals, before they reach storm drains or surface waters, and which is used to stabilize soils and improve the roadside appearance. In urban parks and green spaces, through the careful design of native plant assemblages, multiple benefits can be gained, such as recreational opportunities, microclimate cooling through shading and evapotranspiration, and gradual removal or immobilization of soil and air pollutants, and thus, transform passive green spaces into active remediation zones. Native metal tolerant plants can be planted at the start of brownfields redevelopment to stabilize contaminated soils, minimize erosion/dust, and start the process of gradual soil clean up, allowing for safe redevelopment without extensive excavation or chemicals (Hou *et al.*, 2022) [14]. Further, green roofs and walls with native succulents, grasses, or small shrubs can also help to reduce air pollution deposition, enhance building energy efficiency, and help to retain storm water, while having relatively low maintenance demands compared to engineered green roofs and walls. These systems can be linked to modern smart city tools like sensors that measure soil moisture, temperature, pollutant levels, and vegetation cover to monitor changes in the effectiveness of native plant phytoremediation over time and for use in adaptive management. Meanwhile, citizen science projects can help to increase the scope of monitoring and improve community ownership, by involving local residents in the maintenance of native plants, data recording, and pollution awareness raising, promoting the social and ecological sustainability of native plant based remediation in urban environments (Asante-Badu *et al.*, 2024) [13].

#### Challenges, limitations, and sustainability considerations

Even though native plant phytoremediation has a number of benefits, there are a number of challenges to overcome in order to be sustainable in the long run. Time scale is one major disadvantage; phytoremediation is usually slower than conventional methods, with significant decreases in concentrations of contaminants or pollutants often taking

years to decades depending on the type of contaminant and its depth in the soil. Other are contaminant specificity, that is, some of the native species are effective against certain metals or organics, but not against others, so mixed species or polyculture plantings need to be designed to address the complex mix of contaminants common in urban settings. Another challenge is the disposal of contaminated biomass, as biomass collected from metal-rich sites needs to be collected, transported and processed safely (e.g. by incineration, secure landfilling, phytomining etc.), to avoid secondary pollution and protect human and environmental health. Lastly, however, even native plants can be placed under stress by climate change and urban stress (increased temperature, more frequent droughts, more severe heat island effects, and unpredictable rainfall), if not carefully selected and matched to site conditions, and if their growth and ability to remove pollutants and withstand stresses over time is affected (Boi *et al.*, 2022) [12]. Microbial inoculation with plant growth promoting rhizobacteria and mycorrhizal fungi to improve nutrient uptake and stress tolerance and pollutant degradation in the native plants, and to enhance the speed and reliability of native plant uptake and removal of pollutants in urban landscapes; and the combined use of native plants with soil amendments (organic matter, biochar, lime, phosphate) to improve soil structure, nutrient availability, and pollutant bioavailability (Amogha *et al.*, 2023) [11].

#### Conclusion

Overall, native plants have great potential in the field of sustainable phytoremediation of urban environmental pollution owing to their ecological adaptability, resilience and pollutant tolerance. They can absorb, accumulate, stabilize or degrade a wide variety of contaminants, making them an environmentally friendly and cost-effective alternative to traditional remediation methods. Evaluation of native species reveals that not only does phytoremediation help to remove heavy metals, particulate matter and other urban pollutants, it also improves the biodiversity, ecological stability and environmental quality of the urban habitat. In addition, locally adapted vegetation helps to ensure long-term sustainability by minimising maintenance needs and enhancing survival rates in the climatic conditions of the region. Therefore, the use of native plants as phytoremediator in urban environment can be a key part of environmental rehabilitation, green infrastructure and climate resilience. Further research on efficiency of remediation, physiological adaptation and field level application of phytoremediation will further bolster the implementation of phytoremediation as a long-term solution to urban environmental pollution.

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