Geoecological zoning of the territory to assess the impact of municipal solid waste landfills on adjacent agricultural land

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Abstract. The paper shows that as a result of scientific study, original geoecological zoning of agricultural areas was developed to take into account and evaluate the impact of pollutants contained in the soil cover on the geoecological potential of the analyzed area. Zoning uses original criteria not previously used for these purposes, which also determines the novelty of the proposed study. The results of this zoning during the implementation of proposed works on the assessment of the territory will have critical and promising significance. This is determined by the fact that the proposed zoning will allow not only obtaining new, previously not used geoecological characteristics of the analyzed territory, but also assessing the geoecological stability of territorial complexes from the point of view of both a natural and an economic object in conditions of active impact of negative anthropogenic activity. The use of the proposed zoning is illustrated by the effect of municipal solid waste (MSW) landfill on adjacent agricultural land. As shown in the above example, such zoning, along with the above, will allow determining the possibility of promising (planned) environmental and economic use of each of the allocated territorial zones taking into account the content of heavy metal salts in the soil with the development of methods and techniques for rehabilitation and restoration of the territories of these zones. The obtained zoning results may also be used for spatial correction, including the selection of locations for MSW landfills, incinerators, points of observation (monitoring) of the spread of pollutants, as well as the basis for initiating lawsuits related to the violation of the ecological state of territorial facilities and the geoecological state of the territory as a whole. The most important result of using the method of zoning agricultural areas described in the paper is the possibility of using the geospatial properties of the land to solve the economic and environmental problems of the country – the strategic task of its sustainable development.

1. Introduction
Pollution as a modern world problem is associated with many different factors of humankind development [1–3]. They include social, cultural, economic, man-made and other factors. The most important of these is the man-made factor, which largely forms the interaction in the human-environment system.
Modern technologies, the large-scale use of which, based on the technical capabilities of the social development of humankind, determine the essence of the man-made factor, are not able to ensure waste-free production. This is the first cause of environmental pollution. The technologies themselves are not balanced with the capabilities of self-regulating natural recovery and adaptation processes. This is the second cause of environmental pollution. The third, among other reasons associated with technogenesis, are underdeveloped technologies for cleaning and recycling production and consumption waste.

As a result, large areas of human habitation are subject to pollution, are being contaminated or are already contaminated [1, 4]. It is obvious that as a result of the devastating effects the areas in which crops are cultivated, as well as the land used for raising livestock, i.e. agricultural territories, are the most dangerous, in addition to the places where people live.

2. Results and Discussion
Our studies show that the sources of pollution of agricultural areas are not only industrial enterprises, but also agricultural production itself due to the negative impact of the previously mentioned technological factors. Along with them, landfills of municipal solid waste (MSW landfills) are dangerous sources of pollution of agricultural areas. The emergence of such a source of environmental pollution is paradoxical, since MSW landfills for their intended purpose are designed to prevent the possibility of pollution, eliminate (stop) pollutants and prevent their occurrence. The reason for such sources of pollution as MSW landfills is the lack of proper control over the process of their operation.

Moreover, the territories of MSW landfills may pose an increased risk compared to other sources of environmental pollution. This is caused by the fact that at MSW landfills waste is considered not so much as deposited (deferred) or currently unused resources, but as resources to be transformed. The main result of this transformation is biogas. Along with biogas, during the transformation process, salts of heavy metals (HM salts) are released, which, together with other pollutants, enter the aquatic and soil environment of their adjacent, typically agricultural areas.

Besides, the danger of MSW landfills is characterized by a significant duration (15-20 years) of their negative impact, as well as their proximity to settlements and territories of active agricultural production.

Currently, neither Russian nor world agricultural production can abandon the production of agricultural products on contaminated lands. This is due to limited arable and foraging land, as well as the lack of widespread and reliable information on the content of pollutants in the soil cover of these lands.

It should be noted that while the expansion of arable and fodder land is strictly regulated (limited) by the possibility of developing new land with the progressive growth of cities, the current trends in digitalization, remote sensing techniques and aerospace technologies currently allow for a significant increase in the detection of contaminated land used for agricultural production [5, 6]. We believe that these circumstances should be considered as one of the leading ways to solve the problem.

However, the results obtained through modern research methods are only an information base for solving the problem of using agricultural areas subjected to negative man-made impacts (pollution).

Zoning of agricultural land is one of the efficient methods of processing and using information on the state of agricultural land. Zoning as a technological process is carried out to allocate areas (form zones) with the same properties necessary (important) for the implementation of the zoning purpose. Zoning is widely used in land management [7–9], which improves the use of agricultural technologies, soil conservation and the organization of the territory as a whole.

As proposed in this paper, the purpose of agricultural zoning is the allocation of territories (formation of territorial zones), the content of pollutants in the soil cover of which determines the subsequent use of crops grown in these zones.

