Phytotoxic assessment of sewage treatment methods in disposal sites

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Abstract. The paper presents the assessment of the impact of disposal sites on biota through definition of phytotoxic influence of polluted soil and landfill leachate on seedlings, growth and root system of plants Triticum aestivum. It is found that soil collected around a disposal site of municipal solid waste, the seedlings of plants are 16% lower in comparison with standard (clean soil), the length of a land part is 22% lower, the average length of roots is 44% less. The green weight of top and the weight of a root system of plants in the soil from a disposal site is 52% and 43% less respectively. This influence is characterized as above the average toxicity level. It is defined that with the introduction of Sviteco-PBG prebiotic (10% dilution) to the polluted soil the seedlings of plants are 5.2% better in comparison with the polluted soil without the prebiotic, the length of a land part – by 11.6%, the average length of roots – by 40.2% respectively; the green weight of top and the weight of a root system of plants is 14% and 16.5% higher in comparison with the polluted soil without the prebiotic. Thus, the use of prebiotics allows improving the quality of soil and reducing its phytotoxicity. In particular, if the influence on a root system of the polluted soil is characterized as toxic above the average, then after the application of prebiotics – as the average toxicity by root weight and absent (weak) toxicity by root length. It is found that when Sviteco-PBG (10% dilution) and Ca(OH)₂ are added to sewage waters of a MSW dump at pH 10, their maximum purification from heavy metals is reached, the phytotoxic effect is estimated as weak toxicity. The phytotoxic effect of the polluted filtrate without purification – above the average toxicity. Thus, prebiotics allow improving the efficiency of soil cleanup from heavy metals, giving an opportunity in the long term to return contaminated land to their economic circulation. Ca(OH)₂ and Sviteco-PBG (10% dilution) at pH 10 allows improving the quality of technogenically polluted soil, reducing toxic impact on biota and increasing the efficiency of sewage treatment in waste disposal sites.

1. Introduction
Technogenic environmental pollution leads to degradation of ecological systems, global climatic and geochemical changes, regional and local environmental crises and accidents. Lithosphere is mostly damaged due to human activity. Surface solid waste storage pits, in particular sewage waters of municipal solid waste (MSW) dumps, cause damage to flora and fauna, health of the population and affect dynamic balance of the biosphere as a result of non-compliance with rules of their storage and burial. The accumulation of toxic substances leads to gradual change of the chemical composition of soils, violation of integrity of geochemical environment and living organisms. Any pollution of a lithosphere with solid wastes can entail the pollution of surface, underground water and the atmosphere. Despite this fact, the most widespread method of waste handling in many countries of the world, including Ukraine, is their burial. Valuable agricultural resources are used as waste sites [1-3].
Works of famous domestic and foreign researchers are devoted to the improvement of solid waste handling [4-10]. But the issue of reducing the area of contaminated lands, which formation is caused by waste disposal places, as well as their restoration and return to economic turnover are insufficiently studied and remain relevant for scientific community.

The purpose of the paper is to study the toxic impact of sewage waters in disposal sites on the stability of *Triticum aestivum* and to develop recommendations on the improvement of sewage treatment around disposal sites.

2. Materials and methods

At the first stage *Triticum aestivum* was seeded in separate containers with different types of soil (100 pieces each). Four pilot sites with quadruple repetition are identified:

1a) control site of clean soil (standard) and watering with clear water (distilled);
1b) site of clean soil and watering with distilled water with Sviteco-PBG (10% dilution);
1c) site of soil from MSW dump and watering with distilled water without prebiotic;
1d) site of soil from MSW dump and watering with distilled water with Sviteco-PBG (10% dilution).

