Properties of Technogenous Substrates and Assessment of their Suitability for Recultivation – Technosol Development Projection

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Summary

Soil damage comes as a result of various types of soil utilization in regard to its technical functions, and during that, huge quantities of various waste materials form (industrial, communal, mines, etc.). Such materials cover up vast land areas, which lead to a significant reduction of land fund. It is essential to identify the ways and appropriate measures for transforming such areas into the areas suitable for any environmental functions. While executing these measures, various materials are identified as technogenous substrates. When it comes to conducting the rehabilitation measures, it is important to have a good knowledge of the substrate properties, both general and specific. The general ones include: pH reaction, content of $CaCO_3$, physiologically active calcium (CaO), organic matter, texture, content of skeleton. The specific properties encompass: heavy metals content, biological infection and radioactivity of the soil.

This paper identifies seven basic groups of technogenous substrates: suitable, medium suitable, less suitable, unsuitable, very unsuitable - toxic, infectious and radioactive. The actions for the application of direct or indirect recultivation are developed by the subject groups. Direct recultivation includes the actions of immediate execution of rehabilitation measures, while indirect recultivation includes the application of a special layer of soil (suitable geological material or natural soil). It also provides the appropriate depths of such materials for the corresponding technical substrate. The paper's attention is focused on the follow-up of the impact of pedo-technogenous factors on the processes within the established disposal sites. Therefore, further elaboration and classification of technogenous soils continues to be important.

The paper also provides a projection of development of technogenous soils that encompasses three different substrates: natural geological substrate, industrial waste, and communal waste, outlining specific developmental stages, as well as morphological denotation of the profiles, with stated monocyclic and two-layer profile composition.

Key words

recultivation, technogenous substrates, pedo-technogenous factors, classification

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Introduction

The soil and land damaging processes have already affected significant areas and their expansion is rapid. This is a result of an increasing population growth, requirements in various raw materials, development of settlements, development of industry, road construction, exploitation of various minerals and organic matter, disposal of various waste materials, incidence of fire sites, erosions and landslides, as well as non-economical utilization of land in agricultural production. All these have led and continue to lead to a growing number of damage causes and their effects. Such events disrupt the basic soil functions, i.e. its ecological functions, causing increased use of soil in terms of its technical functions. Destruction of natural soil and accumulation of huge quantities of waste materials that should serve as a substrate in creation of new soil formations, represent one of the consequences of such activities.

This presentation will address just one aspect of such effects based on the utilization of various waste materials, i.e. possibility of land recovery and return to its major ecological function - plant production.

The paper addresses the following issues:

- effects of soil damages,
- technogenous substrates and assessment of their suitability for recultivation,
- technogenous soils – classification and position within the classification,
- prognosis of technogenous soils development and establishment of new developmental systematic units.

Aspects and effects of soil and land damages

When it comes to the soil damage causes, majority of them are related to exploitation of various ores and disposal of waste materials on arable land. These waste disposal sites cause soil damages through a number of processes, which includes biological contamination (infection) – chemical contamination – physical destruction of soil, which lead to the exclusion of such soils from agricultural production.

The most common waste materials include: overburden materials formed due to surface mining of various ores, communal waste (garbage), industrial waste (fly ash, slag, red mud, etc.), metal waste, medicinal and pharmaceutical waste materials, electrical and radioactive waste, packing materials etc.

Technogenous substrates and their suitability for re-cultivation

Within the scope of new soil formations, a special place belongs to technogenous substrates. These substrates, by their origin and influence on the soil formation processes, are specific in comparison to the substrates having a key role as pedogenetic factors in formation of natural soils.

Unlike natural geological substrates, the technogenous substrates can be differentiated by:

- origin,
- properties,
- way of use,
- participation in the solid soil formation phase;
- with regard to the origin they could be: natural-geological substrates – various waste materials, industrial, communal, etc.;
- according to the properties, they range from favorable to extremely unfavorable, as well as very toxic;
- according to the way of use, there are two options: direct and indirect cultivation;
- according to the participation in solid phase, they vary within the range of two extremes, i.e. from full participation to its complete absence.

