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Evaluation of the Phytotoxicity of Leachate from a Municipal Solid Waste Landfill: The Case Study of Bukov Landfill

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Abstract: Municipal solid waste landfilling, landfilling process and landfill reclamation result in leachate, which may be dangerous to the environment. Municipal solid waste leachate phytotoxicity tests were performed using the toxicity test and a subchronic toxicity pot experiment by direct application of leachate to reference soil in 5, 25, and 50% concentration for a period of 28 days. White mustard (*Sinapis alba* L.) seeds were exposed to different leachate dilution. Leachate were collected monthly in 2018 in the period from April to September. Furthermore, pH, conductivity, and dissolved oxygen were measured. The inhibition results on *Sinapis alba* L. seeds in the tested leachate samples ranged from −18.02 to 39.03%. Lower concentration of leachate showed a stimulating effect (only for Sample 1 and Sample 2 at 5% concentration). It was found out that leachate taken at the landfill is phytotoxic. The results of measurements are based on rainfall which affects the quantity and quality of the leachate. The values of germinated seeds/growing plants from the subchronic toxicity pot experiment ranged from 80 to 104%; therefore, the leachate is considered phytotoxic. However, it was confirmed that leachate may be used for landfill irrigation.

Keywords: landfill; inhibition of root growth; subchronic toxicity pot experiment; *Sinapis alba* L.

1. Introduction

There are a number of methods of waste removal but landfilling is still one of the most common methods. It is the world's most widespread waste management method, especially in relation to municipal solid waste (MSW) [1–3]. A landfill site is a technical installation that changes the appearance of the landscape and affects natural ecosystems [1–5]. MSW landfills may be sources of anthropogenic pollution [6–9], as biological, chemical, and physical reactions take place inside the landfill body [10]. These transformations result in the formation of leachate [11]. The type of landfill, type of deposited waste, the degree of its compaction, and water content inside the landfill body significantly affect the resulting quality and quantity of leachate [12]. The quality of leachate also depends on the location and/or the local climate, the rainfall total rate, and the waste moisture content [13]. Leachate is considered a source of environmental concern because the pollutant mixture can have adverse effects on ecosystems and public health when leachate reaches soil, surface and groundwater surrounding the landfill [14]. Leachate is harmful and factors such as pH, ammonia, organic compounds, and heavy metals (HM) contribute to its toxicity and carcinogenic potential even at trace levels [15]. The decomposition of MSW organic fractions results in a complex mixture of inorganic salts, organic nutrient compounds, and HM [13]. Possible methods of dealing with leachate include phytoremediation, which is a low-cost and environmentally friendly method [16]. Phytoremediation can be applied in-situ in various configurations. The success of this method depends on the plant's ability to resist stress caused by the toxic of leachate [17]. Some plants can accumulate pollutants (e.g., HM) inside their bodies, and there is a risk of pollutants entering the food chain [8]. Likewise, various additives may be used, such as biochar, which should reduce the toxic effects. The bioavailability and absorption of HM can be reduced by adding additives to the contaminated material. Biochar has such characteristics and its application may supports plant growth [18]. Biochar is charred biomass, used mainly in soil applications thanks to its properties: water retention, improving porosity, and reducing acidity [19].

The use of leachate is a significant problem. However, if it is non-toxic, leachate can be used to water the landfill body. Fire is a risk factor related to waste management (WM), especially in landfills. Significant changes have been made to prevent this risk over the last two decades (e.g., regular waste covering with inert material). Regardless of these measures, landfill fires are still quite common, they are usually difficult to extinguish and they are always resource (water) intensive [20]. Leachate can be used to irrigate the landfill body, be in given concentrations to stimulate vegetation growth, and result in increased moisture content in the upper layers of the landfill body, which can lead to fire prevention. To the best of our knowledge, research does not focus on the reuse of leachate on landfill body or as a prevention against landfill fire. Therefore, the use of leachate to moisten the landfill body seems to offer an innovative solution.

The germination index (GI) [21] is used to determine the phytotoxicity of various materials (including leachate), more precisely root growth inhibition (RI) [22,23]. Pollutants are usually evaluated in terms of environmental risks and phytotoxicity is one of them [23]. Seed germination and root elongation are investigated worldwide to assess phytotoxicity as they are key events for plant growth and interact with their environment and pollutants [24]. Phytotoxicity tests in the early germination phase provide several advantages. These tests are quick, easy and cheap. Plant seeds can be used in less favorable and changing environments without the need to add other plant nutrients [23]. The objective of the present study is to: (a) verify phytotoxicity of leachate taken from an MSW landfill, (b) perform a subchronic toxicity pot experiment with an addition of biochar as an additive to reduce phytotoxicity, and (c) determine the potential use of leachate.