The soil was collected via standard techniques from the territory of the MSW dump located 750 m southeast from Makukhovka village (Poltava district, Poltava region, Ukraine). The area of a dump makes 17.4 hectares, filling percentage – 105%. The place of waste disposal is disordered, its opportunities to accept and neutralize waste are fully utilized. The filtrate is accumulated from the north side of the MSW dump. The potential volume of the filtrate in the dump is 51975.2 m³/year [11]. A.I. Gorova scale was used to define phytotoxicity of a filtrate [12]. The experiment was carried out during 14 days, then the following was defined: quantity of germinated seeds; length of aerial parts of plants; length of roots (after drying) and their weight (weighing in Petri dish).

At the second stage we studied the phytotoxic influence of a dump filtrate after its cleaning with Ca(OH)₂ (lime hydrate) and Sviteco-PBG (10% dilution) for *Triticum aestivum* growth and root system. *Triticum aestivum* was seeded 100 pieces in separate containers with soil from the MSW dump (eight pilot sites with quadruple repetition):

2a) site with watering with drinking water (local well) and addition of Ca(OH)₂ at pH 9.0;
2b) site with watering with a filtrate from the MSW dump and addition of Ca(OH)₂ at pH 9.4;
2c) site with watering with a filtrate from the MSW dump and addition of Ca(OH)₂ at pH 9.3;
2d) site with watering with a filtrate from the MSW dump and addition of Ca(OH)₂ at pH 10.0;
2e) site with watering with drinking water (local well) and addition of Ca(OH)₂ at pH 9.45 and Sviteco-PBG (10% dilution).
2f) site with watering with a filtrate from the MSW dump and addition of Ca(OH)₂ at pH 9.45 and Sviteco-PBG (10% dilution)
2g) site with watering with a filtrate from the MSW dump and addition of Ca(OH)₂ at pH 9.31 and Sviteco-PBG (10% dilution) 
2h) site with watering with a filtrate from the MSW dump and addition of Ca(OH)₂ at pH 10.0 and Sviteco-PBG (10% dilution).

The experiments were conducted within a month then the following was defined: quantity of germinated seeds; length of aerial parts of plants; length of roots (after drying) and their weight (weighing in Petri dish). Repeatability of experiments – four times, single trial establishment. To check the reliability of the difference, the Student’s coefficient was defined after testing for normality of distribution between statistical characteristics of two alternative data sets [13].

3. Results and discussion
The study represents a complex analysis of the influence of the MSW dump on growth and root system of *Triticum aestivum* seeds using Sviteco-PBG prebiotic (10% dilution) at the first stage, and addition of prebiotic and \( \text{Ca(OH)}_2 \) at various pH values at the second stage.

The phytotoxic influence of soil medium on *Triticum aestivum* growth and root system was defined as follows [12]:

\[
PI = \left( \frac{M_o - M_k}{M_o} \right) \times 100 \%
\]

where \( M_o \) – weight or growth indicators of plants with a control sample of soil; \( M_k \) – weight weight or growth indicators of plants in the studied soil.

The results of the first stage allowed defining the following. On the seventh day the seedlings in site 1a (control) made 95%, in site 1b (clean soil and watering with prebiotics) – 97%, in site 1c (polluted soil and watering without prebiotic) – 69%, in site 1d (polluted soil and watering with prebiotics) – 85%.

The experiment was carried out during 14 days then the following was defined: quantity of germinated seeds (Figure 1); length of aerial parts of plants (Figure 2); length of roots (after drying, Figure 3) and their weight (weighing in Petri dish, Figure 4-5).

![Figure 1. Average number of germinated seeds, %](image1)

![Figure 2. Length of a land part, cm.](image2)

![Figure 3. Average length of roots, cm.](image3)

![Figure 4. Weight of a land part, g.](image4)

![Figure 5. Weight of a root system, g.](image5)
The received results allowed concluding that the germinated seeds in the soil collected around the MSW dump are 16% lower in comparison with the control soil, the of aerial parts of plants is 22% less, the average length of roots is 44% less. The weight of a land part and weight of a root system of plants in the soil from the dump is 52% and 43% less respectively. The addition of prebiotic to the control (reference) and polluted soil gave the following results:

- in the control soil sample with addition of prebiotic addition the seedlings of germinated plants were 1.5% better, in the soil from the dump – by 5.2% respectively;
- the length of a land part in the control soil with addition of prebiotic was 9.4% more, in the soil from the dump – by 11.6% respectively;
- the average length of roots in the control soil with addition of prebiotic was 11.7% more, in the soil from the dump – by 40.2% respectively;
- the weight of a land part and weight of a root system of plants in the control soil with addition of prebiotic was 5.6% and 11.5% higher, in the soil from the dump – by 14% and 16.5% respectively.

