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Bioindication method of soil research in the landfill of municipal solid waste in the North Kazakhstan region in 2016 and 2018

The methods of ecological assessment of soil condition in the territory of solid household waste landfills in the North Kazakhstan region are considered in the article. The priority method for studying soil quality in the North Kazakhstan region is the bioindication method. This method shows the state of the soil cover on the landfill site. Based on the results of soil biotesting, different levels of pollution are obtained in the territory of the North Kazakhstan region. This is due to the fact that unauthorized landfills have different years of formation and the garbage stored in landfills has a different composition. In the majority of settlements on landfills there are remains of animals, organic garbage, liquid wastes. During the experiment, the method of biological monitoring was used in the territory of solid domestic waste landfills in the North Kazakhstan region. Average soil contamination: Novoishimskoye of the district named after G. Musrepov; Ekaterinovka of Zhambyl district. There is no pollution: Lomonosovka of the district named after G. Musrepov; Chagli of Akkayin district; Svyatodukhovka of Zhambyl district; Rassvet of Kyzylzhar district; Bezlesnoye of Akkayin district; Novokamenka of Kyzylzhar district. Despite the long-term accumulation of solid domestic waste on individual soil samples, seeds of cress-lettuce sprouted even with sprouts with small deviations and slight deformations.

Keywords: solid household waste; landfill for household waste disposal; ecological monitoring; bioindicator biotesting.

Introduction

Anthropogenic changes in the biota of terrestrial ecosystems are determined not only by direct human impact, but also mainly by anthropogenic changes in environmental parameters: atmospheric air, soil, surface and groundwater. For the bioindication of terrestrial ecosystems, indicators of the state of higher plants, lichens, mosses, soil algae, bacteria, etc. are most often used. The correct choice of bioindicators plays an important role.

Bioindicators are biological objects (from cells and biological macromolecules to ecosystems and the biosphere) used to assess the state of the environment. When they want to emphasize that bioindicators may belong to different levels of the organization of a living person, they use the term «bio-indicator systems».

Biotesting methods are increasingly used to determine the levels of pollution of our environment: air, water, soil, industrial waste, materials, etc.

Cress-salad is a bioindicator plant. Cress-lettuce is an annual vegetable plant, which has an increased sensitivity to soil pollution by heavy metals, as well as to air pollution by gaseous emissions from motor vehicles. This bioindicator is distinguished by rapid germination of seeds and almost one hundred percent germination, which decreases markedly in the presence of pollutants.

In addition, the shoots and roots of this plant under the action of pollutants undergo noticeable morphological changes (growth retardation and curvature of the shoots, reduction of the length and weight of the roots, as well as the number and weight of seeds).

Cress-salad as a bioindicator is also convenient in that the effect of stressors can be studied simultaneously on a large number of plants with a small area of the workplace. Very short periods of the experiment are also attractive. Cress-lettuce seeds germinate on the third or fourth day, and most of the experimental questions can be answered within 10–15 days.

When conducting experiments with watercress, it should be borne in mind that the water-air regime and the fertility of the substrate have a great influence on the germination of seeds and the quality of the seedlings. In humified, well-aerated soil (black soil, upper horizon of gray forest soil), germination and quality of seedlings is always better than in heavy clay soil, which, due to low permeability to water and air, has a poor water-air regime. Therefore, as a substrate for control, one should take the soil of the same type as for the experiments.

Thus, the experiment with seedlings of watercress is one of the fastest, and the plant itself allows you to clearly judge the quality of the environment [1].

Materials and research methods

Study area

North Kazakhstan region — the area of the region is 97,993 km² and makes up 3.6 % of the territory of Kazakhstan with a population of about 572 thousand people. North-Kazakhstan region is located in the north of Kazakhstan, occupies the southern edge of the West-Siberian Plain and part of the Kazakh Hills (Sary-Arka). The climate of the region is sharply continental. The winter is cold and long, the summer is relatively hot, with a predominance of clear, often dry weather. The North Kazakhstan region is located within the forest-steppe and steppe zones.