2. Materials and Methods

2.1. Landfill Site Location

The Bukov landfill (49°27′29.5″ N, 16°13′53.2″ E) is a sanitary MSW landfill site located in the Czech Republic (CR) (Vysočina Region, Žd'ár nad Sázavou District), belonging to the S-OO group, subgroup S-OO3 (landfills intended for the disposal of other waste, including waste with a significant content of organic biodegradable substances, waste which cannot be assessed on the basis of its aqueous leachate) [25,26] (Figure 1).

The MSW landfill is operated by a state-owned company which, among other thingsspecializes in remediating consequences of mining activities (uranium, ore, and coal mining) in the CR. The MSW landfill project was designed concerning the surrounding value of the natural and cultural environment and subsequent integration in the landscape after its reclamation with maximum use of the given space. With the current available capacity (44×10^4 m^3) and compaction of 0.8–0.9 Mg/m^3, it is possible to landfill up to 15×10^3 Mg/year of waste. The list of wastes (according to European Waste Catalogue and Hazardous Waste) that can be accepted by the landfill if they meet the acceptance conditions is presented in Appendix A. Drainage is designed as a double drainage system, where contaminated leachate flowing from the landfill and rainwater can be drained separately. Collection of leachates is ensured by means of drainage pipes opening into the downpipe and subsequent discharge into the secured collection pond. This facility is also insulated from the surrounding environment [26,27].

Construction of the landfill commenced on 2 November 1994 in an area covering a former waste dump near the Bukov 1 pit. The first and second stages of the landfill have a usable area of 20,690 m^2 for waste disposal and the estimated capacity is 266 × 10^3 m^3. In July 2006, construction of the third stage started (estimated capacity of 173 × 10^3 m^3) and it has been finally accepted [25,26]. The landfill has been built and secured according to legislative provisions and therefore it is not a source of major environment pollution.

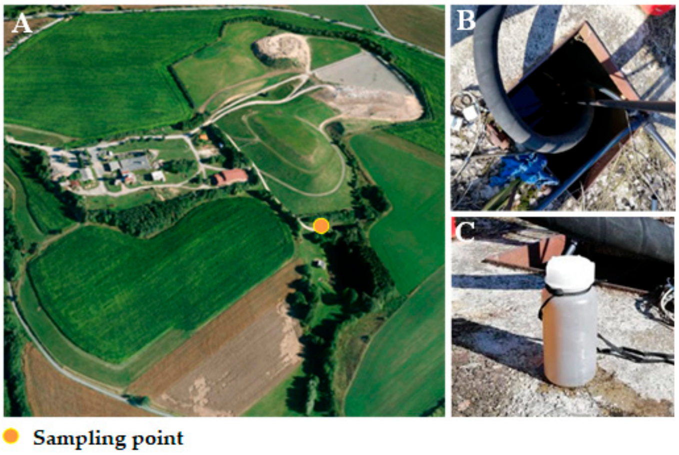

Figure 1. Location of the landfill and the sampling point. Images of (**A**) MSW Landfill Bukov, (**B**) pond of leachate, (**C**) sample of leachate.

2.2. Physicochemical Analysis of Samples

Leachate samples were taken from the leachate pond of once a month over a period of six months (April–September 2018) (sample designation: April—Sample 1, May—Sample 2, June—Sample 3, July—Sample 4, August—Sample 5 and September—Sample 6). Samples (at least 10 L) were collected in polyethylene containers and/or glass bottles sterilized by autoclaving (121 °C, 20 min) and maintained under conditions with minimized exposure to oxygen. Each sample was measured a total of 3 times with individual probes. The resulting measurement value for each sample was obtained by arithmetic average. After transportation to the laboratory, all leachates were stored at 4 °C in the dark and prepared for further analysis within a period of 2 days. Estimation of pH, conductivity (CDC), dissolved oxygen (LDO) were regularly performed always after each collection with the use of TEST KIT HACH (three digital probes: pH, CDC, LDO). CDC probe measures the conductivity, in other words, the conductivity limit (µS/cm), and the LDO probe measures the amount of dissolved oxygen (mg/L). Rainfall (mm) was also monitored throughout the period in a rain-gauge station located at the MSW landfill.