The phytotoxicity of soil in relation to length and weight of land and root parts of a plant was calculated (Table 1).

**Table 1. Assessment of phytotoxic effect of the soil from the MSW dump on the example of Triticum aestivum cultivation**

| Samples                  | Levels of growing disease (phytotoxic effect, %) |
|--------------------------|--------------------------------------------------|
|                          | By length of a land part | By average length of roots | By weight of a land part | By weight of a root system |
| **Site 1c** (soil from MSW dump) | Average toxicity         | Above the average toxicity | Above the average toxicity | Above the average toxicity |
| **Site 1d** (soil from MSW dump with prebiotic) | No (weak) toxicity       | No (weak) toxicity         | Above the average toxicity | Average toxicity |

Thus, the use of prebiotic allows improving the quality of soil and reducing its phytotoxicity, in particular if the toxic influence on a root system of the polluted soil was characterized as above the average, then after the application of prebiotic – as absent (weak) according to the levels of growing disease.

The second stage included the study of the phytotoxic influence of a filtrate from the MSW dump after its cleaning with Ca(OH)₂ and Sviteco-PBG (10% dilution) on seedlings, growth and the root system of Triticum aestivum (Table 2). The experiment was conducted for 1 month.

**Table 2. Assessment of polluted filtrate from the MSW dump on the example of Triticum aestivum cultivation at various methods of cleaning**

| Site | pH  | Share of germinated seeds, % (average indicator) | Length of germination, cm (average indicator) | Length of roots, cm (average indicator) | Weight of root system, g (average indicator) | Weight of land part, g (average indicator) | Average root weight of one seed, g |
|------|-----|--------------------------------------------------|-----------------------------------------------|------------------------------------------|-----------------------------------------------|--------------------------------------------|-------------------------------------|
| 2a   | 94.6| 26.7                                             | 11.3                                          | 2.34                                     | 4.27                                          |                                            | 0.025                               |
| 2b   | 8.4 | 81.3                                             | 12.0                                          | 6.5                                      | 1.45                                          | 2.36                                       | 0.0178                              |
| 2c   | 9.3 | 90.0                                             | 18.0                                          | 8.1                                      | 1.73                                          | 2.87                                       | 0.0192                              |
| 2d   | 10.0| 84.0                                             | 16.0                                          | 7.0                                      | 1.65                                          | 2.73                                       | 0.0196                              |
| 2e   | 8.35| 92.0                                             | 18.4                                          | 8.4                                      | 1.79                                          | 2.92                                       | 0.0195                              |
| 2f   | 9.31| 84.0                                             | 13.0                                          | 6.8                                      | 1.53                                          | 2.56                                       | 0.018                               |
| 2g   | 10.0| 93.0                                             | 22.0                                          | 10.9                                     | 2.34                                          | 4.26                                       | 0.025                               |
It is proved that the addition of Ca(OH)\(_2\) and Sviteco-PBG (10% of dilution) at pH 10 gives the maximum sewage treatment of the MSW dump. In particular:
- by the percentage of germinated seeds (Table 3, Figure 6): seedlings make 98.3% in comparison with the control sample (clean soil, percentage of germinated seeds is accepted as 100%), while simple lime application at various pH values gives 85.9-94.0%, without cleaning – 72.0%; addition of prebiotic – 89.0%, prebiotic and lime at different pH values – 88-95% of seedlings;
- by the relative length of germination of a land part: 83.0% – in site 2c in comparison with the control sample, while simple lime application at various pH values 44.0-66.0% in comparison with the control sample, and addition of prebiotic at different pH values – up to 67.0%.