On the territory of North Kazakhstan region there is one landfill for solid waste disposal.

The objects of analysis were soil samples collected in the territories adjacent to landfills of solid household waste of the North Kazakhstan region. A total of 7 samples were selected in various parts of the region. Soil samples were collected at landfills with a different composition and a different year of formation.

Representatives of the departments of natural resources and environmental management, energy and housing and communal services, the department of ecology in the North Kazakhstan region, with the participation of representatives of the district housing and communal services departments, optimize landfills in the North Kazakhstan region, conduct regular visits and inspection landfills in areas of the region.

At the end of 2015, there were 579 conditionally-organized landfills. The number of landfills in the North Kazakhstan region exceeds the number of landfills in other areas of the Republic of Kazakhstan [2].

Soils were selected in the summer period of 2016, 2018 from the surface horizon of 0–20 cm by an envelope method with a side of 1 m square. The selection and preparation of soils were carried out according to the requirements of State standart and soil analysis techniques for the components to be determined [3].

Studies were carried out according to the method proposed by A.I. Fedorova and A.N. Nikolskaya. Soil toxicity was assessed by biotesting according to the germination and growth of cress seed. According to the method, the assessment of substrates is carried out in the following variants:

– growing seeds of cress-lettuce on substrates, the pollution of which must be assessed (soil);

– watering the seedlings of an experimental plant with water taken from various sources.

Signs that were used for soil biotesting: seed germination.

For each selected soil sample, 3 samples were prepared at one landfill. As a result, mean values were selected. Depending on the results of the experiment, the substrates are assigned one of four levels of pollution:

1. There is no pollution. Seed germination reaches 90–100 %, seedlings are friendly, sprouts are strong, even. These signs are typical for the control, with which to compare prototypes.

2. Weak pollution. Germination 60–90 %. Seedlings are of almost normal length, strong, smooth.

3. Average pollution. Germination of 20–60 %. Sprouts compared with the control shorter and thinner. Some sprouts have deformities.

4. Heavy pollution. Seed germination is very weak (less than 20 %). Seedlings are small and ugly.

Before setting up an experiment on bioindication of pollution using watercress, a batch of seeds intended for experiments is checked for germination.

Germination is carried out at a temperature of 20–25 degrees. Germination of 90 to 95 % of seeds within 3 to 4 days is considered the norm. The percentage of germinated seeds of the number of sifted is called germination. Watering was performed with settled tap water.

After determining the germination of seeds, the experiment is started in the following sequence:

1. Petri dish filled to half of the investigated substrate. In another cup they put the same volume of a deliberately clean substrate that will serve as a control with respect to the material under study.

2. Substrates in all cups are moistened with the same amount of tap water until saturation prizes appear.

3. In each cup, 25 seeds of watercress are placed on the surface of the substrate. The distance between adjacent seeds is as much as possible.

4. Cover the seeds with the same substrates, pouring them almost to the edges of the cups and gently leveling the surface.

5. Moisturize the upper layers of substrates to lower moisture.

6. For 10–15 days, seed germination is observed, and the substrate moisture content is approximately the same.

7. The results of the observations recorded in the table.

Statistical processing of monitoring results. Biotesting indicators expressed as arithmetic mean values of the growth of test plants from the n-th number of definitions. The significance of the discrepancy between the mean values was assessed using Student's t-test for a confidence level of P = 95 %. This criterion was developed by William Gossett for assessing the quality of beer at Guinness. In connection with the obligations to the company on non-disclosure of commercial secrets, the Gosset article was published in 1908 in the journal «Biometrics» under the pseudonym «Student». Student's *t*-test is used to determine the statistical significance of differences in averages. It can be used both in cases of comparing independent samples (for example, a group of patients with diabetes mellitus and a group of healthy ones), and when comparing related sets (for example, the average pulse rate in the same patients before and after taking an antiarrhythmic drug). In the case of watercress, seedlings grown on soil samples were selected on the territory of landfills with seedlings that were grown in ecologically clean soil.