2.3. Leachate Toxicity with the Use of Microbiotests

Leachate toxicity was tested to determine the degree of toxicity using white mustard plant seeds (*Sinapis alba* L.) based on the Phytotoxkit™ methodology [28]. *Sinapis alba* L. is sensitive to pollutants present in the tested material. The presence and influence of pollutants act on the plant as a stress factor that negatively affects its growth [17,29,30]. On the basis of the authors long term research in this field [22,31,32], the samples were tested in 5, 25, and 50% concentrations using the Phytotoxkit test. The 5% leachate concentration was chosen to verify whether leachate at low concentrations is also phytotoxic. Distilled water was used as a control sample. A soil mixture reference (artificial soil OECD) (85% air-dried silica sand, 10% kaolin clay, 5% peat, and $CaCO_3$) was applied to the Phytotoxkit test in combination with distilled water and leachate in specified concentrations. A total of 10 vital and healthy-looking seeds of *Sinapis alba* L. were placed on filter paper. The prepared sample box was sealed and placed vertically in a holder and incubated at a controlled constant temperature of 25 °C and in the dark in an ECOCELL incubator for 72 h. After this specified time, photo documentation was taken (Figure 2) and partial root lengths were measured using Image Tool 3.0 for Windows (UTHSCSA, San Antonio, TX, USA). The results were evaluated using Image Tool 3.0 for Windows (UTHSCSA, San Antonio, TX, USA), which determines whether the growth of *Sinapis alba* L. is inhibited or stimulated (the so-called "inhibiton of rootgrowth"-IR), based on the concentration of leachate applied. If the percentage IR is <0, it is a case of root growth stimulation, and if IR > 0, the root growth is inhibited followed by IR calculation according to the following equation [22,28] (Equation (1)):

$$IR\ [\%] = \frac{(A - B)}{A} \times 100 \tag{1}$$

where A is mean root length in the reference substrate (mm) and B is mean root length on the tested substrate (mm) [22,28].

Figure 2. Process of test phytotoxicity of leachate. Images of (**A**) preparation of laboratory instruments, (**B**) mixture of OECD soils with a blank sample, (**C**) application of the mixture to the sample box, (**D**) application of *Sinapis alba* L. seeds, (**E**) closing and placing the sample box in the holder, (**F**) incubation of the mixture in Ecocell oven, (**G**) evaluation.

2.4. Subchronic Toxicity Pot Experiment

The subchronic toxicity pot experiment was performed in accordance with ČSN EN 13432 concerning the testing of chemicals 208 plant growth test [33]. The plant species used for the experiment was white mustard (*Sinapis alba* L.) (designation in the SIA experiment), which was planted in a substrate mixture complying with European national standards (substrate mixture without added artificial fertilizers, composition: peat, silica sand, and soil). The substrate was enriched with 5% biochar (designation in experiment + B). The leachate samples were mixed and 5, 25, and 50% concentrations were subsequently applied to the substrate 3 times a week, for 28 days, each test having 3 repetitions (designated as 1, 2, and 3). Substrate watered with distilled water was used as a control (designated as E). The individual pots were designated according to the added concentrations of leachate. Pots E1–E3 SIA designated the control sample-substrate watered with distilled water, pots E1–E3 SIA + B designated the control sample enriched with 5% biochar, pots 5, 25 and 50% P SIA 1-3 designated substrate watered with 5, 25 and 50% leachate and pots 5, 25 and 50% P SIA 1-3 + B designated substrate watered with 5, 25 and 50% leachate enriched with 5% biochar. After the end of the pot experiment, the condition was evaluated; a comparison of the number of germinated seeds/growing plants (Figure 3).

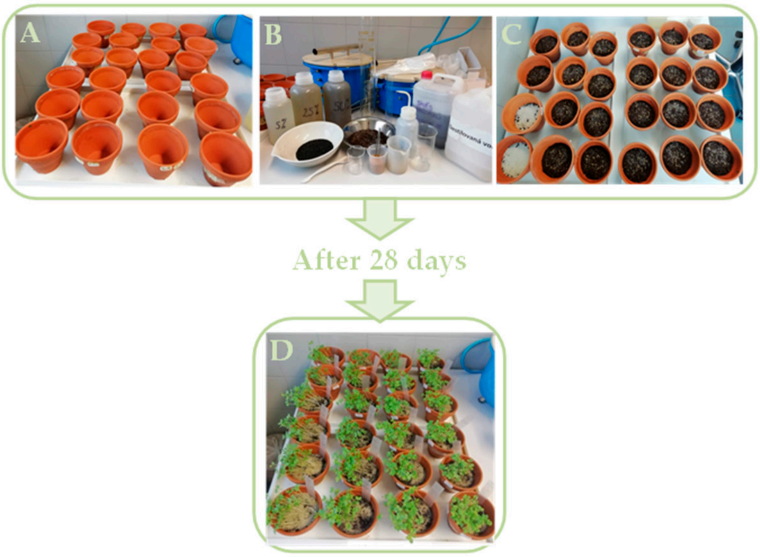

Figure 3. Subchronic toxicity pot experiment. Images of (**A**) preparation and labeling of pots, (**B**) preparation of substrate mixture, 5%, 25% and 50% of leachate concentration and laboratory instruments, (**C**) application of a substrate mixture, *Sinapis alba* L. seeds and specified leachate concentration, (**D**) evaluation after 28 days.