In our opinion, this is the main condition for the possibility or forced need to use contaminated land for agricultural production. Heavy metals with negative effects on various crops are considered as a pollutant.
Table 1 presents the main criteria for levels of heavy metals in the soil-plants system that affect the use of grown crops and the formation of territorial zones based on them.

**Table 1. Criteria for zoning areas exposed to heavy metals (HMs)**

| HM in soil | Criterion for HM content in soil (in the soil-plants system) |
|------------|-------------------------------------------------------------|
| I          | Transition of HM to plants above the permissible level for food products used in raw form for baby food |
| II         | Accumulation of HM in plants above MPC for food raw materials and food products |
| III        | Accumulation of HM in plant products intended for cattle feed – in excess of the established standards |
| IV         | Significant reduction of yields of high and medium HM-sensitive crops, beginning of death of high HM-sensitive crops |
| V          | Significant reduction in yields of HM-resistant crops, onset of death of medium-sensitive crops |
| VI         | Loss of HM pollution-resistant crops |

Areas that are not included in the presented zoning system should not be considered contaminated, and crops growing in these areas are not limited in use.

Table 1 shows that the maximum permissible concentration (MPC) is used as an indicator to estimate the value of the accepted criterion. It should be noted that different MPC are used for zoning the territory, each of which characterizes qualitative changes in the use of cultivated crops. The significance of these indicators is contained in various regulatory directories regulating the quality of crop production [10].

Different heavy metals in the arable soil layer and their quantitative values in the form of MPC have different effects on the possibility of subsequent use of crops growing on them. In this regard, Table 2 shows the calculated indicators for classifying the most common heavy metals as pollutants to the six soil levels indicated in Table 1.

**Table 2. Heavy metal (HM) levels in soil (MPC share)**

| Indicator | HM | I  | II  | III | IV  | V   | VI  |
|-----------|----|----|-----|-----|-----|-----|-----|
| HM content in soil (MPC share) | Cd | 1.0-2.0 | 2.0-3.0 | 3.0-5.0 | 5.0-7.0 | 7.0-10.0 | >10.0 |
|          | Cu | 1.0-1.5 | 1.5-2.3 | 2.3-3.8 | 3.8-5.3 | 5.3-7.6 | >7.6 |
|          | Ni | 1.0-2.5 | 2.5-3.8 | 3.8-7.5 | 7.5-10. | 10.0-12.5 | >12.5 |
|          | Pb | 1.0-1.6 | 1.6-2.3 | 2.3-7.8 | 7.8-11.0 | 11.0-15.6 | >15.6 |
|          | Zn | 1.0-1.4 | 1.4-1.8 | 1.8-4.5 | 4.5-6.4 | 6.4-9.1 | >9.1 |

In addition to the qualitative change in crops cultivated on contaminated soils, there is also a process of decreasing the yield of these crops depending on their sensitivity to pollution.

Table 3 shows an indicative reduction in crop yields based on their sensitivity to pollution.

**Table 3. Reduced crop yields taking into account HM content in soil (%)**

| Behavior of crops to HM in soil | I  | II  | III | IV  | V   | VI  |
|--------------------------------|----|-----|-----|-----|-----|-----|
| Resistant                      | -  | -   | < 2 | 2-40 | 40-70 | 70-100 |
| Low sensitive                  | -  | < 2 | 2-5 | 5-50 | 50-80 | 80-100 |
| Medium sensitive               | < 2 | 2-5 | 5-10| 10-70| 70-90| 90-100 |
| High sensitive                 | < 5 | 5-10| 10-20|20-90| 90-100| 100  |

Crop types grouped by sensitivity to heavy metals are shown in Table 4.
It should be noted that the most sensitive crops are those grown in gardens, homesteads and summer cottages, which, as a rule, are very rarely checked for the content of pollutants, which once again emphasizes the importance of zoning in areas affected by pollution.

The data given in Tables 1-4 allow to accurately calculating losses of agricultural products when placing crops near MSW landfills. Zoning and the calculations of product losses based on it under the influence of the negative impact of MSW landfills may be a real basis for the legal justification of the procedure for initiating claims for compensation for losses, damages and lost benefits from MSW landfills.

**Table 4.** Grouping of crops by sensitivity to heavy metals

| Types of crops                                                                 | Crop group on sensitivity to heavy metals |
|--------------------------------------------------------------------------------|-----------------------------------------|
| Rye, oats, barley, corn, wheat, sunflower.                                     | 1. Resistant                             |
| Potatoe, radish, turnip, onion (bulb onion), cabbage, celery.                 | 2. Weakly sensitive                      |
| Carrot, beet, zucchini, tomatoe.                                               | 3. Medium sensitive                      |
| Cucumber, parsley, dill, onion (leaf), spinach, lettuce.                       | 4. Highly sensitive                      |

Along with this, the proposed zoning of contaminated land will lead to the need to adjust the calculation of the differential rent received from these lands (agricultural land), the price of these lands, their cadastral value and, as a result, serve as a basis for changing the value of taxation for their use.