Results and discussion

1. Biological assessment of soil samples of the North-Kazakhstan region for the period of July-August 2016.

Soil sampling for the study was conducted in July 2016 at 7 points in the North Kazakhstan region:

1. Kiyaly, Akkayin district.
2. Bezlesnoye, Akkaiyn district.
3. Petrovka, Zhambyl district.
4. Svyatoduhovka, Zhambyl district.
5. Krasnaya Gorka, Kyzylzhar district.
6. Novoishimskoye, district named after G.Musrepov.
7. Druzhba, district named after G.Musrepov.

According to the results of the experiment, it was determined that the highest percentage of germination of cress-lettuce seeds is noted at the sampling points: Svyatoduhovka, Zhambyl district (96 %); Bezlesnoye, Akkayin district (92 %).

The smallest percentage of germination of cress-lettuce seeds is noted in the points: Novoishimskoye district named after G. Musrepov (56 %). The average indicator has the following locations: Kiyaly of Akkayin district; Petrovka of Zhambyl district.

During the study, the percentage germination of cress-lettuce seeds was calculated. Based on these data, the level of soil pollution was calculated. It has been determined that:

– contamination is absent at points: Svyatoduhovka, Zhambyl district; Bezlesnoye, Akkayin district;
– low pollution at points: Kiyaly, Akkayin district; Petrovka, Zhambyl district; Krasnaya Gorka, Kyzylzhar district; Druzhba, district named after G. Musrepov;
– average pollution at points: Novoishimskoye, district named after G. Musrepov.

The main natural resources of the region are the soils represented in arable land by 70 % black soil. The territory, despite the general flatness, is characterized by heterogeneity of soil formation conditions. The presence of highly developed meso and microrelief, the heterogeneity of the chemistry and lithology of the parent and underlying rocks cause differences in soil moisture and salt regime even in relatively small areas. Separate soil-forming processes are geographically severely narrowed, and often combined with each other. All this causes the extreme diversity and complexity of the soil cover.

2. Biological assessment of soil samples of the North-Kazakhstan region for the period June-September 2018.

Soil sampling for the study was conducted in June-August 2018 at 7 points in the North Kazakhstan region:

1. Kiyaly, Akkayin district.
2. Bezlesnoye, Akkaiyn district.
3. Petrovka, Zhambyl district.
4. Svyatoduhovka, Zhambyl district
5. Krasnaya Gorka, Kyzylzhar district
6. Novoishimskoye, district named after G.Musrepov
7. Druzhba, district named after G.Musrepov

According to the results of the experiment, it was determined that the highest percentage of germination of cress-lettuce seeds is noted at the sampling points: Svyatoduhovka, Zhambyl district (94 %); Bezlesnoye, Akkayin district (92 %).

The smallest percentage of germination of cress-lettuce seeds is noted in the points: Novoishimskoye, district named after G. Musrepova (67 %).

The average indicator has the following locations: Kiyaly of Akkayin district; Petrovka, Zhambyl district; Krasnaya Gorka, Kyzylzhar district, Druzhba, district named after G. Musrepov.

3. Comparative characteristics of the biological assessment of soil samples of the North-Kazakhstan region for 2016, 2018.

In 2016–2017, akimats of the districts carried out work to reduce the number of landfills. «On this issue, it is necessary to note a formal approach, since work in this direction has been going on for several years, and the number of completed landfills is not increasing», said the chief ecologist of the region, «Optimization was carried out according to the following criteria: unpromising villages, one waste disposal facility for several nearby settlements. According to the results of optimization, the total number of waste disposal facilities is 472, land plots are decorated for 235».

When studying the quality of the soil in the landfill site for two years, no dramatic changes have occurred, since nature has been spending more than one hundred years to restore one centimeter of the fertile soil layer (Fig. 1).