3. Results

3.1. Results of Phytotoxicity Tests

The IR results for the tested samples are shown in Figure 4.

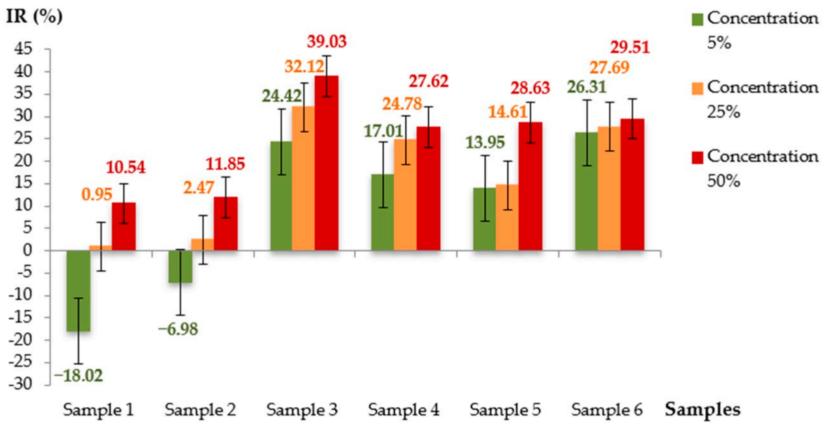

Figure 4. Inhibition of root growth of samples in leachate phytotoxicity tests.

The error analysis of the experimental procedure was created using error bars in Microsoft Excel. These lines help to assess the accuracy and reliability of the measurement despite the random nature of this measurement.

The highest IR values were recorded in samples using 50% leachate, especially in Sample 3 (39.03%) and Sample 6 (29.51%). The lowest IR values were recorded in Sample 1 and Sample 2, at 5% leachate. The 5% concentration showed the lowest IR over the whole reported period. As the concentration of leachate increased, so did the IR values. Sample 1 and Sample 2 at larger concentrations (5, 25, and 50% leachate) showed the lowest IR values for the whole test period.

3.2. Measurement of Leachate Parameters

Using the HACH test kit, leachate samples were tested for pH, CDC (µS/cm), and LDO (mg/L). The samples showed a gradual increase in all measured parameters with respect to the rainfall total (mm) (Figure 5).

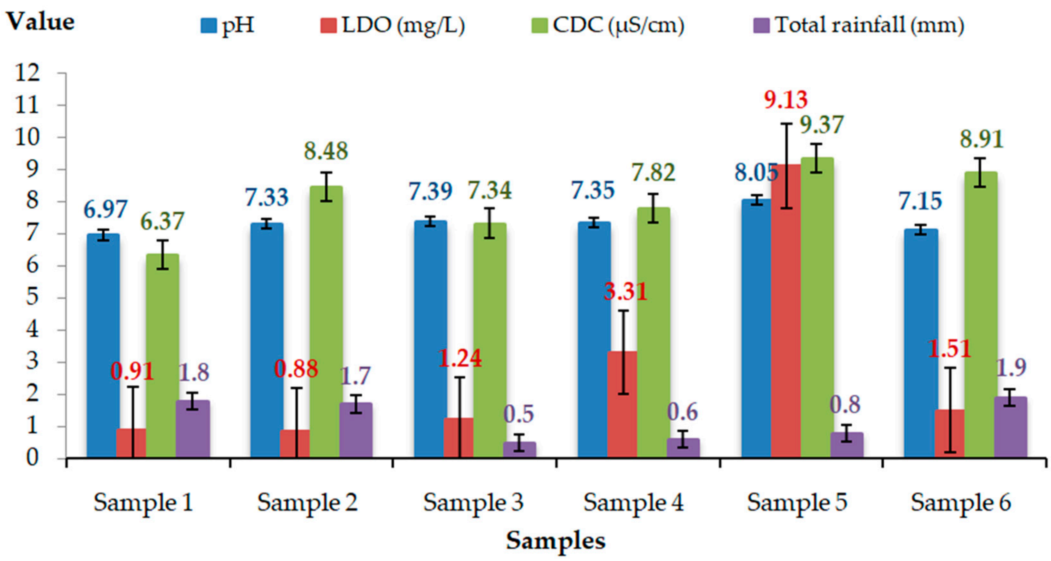

Figure 5. Dependence of rainfall total on the measured parameters.

The error analysis of the experimental procedure was created using error bars in Microsoft Excel. These lines help to assess the accuracy and reliability of the measurement despite the random nature of this measurement.

