**Constructed Technosols**

*Subjects: Environmental Sciences*

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### Definition

Constructed Technosols means the creation of soils designed to mimic natural soil and suitable for vegetation growth.

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**1. Introduction**

According to the World Reference Base for Soil Resources (WRB) [1], Technosols include soils whose properties and pedogenesis are dominated by their technical origin. They contain a significant amount of artefacts (something in the soil recognizably made or strongly altered by humans or extracted from greater depths) or are sealed by technic hard material (hard material created by humans, having properties unlike natural rock) or contain a geomembrane. They include soils from wastes (landfills, sludge, cinders, mine spoils, and ashes), pavements with their underlying unconsolidated materials, soils with geomembranes and constructed soils.

In recent years, some pedological engineering studies [2][3] showed the ad hoc construction of Technosols (thus the punctual formulation of soils with the correct physical and chemical parameters for the studied or remediated site) as a potential solution for restoration of mined lands and urban greening.

Usually, the demand for restoration of brownfields, dismissed sites, and polluted areas has been met with the development of remediation techniques designed to remove or immobilize the contaminants from the soil. These techniques, although often efficient, are usually very expensive, favoring the removal of the contaminated soil and its replacement with clean soil or soil material. To avoid the use of soil excavated from uncontaminated areas for this purpose, appropriate purpose-designed Technosols have been constructed to be placed on the affected site. These constructed soils are intended to be fertile substrates for plant growth even if their composition is sometimes far from the ideal.

In the urban areas of the developed countries, the demand for green areas is increasing; this is due in part to a change in the way of living and expectations of urban dwellers and in part to the reduction of the industrial framework that left large, dismissed areas behind [4]. If, on the one hand, extensive areas with poor-quality soils are available, on the other hand city transformations produce large amounts of excavated materials—e.g., from the construction of underground lines—that must be disposed of. In addition, more and more frequently municipal organic waste is collected to be recycled as compost. The import of fertile agricultural soil from surrounding areas is becoming less and less feasible from many points of view: agronomic, environmental, and economic. In view of the necessary ecological transition [5], constructed soils appear to be an attractive and modern solution to respond to the urgent request of green areas within the urban fabric, with the aim to obtain a suitable substrate for plant growth [6]. Such solutions are currently studied worldwide; for example, in Roubaix (France) an experimental plot with constructed soils has been placed inside the “Ecoquartier de l’Union” [7], while in New York (USA) technosols made from waste have been tested to be used for urban gardening [8]. In the near future, the development of good quality soils for horticulture in urban spaces may lead to the realization of cultivated urban areas intended for providing food supplies for citizens [9].

**2. Designing Technosols**

Soil is a dynamic and constantly evolving system. This extremely complex matrix, in which lithosphere, hydrosphere, atmosphere, and biosphere interact, requires continuous and long-term monitoring. There is no unique “recipe” for constructed technosols, but many studies in the literature [10] have aimed to obtain a suitable formulation that is obviously similar to the composition of a natural soil: a structural, inorganic material and an organic material in various proportions [11][12].
A suitable formulation for the construction of a technosol would depend on many variables: (i) the problem to be tackled, as the area to be recovered can have remnants of previous activities such as contamination, rubbles, compaction; (ii) the final aim of the intervention, such as an urban green area or the remediation of a mining site; (iii) the local availability of materials; and finally (iv) the envisaged timespan of the project.

Several materials can be used to construct a technosol (Table 1), but they must show an adequate capability to support plant growth, usually in addition to other components. In recent years, different materials have been investigated to identify their suitability in terms of cost and performance \cite{10}, from natural substrates such as coffee grounds \cite{13} to man-made recycled materials like concrete \cite{14}. Some of these materials have already been used as growing media to support containerized plant production and in the creation of green roofs, e.g., a mixture of coco peat and perlite \cite{13}, heat expanded shale, slate or clay \cite{16}, mineral wool, vermiculite and volcanic rocks. In Europe peat moss is mainly used, often in mixtures with barks, sand, wood products, volcanic products, compost, and manures \cite{17}\cite{18}. Unfortunately, very often, the energetic costs and environmental impacts of the production of these materials make their use scarcely convenient.

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<tr>
<th>Waste</th>
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<tr>
<td>Inorganic waste materials</td>
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<td>Construction and Demolition Waste</td>
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<td>Excavated subsoil</td>
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<td>Bricks</td>
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<td>Concrete waste</td>
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<td>Dredged sediment</td>
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<td>Residual sludge from stone processing</td>
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<td>Mining wastes and tailings</td>
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<td>Organic waste materials</td>
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<td>Compost from urban bio-wastes (food and garden)</td>
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<td>Compost from sewage sludge</td>
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<td>Anaerobic digestate from bio-waste and sewage sludge</td>
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<td>Anaerobic digestate from agriculture and farms</td>
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<td>Green wastes</td>
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<td>Paper mill sludge</td>
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<td>Biochar</td>
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<td>Coffee grounds</td>
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The use of alternative materials, such as recycled waste, could lessen the environmental impact of substrate accomplishment. Some of these materials are bricks \cite{29}\cite{30}\cite{31}, construction and demolition waste material (Figure 1) \cite{31}\cite{32}\cite{33}, crushed porcelain and foamed glass \cite{34}, recycled glass \cite{35}, concrete \cite{36}, clay and sewage sludge, paper ash, carbonated limestone \cite{32}, and sieved waste \cite{37}.
It is fundamental to choose components properly, paying particular attention to the destination of the constructed Technosol: a park in the inner city would require a high global quality whereas, in the restoration of an abandoned mining area, a lesser soil performance might be acceptable. The same holds for the plants expected to host: pioneer, low-demanding plants can be used if a low soil quality is obtained in relation to the availability of materials.