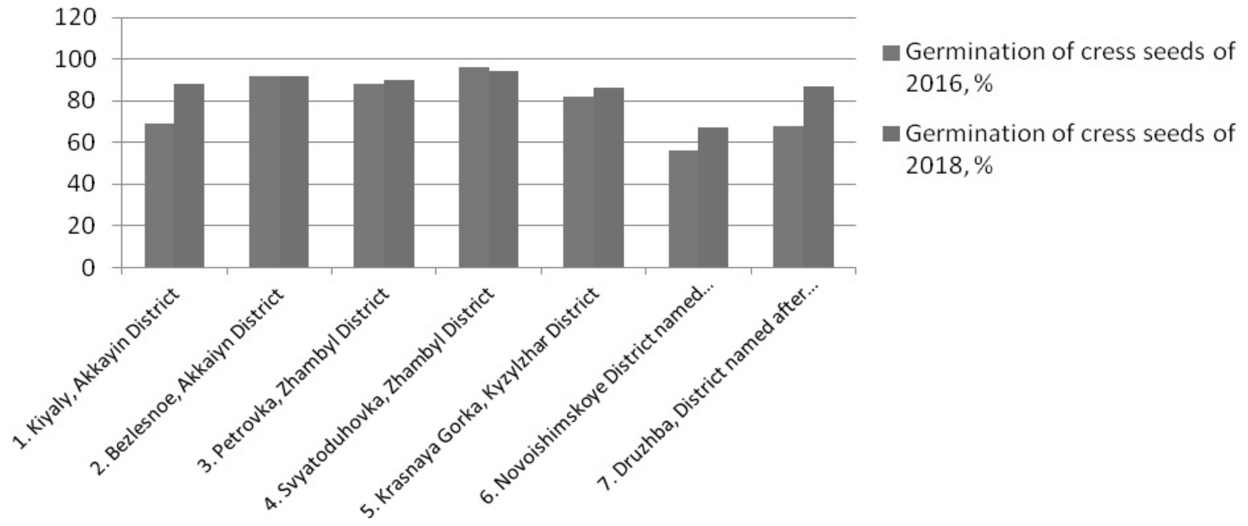

Figure 1. Germination of watercress seeds for 2016, 2018

4. Statistical processing of monitoring results.

In biomedical research, it is sufficient to have a t value equal to or greater than 2, then the identified differences are not accidental, reliable, statistically confirmed (with a probability of more than 95 %). If the value of the criterion is less than 2, then the difference is not proven, is random, not statistically confirmed (probability less than 95 %).

In 7 shoots of watercress for 2018, the average length of M1 was 6.64 cm (m1 = ± 0.17 cm). In the control group (7 shoots in 2016), these figures were: M2 = 6.12 cm, m2 = ± 0.13 cm.

The difference in the average number of shoots 2018 length and the control group in 2016 was quite convincing (Fig. 2).

$$t = \frac{6.64 - 6.12}{\sqrt{0.17^2 + 0.13^2}} = \frac{0.52}{\sqrt{0.0458}} = \frac{0.52}{0.21} = 2.5$$

Figure 2. Calculations of the confidence factor

Conclusion

Soil is the bio-axial formation of the biosphere, the result of the interaction between the atmosphere, hydrosphere, lithosphere and living organisms. Chemical, physical and biological processes constantly and simultaneously take place in the soil.

The principle of biological soil diagnostics is based on the idea that soil as a habitat constitutes a single system with populations of different organisms inhabiting it. Depending on the combination of natural factors that determine the soil-forming process, different soils differ in the composition of their biota, the direction of biochemical transformations and the content of those chemical components that are products of these transformations or their agents.

The strengthening of the anthropogenic press has led to the need to develop methods that can detect the anthropogenically caused degradation of natural ecosystems in time, establish long-term trends and the buffering capacity of biological systems in relation to diverse and mostly concurrent disturbing factors. The active use of biological methods for diagnosing anthropogenic disturbances is currently associated primarily with the rapid response of organisms to any deviations in the environment from the norm. In addition, such a reaction makes it possible to evaluate the anthropogenic impact in terms that have a biological meaning and often those that can be transferred to humans [4].