The technogenous materials that are being formed during various utilizations of soil in terms of their technogenous functions raise the issue of how and with what actions these destroyed soil formations could again be made suitable for agricultural production. The array of actions used to achieve this are called recultivation actions. During the recultivation process, huge changes take place in terms of the properties of new soil formations. This process could also be referred to as anthropogenization.

The process of anthropogenization leads to change of properties and way of use of these formations. As a result of the anthropogenization processes, this class of technogenous soils can be called anthropogenic-technogenous.

The following table provides an overview of various technogenous substrates and their role in the implementation of recultivation actions (Table 1).

Table 1. Technogenous substrates

Origin	Substrate	Suitability for recultivation
Loose natural rocks, carbonate and silicate	Loes and loeslike substrates, sand marl sand loam	Very suitable
Building waste	Brick, mortar, rubble	Suitable
Industrial waste	Fly ash, slug, red mud	Unsuitable
Communal waste, packaging material	Garbage, plastic, wood, glass	Unsuitable infectious
Other types of waste	Medical waste, pharmaceutical waste, packaging waste, metal waste	Very unsuitable
Radio-active waste	From industry, medicine	Dangerous

The basic meaning of technogenous substrates and their role in the implementation of recultivation actions can be classified in four groups:

- suitable for direct re-cultivation,
- only indirect re-cultivation is possible,
- extremely unsuitable, i.e. toxic, and
- dangerous.

While considering the issues related to the properties, development and particularly the implementation of recultivation actions, it is extremely important to have a good knowledge of the properties of technogenous substrates.

The technogenous substrates imply that their origin is related to urban, industrial and mining activities. The role of such substrates in the process of formation of new soil is either active or passive.

They play the active role in the sense of direct influence on the formation of new soil. The recultivation actions used in this case are direct.

Their passive role is reflected in the fact that such substrates cannot be used directly in recultivation. The reason for the inability to use them directly lies in the presence of harmful components. These primarily include the following: heavy metals, parasites and radiation. Over the time, their role declines, i.e. through the application of decontamination, detoxification and leaching processes they are being turned into possibly usable.

The listed technogenous substrates can further be divided in three basic groups, as follows:

- very suitable substrates for direct recultivation,
- unsuitable substrates – only indirect recultivation is possible, and
- infectious and toxic substrates – dangerous (risky), only indirect recultivation is possible.

By implementing the recultivation, there are two options, as follows:

- direct recultivation,
- indirect recultivation.

The group of favorable substrates includes those which form the overburden in the process of mineral exploitation (coal, bauxite, iron ore, etc.). These include: materials, fragmented silicate materials, limestone dolomite materials and sands. However, they may include more or less favorable substrates. The sandy substrates are favorable, whereas clayey and very skeletal are unfavorable.

The unfavorable substrates encompass the materials where only indirect recultivation is possible. These include majority of industrial waste materials (such as fly ashes, slug, red mud, etc.), as well as communal waste, packaging materials, etc.

While evaluating the suitability of each individual material it is very important to have a good knowledge of their chemical, biological and physical properties. For example, some materials containing more than 30% clay particles (< 2 μm) and sandy ones with more than 50% sand particles (2.0-0.02 mm) are unfavorable.

From the aspect of unfavorable technogenous substrates, it is necessary to research the following:

- content of heavy metals and organic pollutants,
- presence of radioactivity,
- parasite infection.

Larger fragments of geological substrate (huge stone blocks, especially in quarries) can also be included in the group of substrates unsuitable for recultivation.

Direct recultivation represents a measure performed directly on the surface of the overburden materials. Such technogenous layers from natural and geological materials may be either:

- uniform, i.e. of same geological material; or
- mixed, i.e. composed of several types of geological materials.

Therefore, it is very important to know the composition and properties of such technogenous layers.