The results of pH measurements are based on total rainfall. Especially in the summer months, the pH value is alkaline and the average monthly rainfall total is one of the lowest in the observed period. The average leachate pH value in the observed period was 7.37. The highest measured leachate pH was in Sample 5 (pH 8.05) and, conversely, the lowest measured pH (6.97 in Sample 1) approached the pH value of clean water. Likewise, the LDO values increased in the summer period; Sample 5 showed the highest LDO value over the observed period, namely 9.13 mg/L. The average leachate LDO value in the observed period totaled 2.83 mg/L. In the summer, the leachate had a dark brown color, with a typical odor. The lowest LDO value was recorded in Sample 2 (0.88 mg/L). As regards the CDC parameter describing electrical conductivity, the highest value was measured in Sample 5 (9.37 µS/cm) and the lowest value was measured in Sample 1 (6.37 µS/cm). The average CDC leachate value in the observed period was 8.05 µS/cm.

3.3. Results of Subchronic Toxicity Pot Experiment

Results of subchronic toxicity pot experiment (Figure 6) were compared in accordance with the ČSN EN 13432 standard, which specifies that if the germinated seed/growing plant indicator value is above 90% in comparison with the germinated seeds/growing plants in sample E SIA and E SIA + B, the substrate mixture watered with leachate, is not phytotoxic. Moreover, Baran and Tarnawski [34] states: IR values in the range of 90 to 110 percent were classified as "no effect/non-toxic", IR values of 90 percent were classified as inhibition, and IR values of 110 percent were classified as stimulation. Substrate watered with 5% leachate showed a 104% germination rate compared to the blank E SIA sample. Substrate watered with 5% leachate with the addition of biochar (+B) also showed a 104% germination rate and substrate watered with 25% leachate +B, showed 98% germination rate compared to the blank sample E SIA + B. Thus, phytotoxicity was not proved for these three substrates. Other substrates watered with concentrations of leachate showed values of germinated seed/growing plant indicators below 90% in comparison with germinated seeds/growing plants in sample E SIA and E SIA +B. These three substrate mixtures were shown to be phytotoxic based on germination (Figure 6).

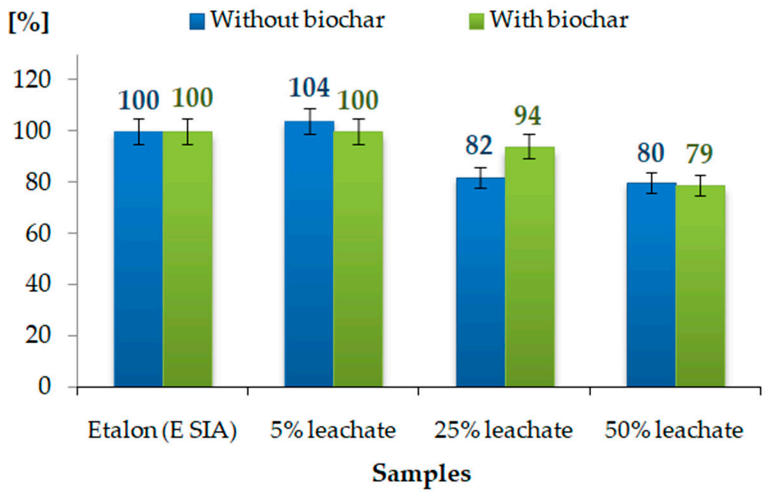

Figure 6. Percentages of germinated seeds/growing plants per 28 days.

The error analysis of the experimental procedure was created using error bars in Microsoft Excel. These lines help to assess the accuracy and reliability of the measurement despite the random nature of this measurement.

The use of biochar in the subchronic toxicity pot experiment was proved to improve soil (substrate) conditions. Results of the experiment show that the use of biochar can at least partially increase the number of germinated seeds/growing plants.

4. Discussion

4.1. Phytotoxicity Tests

Testing leachate phytotoxicity with the Phytotoxkit^{TM} test kit has proved that the growth of *Sinapis alba* L. was significantly inhibited at higher concentrations of leachate. As regards lower concentrations of leachate, stimulation of root growth of *Sinapis alba* L. germinating seeds was demonstrated only in Sample 1 and Sample 2 in the 5% leachate concentration. Zloch et al. [31] tested leachate phytotoxicity at the Kuchyňky MSW landfill. Hydroponic medium and leachate in concentrations of 25, 50, 75, 90, and 100% were used for this testing, and samples were taken from February to June 2017. The plant used for testing was *Sinapis alba* L. The lowest values of growth inhibition in a leachate sample taken in February (2017) were in the 25% leachate concentration (−15.66%) and in the 25% leachate concentration (−24.49%). Leachate samples taken in March (2017) showed the lowest inhibition values at 25% leachate concentration (−20.9%). For other samples and leachate concentrations (March–June 2017), the growth of *Sinapis alba* L. was strongly inhibited [31]. Vaverková et al. [35] also tested leachate phytotoxicity at the Těmice MSW landfill, with the samples collected between April and July 2016. Hydroponic medium and leachate in concentrations of 25, 50, 75, 90 and 100% were used for this testing. The plant used for testing purposes was *Sinapis alba* L. The inhibition results were the lowest when testing with a leachate content of 25%. The values ranged from 0.52 to 10.11%. At higher concentrations, *Sinapis alba* L. was significantly inhibited. The results of leachate testing from the Bukov MSW landfill also show, in comparison with two other MSW landfills [31,35] that leachate at lower concentrations can also have a positive effect, i.e., stimulation of the roots of *Sinapis alba* L. germinating seeds. At higher levels of leachate (starting at 25%) there may be quite significant inhibition of the test plant's root growth. When testing the leachate phytotoxicity, the sampling season also plays a role. Leachate from the Bukov MSW landfill and the Kuchyňky MSW landfill proved to show lower inhibition (and possible stimulation of *Sinapis alba* L. growth) in colder and rainier months compared to the summer.