The capacity of the substrate to fulfil soil functions is affected by local conditions, such as the climate, the surroundings surfaces, and the soil use, thus an appropriate design of the Technosol must be pursued. For example, a zone with high precipitation intensity requires a soil with a sandy texture to provide adequate water drainage and to avoid stagnation, flooding, and run-off. On the other hand, if the soil has a very low available water capacity, it can be improved adding porous additives able to increase the hydraulic conductivity, such as the geogenic coarse porous materials (CPMs). The CPMs are widely used as mineral components for constructed substrates. They derive from natural geological processes, and in most cases, they need to be simply crushed before use; the great availability and low contamination make them a good choice in soil design. Some commercialized CPMs are porlith, tuff, pumice, expanded clay, perlite, and expanded shale mixed in appropriate ratio with sand or silt. These materials have good porosity, lightweight, moderate values of pH, and large grain sizes. Thanks to these properties and their structural stability, they can be added to pure quartz sand or to sandy soils in order to enhance their water retention capacity. Flores-Ramirez et al. tested various commonly used CPMs to establish the best additive for constructed soils in formulation with sand in ratio CPM:sand of 1:4. Four of the six investigated CPMs (pumice, expanded clay, perlite, and expanded shale) showed low retaining water enhancement, whereas only porlith and, to a lesser extent, tuff increased the available water capacity of sand. The authors suggested an appropriate choice of materials considering the specific purpose, environment and climate conditions and the use of these CPMs in high mixing ratios with sand. Moreover, the use of silt instead of sand, combined with organic matter, increases the water retention capacity of these soils. As regards pumice, a study conducted by Gunnlaugsson and Adalsteinsson attested the low water-holding capacity of this material, suggesting its use in water beds with a water reservoir at the bottom. Despite its water retention properties, pumice is a cheap alternative with a good chemical buffering capacity, that can be easily cleaned and reused, and it has already been successfully employed in horticulture.

Other categories of studied materials to be used in constructed technosols are silicate-based additives. Not many researches have been made on it, but they have been already widely used to improve the water retention of golf courses and vegetable gardens in arid regions. As an example, using this material with sandy soils, the study of Hosseini et al. proved its benefits to increase root biomass of olive seedling
by 50% while halving the irrigation frequency [39]. Hydrogels have been also investigated for their use for agricultural, horticultural, and forestry applications in arid regions [39]. They have shown positive effects in reducing irrigation needs [40], increasing the survival of transplanted seedlings [41][42] and of roots under short-term desiccation [43] in reforestation actions.

Biochar and hydrochar are also used to enhance water retention properties of sandy soils, while they also favor carbon sequestration. Several studies have observed an increase in nutrient content and water availability and a reduction of bulk density with the addition of biochar to sandy soils [30][44][45][46][47][48].

The most important benefit of organic components is the input of organic matter that can be readily decomposable or stable, promoting immediate or long-term effects. Organic matter enhances physical, chemical, and biological properties of the soil as it hosts and promotes the development of a consistent microbial biomass and the subsequent cycling of elements [49]. Organic materials used as soil amendments are manure, compost, wood and crop residues, pulp and paper mill sludge and food processing waste. Large addition of these organic amendments may favor the initial reclamation of the soil in a green area and lead to a self-sustaining ecosystem [49]. Furthermore, they can adsorb or foster the degradation (through the development of microbial biomass) of some contaminants promoting the soil restoration and reducing soil hazard.

3. Conclusions

The construction of artificial soils with recycled wastes or by-products has proven to be the most sustainable choice for the development of constructed technosols in view of the circular economy approach. Considering the case-specific needs they appear also as a possible solution to the problems of land degradation and urban green as they can be an alternative to the remediation of contaminated sites and to importing fertile agricultural soil. However, the use of wastes requires analysis to ensure that the starting materials are not contaminated excluding toxic effects for plants growth and living being’s health. In this framework, tools such as the Clean Soil Bank of New York or the local management of sediments recycling can be very useful. Constructed technosols made with materials produced on site or nearby to urban green areas minimize the cost and environmental impact of transport. For this reason, the involvement of local stakeholders in the urban land management must be encouraged.

These artificial soils demonstrated their capability of supporting plant growth as they have been shown to be as fertile as natural soils or more. However, it is necessary to carry out further in-field studies to obtain the most suitable formulations considering the intended use of the Technosol and the plant species that will grow there.

Evidence from the available literature points to the need to consider a number of variables in the adequate design of a constructed technosol. Considering the scope of the project, the state of the area, the availability of materials demand for an iterative process of testing different solutions toward the optimal recovery of a degraded area. It cannot be excluded that the final result would be different from what expected after due consideration of the variables involved.

References


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**Keywords**

constructed soils;land degradation;remediation;waste recycling;organic biowastes

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