Tehnogenous soils – technosols, anthropogenic-tehnogenous soils

The term technogenous soil implies the new formations created on technogenous substrates. These substrates can have a bigger or lesser influence on technogenous soils. The technogenous soils differ from anthropological soils primarily by their genesis. Namely, the anthropogenic soils are being formed due to anthropogenic activities and changes deriving from such activities. Generally, soil undergoes through bigger or lesser changes of properties that normally occur *in situ*. Within the soil systematic, technogenous soils are included into a specific class named technogenous class, or anthropogenic-technogenous class.

As a result of various causes resulting in a distinctive change of natural soil properties and their genesis, some new soil formations have formed. These newly formed soils are specific for their specific properties, processes, morphology and represent entirely new formations. Currently, they are included in technosols as a part of a separate class referred to as technogenous class. Additionally, in utilization, morphology and denotation of individual layers, the symbols used differ from those used in case of natural soils.

Table 2 provides a list of the newly formed soils. Specific symbols, such as Y, yY etc., are used in denoting specific layers.

Grouping such soils into a separate class is important not only from the genetic point of view, but also in terms of rehabilitation and revitalization measures, i.e. restoration of their lost ecological functions. The new formations that are formed through evolution and their proper naming raise a separate issue.

Table 2. Classes of technogenous soils

Name of formed unit	Origin
1. Deposol	Various overburden materials
2. Recultisol	Re-cultivated deposol
3. Cinerosol	Soil on fly ash and slug
4. Rhodic technosol	Soil on red mud
5. Garbisol	Soil on communal waste
6. Pyrosol	Burnt soils
7. Necrosol	Soil on cemeteries
8. Urbisol	Soils of urban areas
9. Technogenous colluviums	Soils on quarry materials
10. Indoor soils	Green house soils

The listed types of this class also could be included in pedosystematic units lower than type, i.e. sub-classes, variety. Some specific properties such as: toxicity, infectivity, presence of artifacts, etc., could be involved here as well.

Technosol techno-pedogenetic projection and establishment of separate systematic units

In to-date research, the focus was on the first phase, i.e. genesis of various soils on various technogenous substrates. Their chemical and physical properties, and later the biological as well, were studied.

Further interest was focused on how to name these new formations, as they have never been defined in previous classifications. The new formations were originally included in technogenious soils, i.e. technosols. In this domain, there were initially three basic groups: urban soils – industrial soils – mining soils. In further development of this domain, it was separated as individual class, i.e. class of technogenous soils. This class encompasses certain systemic units at the type level as well. This classification is generally based on technogenous substrate. This class of technogenous soils has 10 pedo-systemic units, listed in Table 2.

Kuntze et al. (1994), while addressing the technogenous substrates are referring to them as artificial substrates. They list a total of eight different categories, such as: construction site rubble, fly ash, slug, etc.

Blume et al. (2010) also include construction site rubble, fly ash and slug in technogenous substrates.

Sobocka et al. (2001) consider various technogenous substrates that include: communal waste, overburden disposal sites formed in superficial exploitation of various ores, industrial waste, etc.

Burghardt (2001) speaks about technogenous substrates such as numerous altered natural substrates (autoliths) and man-produced waste materials (technoliths) such as rubber, fly ash, slug, silt, etc., as well as solid materials – (ecranolith) and alike. In denotation of technosols he uses affixes, prefixes and suffixes. He also defines technosols as the soils containing more than 20% of artifact volume up to the depth of 100 cm, or with artificial, barely permeable geo-membrane or matter of 5 cm of technically hard rock.

Another issue related to these soils pertains to the direction of the process of their development, i.e. pedo-genetic factors, as well as direction of their further evolution. The predominant factor here is technogenous substrate, actually its properties. Among the technogenous substrates we have distinguished three as extremely important, as follows:

- with only one or several types of geological substrates present, i.e. where they are either uniform or mixed, and soil evolution is similar to the one in natural soils,
- evolution of soil on industrial waste,
- evolution of soil on communal waste.

When it comes to the issue of naming the soils formed during the evolution, we distinguish the following two basic groups:

- on natural geological and mixed substrates
- on various waste, two-layer substrates

In relation to the presence of natural geological materials, the evolution of new developmental phases may be treated in the same way as in natural soils.