4.2. Leachate Chemical Properties Measurement

Alkaline pH is typical of leachate found in older and mature landfills. However, this always depends on the volume and nature of waste received, site weather conditions, maturity, stabilization, and age of the landfill [31,36–39]. During waste decomposition over the years, there has been a significant decrease in total organic carbon and the volume of organic acids resulting in the older leachates being rather alkaline [40,41]. Another factor causing leachate alkalinity is methanogenic bacteria consuming available hydrogen [42]. LDO values are at a maximum level in new landfills that are at the beginning of the landfilling process. Umar et al. [43] report values between 30,000 and 60,000 mg/L, which, however, drop to a minimum during the landfill operation. This concerns a period between six and fifteen years [39], which the Bukov MSW landfill exceeded a long time ago. CDC values indicate the total concentration of ions or dissolved inorganic substances [44]. Thus, a higher CDC leachate value indicates a higher content of dissolved minerals.

The leachate values at the Bukov MSW landfill showed a gradual increase in all measured parameters from April to June 2018. Thanks to the mild climate, the summer season is characterized by minimum rainfall. pH values increased from almost neutral pH (pH 6.97—April 2018) to slightly alkaline pH (pH 8.05—August 2018). LDO showed the highest values when samples were taken in August 2018 (9.13 mg/L). The highest CDC was measured again in the August 2018 sample (9.37 µS/cm). A higher CDC value indicates a higher content of dissolved minerals in the leachate. Mishra et al. [45] also tested seasonal variations in pH, LDO, and CDC in leachate properties at the Turbhe landfill (India, Goa region) from July 2012 to December 2013 (Table 1). Seasonal fluctuations were tested in four areas of the landfill and leachates from a leachate pond were taken for comparison.

Table 1. Measured parameters and their value [45].

A Measured Parameter with Units	Value Measurement (Month/Year)	Value Measurement (Month/Year)
pH	7.1 08/2012	8.3 04/2013
LDO (mg/L)	6000 01/2012	2000 08/2013
CDC (µS/cm)	27 05/2013	5 09/2012

In the Goa region, compared to the CR, the summer season is from September to April. Therefore, it is a period of the minimum rainfall total and the highest recorded leachate values. The highest values were: pH in April 2013 (pH 8.3), LDO in January 2012 (6×10^3 mg/L), and CDC in May 2013 (27 µS/cm). Outside the summer season, there is a monsoon season in the Goa region, which is characterized by higher rainfall. The highest rainfall total was recorded in September 2013, namely 589 mm. Due to the given period, the leachate gets diluted and the measured values are thus many times lower compared to the summer period. The lowest values: pH in August 2012 (pH 8.3), LDO in August 2013 (2×10^3 mg/L), and CDC in September 2012 (5 µS/cm) [45]. Zloch et al. [31] tested leachate parameters at the Kuchyňky MSW landfill from February to June 2017. The measured leachate values are also affected by the season. In February, they measured pH 7.35 at the Kuchyňky MSW landfill (influenced mainly by the snowfall total), in June, pH reached 8.61 (minimum rainfall total). The highest LDO values were measured again in June (2.92 mg/L) and in the same month, the highest CDC values (11.69 µS/cm) [31] were reported, too. According to the results from the Bukov MSW landfill, in comparison with the Kuchyňky MSW landfill and Turbhe landfill, the rainfall total proved to be decisive but not the only reason for changes of these parameters. Other factors influencing the chemical parameters of leachate are also related to the age of the landfill, the volumes, and the nature of the landfilled waste.