Let us address the definition of differential rents of contaminated agricultural land.

Currently, the scientific and methodological literature considers various approaches to calculating the differential rent of contaminated land. Taking into account the drawbacks of the considered approaches [7] it is proposed to define the differential rent of contaminated land as the difference between the social value of products obtained on non-contaminated land and the individual value of products obtained on contaminated land. At the same time, to calculate the public cost of products, we will use the public price of production, calculating it as a weighted average (by types of crops and channels of sale) price of the sale of the main crop on the date of calculation (Pav), and to calculate the individual cost of products on contaminated lands we will use the cost of the main (leading) crop on contaminated lands (Cact).

As a result, the formula for calculating the differential rent of contaminated land will be as follows:

\[ Dr_c = Pav \times Yn - Cact \times Yact \times Pst \] (1),

where \( Dr_c \) is differential rent of contaminated land, RUB/ha; \( Pav \) is weighted average (by crop types and distribution channels) price of sale of the main crop as of the date of calculation (on non-contaminated lands), RUB/c; \( Yn \) is normal (normative) yield of leading crop, c/ha; \( Cact \) is actual cost of leading crop (on contaminated lands), RUR/sec; \( Yact \) is actual yield of the leading crop (on contaminated lands), c/ha, on average for 5-7 years; \( Pst \) is profitability ratio (standard), which ensures expanded production at a given rate.

Given that different pollutants have different effects on yields and costs of different crops, differential rents of contaminated land should be calculated for all crops, taking into account their share in the crop pattern. Then the value \( Dr_c \) will be determined by the following formula:

\[ Dr_c = \sum_{i=1}^{n} Ps_i \times Yn_i \times Sh_i - \sum_{i=1}^{n} Cact_i \times Yact_i \times Sh_i \times Pst_i \] (2),

where \( Ps_i \) is sale price of \( i \) crop received on uncontaminated lands, RUB/c; \( Yn_i \) is normal (normative) yield of \( i \) crop on uncontaminated lands, c/ha; \( Sh_i \) is share of \( i \) crop in the structure of sown areas; \( Cact_i \) is actual cost of \( i \) crop on contaminated lands, RUR/c; \( Yact_i \) is actual yield of \( i \) crop in 5-7 years.
on contaminated lands, c/ha; $P_{st,i}$ is profitability ratio (standard) of $i$ crop, which ensures expanded production at a given rate; $n$ is the number of different types of crops; $i$ is the type of crop.

It is known that the subsequent transition from differential rent to the price of land is determined by its capitalization.

The cadastral value of contaminated land is also based on a rental approach by making adjustments (coefficients) that take into account the decrease in yields and the cost of products from the negative impact of pollution. As a result, significant changes can be made to the taxable base for the use of contaminated land. Given that the tax system has not only a fiscal but also an incentive function, the proposed zoning will contribute to the creation of a certain economic and legal framework to eliminate the negative effects of pollution on productive agricultural lands through a system of tax benefits and other incentive mechanisms.

In conclusion of this brief publication it should be noted that in the current conditions of the active development of digitalization among the three main tasks, the solution of which should be realized on the basis of digital opportunities, along with the formation of sustainable development of natural and anthropogenic territories in the agricultural sector of the economy, a cadastral assessment of land, which involves determining the suitability of land not only for various agricultural lands, but also crops – the implementation of a complex of work on the functional zoning of the territory is a key task. Moreover, zoning should be the key to moving the country from the institution of targeted use to the institution of authorized use of the country’s land fund as a whole.

According to State University land administration scientists, such a transition is expensive, which is obviously the reason for the problem to date, but sooner or later these funds should be sought, since no one can currently propose or justify another alternative to the rational use and protection of land.

3. Conclusion
The materials and arguments presented in this paper allow, along with the previously presented materials, drawing the following conclusions on the example of MSW landfills: zoning the territory to assess the impact of municipal solid waste landfills on adjacent agricultural lands will ensure the following:
- rational and efficient use of these lands;
- legal framework for the recovery of damages and losses of agricultural land users;
- reasonable adjustment of the tax base when using contaminated land, stimulating the need to eliminate pollution;
- conditions for making adjustments to the differential rent, price and cadastral value of contaminated land;
- favorable prerequisites for conducting assessment and cadastral work using digital technologies and a number of other favorable conditions for the use of contaminated agricultural land;
- use of geospatial properties of the earth to solve the economic and environmental problems of the country – the strategic task of its sustainable development.

Any zoning, as a method of assessing the state of a geospatial object according to specific criteria and with a specific purpose, cannot be deprived of rationality and efficiency.

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