In the case of presence of various wastes, development of soil can be considered in two phases or two parts. Namely, in this case the technogenous soil consists of two parts: the upper part – overburden material, and the lower part – corresponding waste material. The first part of the profile will have the similar development as natural soils, depending on the type of material. The second part of such substrates is buried and does not allow development of root system. However, this part of the profile would also sustain the processes of leaching, transformation, oxidation-reduction, i.e. these processes would occur toward the ascendant and descendant processes, humization, etc.

The consideration of soil evolution in such systems can lead to the establishment of the following developmental phases:

1. on favorable geologic substrates the following systemic units will be developed:
- techno regosol
- techno pararendzina
- techno eutric (dystric) cambisol

2. on industrial waste (fly ash, slug) development could follow this pattern:
- techno cinero regosol
- techno cinero pararendzina
- techno cinero eutric (dystric) cambisol

3. on communal waste, (garbage), development could follow this pattern:
- techno garbi regosol
- techno garbi pararanker
- techno garbi eutric (dystric) cambisol

As an option for rehabilitating such formations it is possible to use a cover of either favorable overburden materials or natural soil. The depth of the cover in case of various wastes can range from 40 to 50 cm.

Schematic overview of soil development (Fig. 1-3) shows soil development with phases taking place on specific substrates

Conclusion

The paper addresses some technogenous substrates, as well as development of the specific techno-pedogenetic formations, i.e. technosols. The genesis of technosols includes the formations in which physical destruction of natural land resources took place. Other aspects of damages occurring on natural soil, such as the processes of biological and chemical contamination, anthropogenic degradation, etc., are not addressed. We analyzed the evolution processes of pedogenetic formations, where the following three technogenous substrates were included: natural geological substrate – industrial waste (fly ash) – communal waste (garbage). Some new formations were developed, and they developed very fast as a result of the application of anthropogenic measures.

A specific feature of the creation and development of technosols is reflected in indirect recultivation, due to the participation of two different substrates – natural geological and technogenous substrates. In this two-layer structure of the profile it is possible to expect some specific processes and specific development to take place. Further researches would greatly contribute to acquiring more knowledge on the newly formed soils.

Such researches would identify and determine the differentiation of techno-pedogenetic factors and help us with the information as to how long does it take for these formations to evolve.

They should be focused particularly on the processes occurring in genesis of new formations, as well as the impact of technogenous substrates on development of such soils. The monitoring of the following processes and changes would be essential:

- tehnogenous formations – development and further management of these soils,
- use of technogenous substrates,

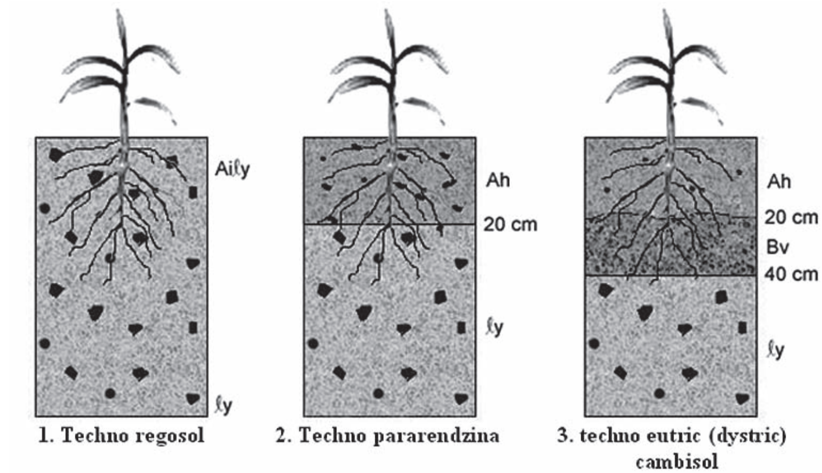

Figure 1. Schematic overview of technosol development on marly mining deposit (direct recultivation)

Symbols: Ai – initial development; *l*y – loose natural geological substrate; Ah – humus horizon; yY – technogenous substrate (industrial, communal); Y – natural geological substrate (uniform or mixed composition); Bv – horizon with higher content of clay particles