4.3. Subchronic Toxicity Pot Experiment

Results of the experiment showed that only three samples did not show phytotoxicity. It was a sample that was watered with 5% leachate, then a sample with the addition of 5% biochar, watered with 5% leachate, and also a sample with the addition of 5% biochar, watered with 25% leachate. Other samples were evaluated as phytotoxic based on seed/growing plant germination. These were samples watered with 25, 50% leachate, and also a sample with the addition of 5% biochar watered with 50% leachate. The inclusion of biochar in the substrate shows that it can improve the soil conditions (in the substrate) and thus increase the number of germinated seeds/growing plants. The experiment aimed to determine the effects of leachate was also performed by Arunbabu et al., [13]. The plant species used in this experiment was *Vigna unguiculata* L. Walp., also known as Cowpea. The substrate consisted of two parts of soil and one part of sand and subsequently watered with leachate in concentrations of 0, 0.5, 1, 2, 5, 10, and 25%. The experiment lasted 14, 28, and 54 days. Substrates watered with leachate concentrations up to 5% showed the highest percentage of seed germination. With the substrate watered with 10% leachate, the plants already showed stunted growth, and watering with 25% leachate showed significant inhibition of seed germination-leaf yellowing and wilting. The experiment shows that leachate at a higher more than 5% can have a significant negative effect on the germination of *Vigna unguiculata* L. Walp seeds. These seeds are a sensitive bioindicator of environmental stress, which impairs seed development and also affects seed growth [13]. Another similar experiment was performed by Guerrero-Rodríguez et al. [46] who used a substrate consisting of 50% sand, 30% peat, and 20% clay loam with *Phaseolus vulgaris* L. (common bean) for the testing. The substrate was watered with 25, 50, 75, and 100% leachate. The root length and weight when watering with different concentrations were monitored. Already, when watering with 50% leachate, the length of the plant changed significantly, 75% leachate strongly affected the root weight, and 100% leachate harmed both the *Phaseolus vulgaris* L. roots and weight [46]. The experiment demonstrated the leachate phytotoxicity, especially at higher concentrations. Furthermore, it was proved that lower concentrations of leachate (compared to experiments up to 25% leachate concentration) have a stimulating effect on the test plants. Gupta et al. [47] demonstrated a dependence between a higher concentration of leachate and higher percentage inhibition of *Vicia faba* L. root growth. The application of high levels of leachate disrupts the plant's defense system and metabolism [47], as demonstrated by this experiment.

4.4. Potential Use of Leachate—Fire Prevention

Extinguishing landfill fires are particularly challenging for fire brigades. Large landfill fires usually require several fire-fighters and time needed to extinguish them. The risk period of landfill fires in spring and especially summer months. Landfill fires most often occur between March and August. Almost 60% of landfill fires occur during this half-year period, with the fire peaks (11%) occurring in July [48]. Landfill fires result in property damage, they can harm human health (injuries, respiratory system damage, etc.) and an overall negative impact on the environment (emissions, smoke, contaminated fly ash, etc.). Fire prevention is much cheaper than the costs associated with firefighting [48]. Plant reclamation of the landfill body is needed to control greenhouse gasses releases and, in a number of cases, also explosive gases, thus preventing the risk of fires. Landfills that are not equipped with a rainwater collection tank can make use of the retained leachate to water the landfill body, thus reducing the risk of fire or its spread. The applied leachate also supplies nutrients, which support vegetation growth and partial phytoremediation of these waters occurs, too. Based on the conducted study, we can conclude that leachate present in low concentrations is not toxic and has a stimulating effect on plant growth. As a result, leachate can be used to irrigate the landfill body, be used in given concentrations to stimulate vegetation growth, and result in increased moisture content in the upper layers of the landfill body, which can lead to fire prevention. Nevertheless, further research is needed.

5. Conclusions

The effects of leachate phytotoxicity based on samples taken from a municipal waste landfill were tested under laboratory conditions. The test results showed that the growth of *Sinapis alba* L. was significantly inhibited in the case of higher leachate concentrations. Growth stimulation was proved in lower leachate concentrations. By measuring the chemical parameters of leachate, the relationship between the rainfall total and pH, conductivity, and the volume of dissolved oxygen was demonstrated. In the summer, the values of these measured parameters are higher than in the spring. The rainfall total is decisive but it is not the only reason for the parameter changes. Leachate phytotoxicity was also monitored by using a subchronic toxicity pot experiment. It was recognized that the application of 5% leachate to the substrate achieved 104% germination and the application of 5 and 25% leachate to the substrate with the addition of 5% biochar achieved 104 and 98% germination. In other cases, a phytotoxic effect was reported. The test results also determined that the addition of biochar to the tested substrate may positively affect the volume of germinated seeds/growing plants. The study showed that leachates cannot have any other use than as permitted by the law, i.e., it can only be used for landfill body irrigation to reduce the dust level and to optimize the moisture content. As we have dealt with drought-related issues in recent years, this leachate could be used, for example, for sprinkling the landfill body (active and reclaimed parts) to prevent fires. Leachates must not escape outside the demarcated landfill area, thus contaminating the surrounding environment.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

List of wastes (according to European Waste Catalogue and Hazardous Waste) that can be accepted by the landfill if they meet the acceptance conditions.