Similar results were obtained through the calculation of the relative length of roots, relative weight of a root system, relative weight of a land part of plants, average weight of a root of one seed (Fig. 6).

**Table 3.** Assessment of phytotoxic effect of a filtrate from the MSW dump on the example of *Triticum aestivum* cultivation

| Samples | Levels of growing disease (phytotoxic effect, %) |
|---------|-----------------------------------------------|
|         | By length of a land part | By average length of roots | By weight of a land part | By weight of a root system |
| Site with watering with a filtrate and addition of Ca(OH)\(_2\) at pH 8.4 | 55.06 | 42.48 | 38.03 | 44.73 |
| Site with watering with a filtrate and addition of Ca(OH)\(_2\), pH 9.3 | 32.58 | 28.32 | 26.07 | 32.79 |
| Site with watering with a filtrate and addition of Ca(OH)\(_2\), pH 10.0 | 40.11 | 38.05 | 29.49 | 36.07 |
| Site with watering with a filtrate and addition of Ca(OH)\(_2\) and Sviteco-PBG (10% dilution), pH 8.35 | 31.09 | 25.66 | 23.50 | 31.62 |
| Site with watering with a filtrate and addition of Ca(OH)\(_2\) and Sviteco-PBG | 51.31 | 39.82 | 34.62 | 40.15 |

**Figure 6.** Impact of a filtrate from the MSW dump on growth and root system *Triticum aestivum* seeds (relative indicators).
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3. Addition of Sviteco-PBG (10% dilution) and Ca(OH)₂: at pH 10 the maximum purification from heavy metals is reached, the phytotoxic effect is estimated as weak toxicity (by the length of a land part according to the average length of roots) and as as no toxicity (by the weight of a land part, weight of a root system). The phytotoxic effect of the polluted filtrate without purification – above the average toxicity.

Thus, the use of Ca(OH)₂ and Sviteco-PBG (10% dilution) at pH 10 allows improving the quality of technogenically polluted soil, reducing toxic impact on biota and increasing the efficiency of sewage treatment in MSW disposal sites.

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4. Conclusion
The experiments allowed estimating the phytotoxic effect of a filtrate from the MSW dump on the example of Triticum aestivum cultivation and recommending methods of sewage treatment in waste disposal sites:

1. In the soil collected around the MSW dump the seedlings are 16% lower in comparison with a standard (clean soil), length of a land part is 22% lower, the average length of roots is 44% lower. The weight of a land part and weight of a root system of plants in the soil from the dump is 52% and 43% less respectively. This influence is characterized as the above average toxicity.

2. Addition of Sviteco-PBG prebiotic (10% dilution) into the polluted soil: seedlings of plants are 5.2% better in comparison with the polluted soil without the prebiotic, the length of a land part – by 11.6%, the average length of roots – by 40.2% respectively; the green weight of top and the weight of a root system of plants is 14% and 16.5% higher in comparison with the polluted soil without the prebiotic. Thus, the use of prebiotics allows improving the quality of soil and reducing its phytotoxicity. In particular, if the influence on a root system of the polluted soil is characterized as toxic above the average, then after the application of prebiotics – as the average toxicity by root weight and absent (weak) toxicity by root length.

| Sviteco-PBG (10% dilution), pH | Above the average toxicity | Average toxicity | Average toxicity | Above the average toxicity |
|------------------------------|---------------------------|------------------|------------------|---------------------------|
| 9.31                         | 17.60 No (weak) toxicity  | 3.54 No (weak) toxicity | 0.00 No toxicity | 0.23 No toxicity |
| Site with watering with a filtrate and addition of Ca(OH)₂ and Sviteco-PBG (10% dilution), pH 10 |  |  |  |  |
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