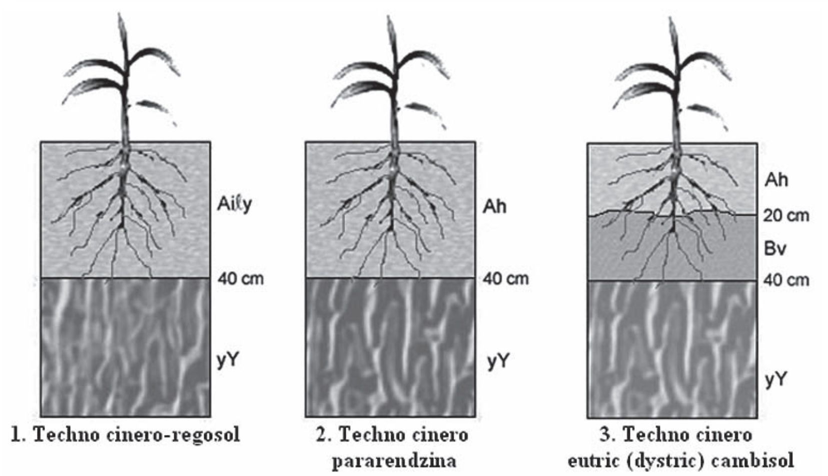

Figure 2. Schematic overview of technosol development on industrial waste (fly ash, slug) (indirect recultivation)

Symbols: Ai – initial development; *l*y – loose natural geological substrate; Ah – humus horizon; yY – technogenous substrate (industrial, communal); Y – natural geological substrate (uniform or mixed composition); Bv – horizon with higher content of clay particles

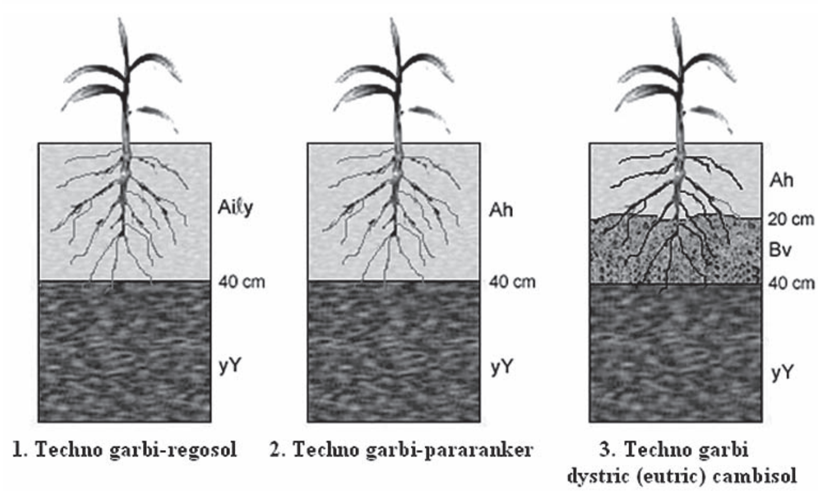

Figure 3. Schematic overview of technosol development on communal waste (garbage) (indirect recultivation)

Symbols: Ai – initial development; *l*y – loose natural geological substrate; Ah – humus horizon; yY – technogenous substrate (industrial, communal); Y – natural geological substrate (uniform or mixed composition); Bv – horizon with higher content of clay particles

- properties of technogenous substrates and suitability for recultivation,
- definition of newly formed formations,
- differentiation of techno-pedogenetic factors in genesis and development of technogenous formations,
- monitoring of physical, chemical, biological and morphological properties of technogenous soils,
- monitoring of health status and fertility of the new formations,
- time periods for the establishment of new developmental stages of such formations.

Ten (10) separate systematic units have been identified within the class of technogenous soils, as well as specific processes related to technogenous substrates. Additionally, a projection of soil development on these substrates has been considered as well as the possibility of utilizing three different overburden materials, as follows: overburden carbonate waste – industrial waste – communal waste.

The projection of soil development on these technogenous substrates is presented in the schematic overview (Fig. 1-3).

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