Waste Type Code	Name of the Type of Waste	Waste Category
02 01 03	Plant-tissue waste	O
07	Wastes form organic chemical processes	
07 02 13	Waste plastic	O
08	Wastes from the manufacture, formulation, supply and use (MSFU) of coating (paints, varnishes and vitreous enamels), adhesives, sealants and printing inks	
08 01 12	Waste paint and varnish other than those mentioned in 08 01 11	O
08 01 18	Wastes from paint or varnish removal other than those mentioned in 08 01 17	O
08 04 10	Waste adhesives and sealants other than those mentioned in 08 04 09	O
09	Wastes from the photographic industry	
09 01 08	Photographic film and paper free of silver or silver compounds	O
10	Wastes from thermal processes	
10 01	Wastes from power stations and other combustion plants (except 19)	
10 01 02	Coal fly ash	O
10 01 03	Fly ash from peat and untreated wood	O
10 01 15	Bottom ash, slag and boiler dust from co-incineration other than those mentioned in 10 0114	O

Waste Type Code	Name of the Type of Waste	Waste Category
10 02 01	Wastes from the processing of slag	O
10 02 02	Unprocessed slag	O
10 09 03	Furnace slag	O
10 09 06	Casting cores and molds which have not undergone pouring other than those mentioned in10 09 05	O
10 09 08	Casting cores and molds have undergone pouring other than those mentioned in 10 09 07	O
10 11 03	Waste basing in glass fibers	O
12	Wastes from shaping and physical and mechanical surface treatment of metals and plastics	
12 01 05	Plastics shavings and turnings	O
12 01 17	Waste blasting material other than those mentioned in 12 01 16	O
12 01 21	Spent grinding bodies and grinding materials other than those mentioned in 12 01 20	O
15	Waste packaging, absorbents, wiping cloths, filter materials and protective clothing not otherwise specified	
15 01 02	Plastic packaging	O
15 01 05	Composite packaging	O
15 01 06	Mixed packaging	O
15 01 07	Glass packaging	O
15 01 09	Textile packaging	O
16	Wastes not otherwise specified in the list	
16 01 19	Plastic	O
16 01 20	glass	O
16 03 04	inorganic wastes other than those mentioned in 16 03 03	O
16 03 06	organic wastes other than those mentioned in 16 03 05	O
16 11 04	other linings and refractories from metallurgical processes other than those mentioned in16 11 03	O
17	Construction and demolition wastes (including excavated oil from contaminated sites)	
17 01 01	Concrete	O
17 01 02	Bricks	O
17 01 03	Tiles and ceramics	O
17 01 07	Mixture of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06	O
17 02 02	Glass	O
17 02 03	Plastic	O
17 03 02	Bituminous mixtures containing other than those mentioned in 17 03 01	O
17 05 04	Soil and stones other than those mentioned in 17 05 03	O
17 05 06	Dredging spoil other than those mentioned 17 05 05	O
17 05 08	Track ballast other than those mentioned in 17 05 07	O
17 06 04	Insulation materials other than those mentioned in 17 06 01 and 17 06 03	O
17 09 04	Mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 0902 and 17 09 03	O
18	Wastes from human or animal health care and/or related research (except kitchen and restaurant wastes not arising from immediate health care)	
18 01 04	Wastes whose collection and disposal is not subject to special requirements in order to prevent infection (for example dressings, plaster casts, linen, disposable clothing, diapers)	O
19	Wastes from waste management facilities, off-site wastewater treatment plants and the preparation of water intended for human consumption and water for industrial use	

Waste Type Code	Name of the Type of Waste	Waste Category
19 05 01	Non-composted fraction of municipal and similar wastes	O
19 05 03	Off-specification compost	O
19 08 01	Screenings	O
19 08 02	Waste from desanding	O
19 09 02	Sludges from water clarification	O
19 09 04	Spent activated carbon	O
19 09 0519 12 04	Saturated or spent ion exchange resinsPlastic and rubber	O
20	Municipal wastes (household waste and similar commercial, industrial and institutional wastes) including separately collected fractions	
20 01 02	Glass	O
20 01 39	Plastics	O
20 02 02	Soil and stones	O
20 02 03	Other non-biodegradable wastes	O
20 03 01	Mixed municipal waste	O
20 03 02	Waste from markets	O
20 03 03	Street-cleaning residues	O
20 03 06	Waste from sewage cleaning	O
20 03 07	Bulky waste	O

The list of received waste also includes usable waste (packaging, glass, plastics). These wastes are accepted at the landfill only if they are wastes that cannot be used materially or energetically and this will be documented by a declaration from the producer. 20 03 02-waste from marketplaces is classified according to Decree 341/2008 Coll. as biodegradable waste. It is accepted for landfill only if the share of biodegradable matter is less than 35%.

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