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2016, 2018 жылдарында Солтүстік Қазақстан облысында қатты тұрмыстық қалдықтар аумағындағы топырақтарды зерттеу әдістері ретіндегі биоиндикация

Мақалада Солтүстік Қазақстан облысының қатты тұрмыстық қалдықтар полигондарының аумағында топырақтың жай-күйін экологиялық бағалау әдістері қарастырылған. Солтүстік Қазақстан облысында топырақ сапасын зерттеудің басымдықты әдісі полигондағы топырақ жамылғысының жай-күйін анық көрсететін биоиндикация әдісі болып табылады. Биотестілеу нәтижесінде Солтүстік Қазақстан облысында полигондар аумағында топырақтың әртүрлі ластану деңгейі анықталды. Бұл санкцияланбаған полигондардың әртүрлі жылдары болғандығына және әртүрлі құрамға ие болуына байланысты. Қатты тұрмыстық қалдықтардың полигондарында жануарлардың қалдықтары, органикалық қоқыс, сұйық қалдықтар бар. Солтүстік Қазақстан облысында қатты тұрмыстық қалдықтар полигондарының аумағында топырақтың жай-күйін зерделеу кезінде биологиялық мониторинг әдісі пайдаланылды. Топырақтың орташа ластануы нүктелерде байқалады: Ғ.Мүсірепов ауданының Новоишимское ауылы; Жамбыл ауданының Екатериновка ауылы. Келесіде ауылдарда ластану жоқ: Ғ.Мүсірепов ауданының Ломоносовка ауылы; Жамбыл ауданының Шағлы ауылы; Қызылжар ауданының Святодуховка ауылы; Қызылжар ауданының Рассвет ауылы; Аққайың ауданының Безлесное ауылы; Қызылжар ауданының Новокаменка ауылы. Іріктелген топырақ үлгілері бойынша аз ауытқулармен және сәл деформациялармен бірге өсімдік тұқымдары өсіретін тұқымдар өсіп шықты.

Кілт сөздер: қатты тұрмыстық қалдықтар, тұрмыстық қалдықтарды көму полигоны, экологиялық мониторинг, биоиндикатор, биотестілеу.

Т.Н. Лысакова, А.М. Нукжанова, П.С. Дмитриев, Ян А. Вендт

Биоиндикационный метод исследования почв на территории свалок твердых бытовых отходов Северо-Казахстанской области в период 2016 и 2018 годов

В статье рассмотрены методы экологической оценки состояния почв на территории свалок твердых бытовых отходов Северо-Казахстанской области. Приоритетным методом исследования качества почв в Северо-Казахстанской области является биоиндикационный метод, который наглядно показывает состояние почвенного покрова на территории свалок. В результате биотестирования почвам на территории свалок Северо-Казахстанской области присуждены различные уровни загрязнения. Это обусловлено тем, что несанкционированные свалки имеют различные годы образования и мусор, складируемый на свалках, имеет различный состав. В большинстве населенных пунктов на свалках, предназначенных для твердых бытовых отходов, встречаются останки животных, органический мусор, жидкие отходы. При исследовании состояния почв на территории свалок твердых бытовых отходов Северо-Казахстанской области использовался метод биологического мониторинга. Среднее загрязнение почвы отмечено в точках: с. Новоишимское, район им. Г.Мусрепова; с. Екатериновка, Жамбылский район, загрязнение отсутствует в точках: с. Ломоносовка, район им. Г.Мусрепова; с. Чаглы, Аккайынский район; с. Святодуховка, Жамбылский район; с. Рассвет, Кызылжарский район; с. Безлесное, Аккайынский район; с. Новокаменка, Кызылжарский район. Несмотря на длительное скопление твердых бытовых отходов на отобранных почвенных образцах семена кресс-салата проросли ровными проростками с небольшими отклонениями и незначительными уродствами.

Ключевые слова: твердые бытовые отходы, полигон размещения бытовых отходов, экологический мониторинг, биоиндикатор, биотестирование.

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