Methodical aspects and results of the assessment of the ecological risk of pollution of soils of the Ukrainian Danube region

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Introduction

Current use of the country's soil resources demands a rapid implementation of the rational nature management which the first and most important stage is making a comprehensive assessment of the quality condition of soils and determination of the permissible anthropogenic impact (Shylov, 2016; Loboda et al., 2020). The land potential of each region makes the basis of its economic development and social and economic welfare.

Figure 1 *Map chart of the Danube basin and the site of the Ukrainian Danube region.*

Topicality of the assessment of the risk of soil of the Ukrainian Danube region (Figure 1) is linked to the following issues: 1 – the unique nature of the Danube region within the boundaries of Odesa region of Ukraine from the viewpoint of its geography, environment and economic development prospects for the movement to integration in Europe; 2 – the necessity to assess the ecological risks because of the more strigent requirements of the environmental legislation and as a preventive measure against possible considerable economic losses in future; 3 – lack of the study of possible ecological risk scenarios for the region under conditions of the ever increasing anthropogenic impact upon the natural ecosystems; 4 – absence of the developed integrated strategy of effective and sustainable management of natural resources based on assessment of the regional risks which is aimed at solving the problems arising between the social and economic development goals and the negative consequences of the destabilizing factors impact (Serbov et al., 2021). The work was aimed at assessment of the ecological risks of soil pollution at the sites where useless plant protection chemicals are stored. These problems necessitated to solve the following tasks: 1) to develop recommendations pertaining to the use of indicators of soil condition with due account of the physical degradation and pollution of soil; 2) to assess the general condition of the land resources in the Danube region of Ukraine and assess the risk of instability of the soil ecosystems; 3) to assess the ecological risks associated with handling useless plant protection chemicals.

Method of investigations

The integrated assessment of the ecological condition of soil and bottom sediments in the Danube region of Ukraine and the determination of the risk of their pollution were accomplished with the use of method proposed in the work (Serbov et al., 2021).

The above mentioned method were adapted to the conditions of our country and made it possible to determine the allowable anthropogenic load so as to preserve the balance of the ecosystem and its main components. When performing assessment of the soil pollution risks in the Danube region of Ukraine, the following considerations were taken into account: 1) the current condition of the agricultural lands, including determination of their structure and top soil, ecologic resistance of the lands, content of humus and the main elements of plant nutrition, productivity of main agricultural crops, the existing erosion and salting level as well as scoring of lands; 2) condition of the wooded lands indicating their structure, forest coverage with relation to land areas, forest quality, forest stand, stock of forest forming species and the average wood increment; 3) current state of the nature reserve lands (NRL) indicating the NRL structure, number and locations of the existing NRL objects according to the territorial taxons and percentage of the NRL in the land structure of the corresponding taxon. The integral indicators of the land condition (I_{z_st}) were determined as the average score of all indicators

$$I_{z\_st} = \frac{1}{k}\sum_{i=1}^{k} Z_i ,$$

where Z_i – scores of the i^{th} indicator; k – number of indicators.

The integral indicator of the land pollution (I_{zab}) was calculated by the formula

$$I_{zab} = \max(I_1, I_2, \frac{1}{4}\sum_{i=3}^{6} I_i, I_7, \frac{1}{3}\sum_{i=8}^{10} I_i) ,$$

where I_i – score of the i^{th} indicator (1 – good condition; 2 – satisfactory; 3 – medium, 4 – bad; 5 – very bad). Soil resistance to pollution depends on a great number of factors, the main being: slope steepness, stoniness, specific resistance, structure, mechanical composition of soil, water conditions, humus content and others. Depending on the value of the factor of the territory, the indicator score of the territorial taxon was determined. At the concluding stage the integrated evaluation of the ecological resistance of soil (C, %) was determined by the formula shown below

$$C = \frac{100}{Q}\sum_{j=1}^{N} C_j ,$$

where C_j – score of the j^{th} assessment indicator; N – number of indicators used in the calculation pattern used for assessment; Q – the maximum possible sum of scores of the indicators used for making the calculation (Q = 4N) in accordance with the used indicators. As the indicator value characterizing circulation of the industrial waste and its accumulation, proposed was the reduced density indicator of the industrial waste formation for a year (Z_W, t/km^2) which was calculated by the formula

$$Z_W = \frac{I_{zuv}}{S} ,$$

where I_{zuv} – integrated indicator of the total waste formation (accumulation), t/year; S – area of the appropriate territorial taxon, km^2. In its turn, I_{zuv} was determined by the formula

$$I_{zuv} = 5000 M_1 + 500 M_2 + 50 M_3 + M_4 ,$$

where M_1, M_2, M_3 and M_4 – number of the formed (accumulated) industrial waste classified according to the *1st, 2nd, 3rd* and *4th* hazard category, t/year. The indicators of the ecological condition of soils are: the land areas withdrawn from the agricultural use because of their degradation, coverage of the humus layer with abiotic depositions, increase of soil density, high groundwater level and loss of humus for the last decade. Also, the following factors were accounted for: increase of the highly soluble salts and a fraction of the exchangeable sodium in soil, decrease of the active microbial mass level, excessive values of the MAC of chemicals, a part of the polluted agricultural products and decrease of the average productivity of the agriculture. The integrated index of the ecological condition of soils (I_{Gr_st}) was determined as the maximum score of the worst indicator

$$I_{Gr\_st} = \max(I_1, I_2, ..., I_j, I_k) ,$$

where I_j – score of the j^{th} indicator; k – number of indicators. On the basis of the accepted approach for the integrated assessment of the land condition, the regional assessment of the ecological risk at the current condition of the i^{th} component of the environment was calculated by the formula (Rybalova et al., 2013)

$$P_i^c = f_i(K_i^c, H_i^c) ,$$

where P_i^c – probability of the soil resistance deterioration under the current condition of the i^{th} components of the ecosystem; K_i^c – current condition of the i^{th} component of the environment; H_i^c – anthropogenic load value resulting from the impact of negative factors on the i^{th} component of the environment. The ecological risk for soils (P_s^c) was determined by the formula

$$P_s^c = f(S_d \langle d = \overline{1, N_S} \rangle, H_{SI} \langle l = \overline{1, N_{HS}} \rangle) ,$$

where S_d – current condition of soils; H_{SI} – integrated assessment of the anthropogenic load resulting by the impact of the negative factors on soils according to the d^{th} indicator. The critical condition value (K_i^K) of the i^{th} component of the environment, when degradation starts and the resistance of the ecosystem is disturbed, occurs in accordance with the following two scenarios. First, when the current condition of the ecosystem is close to the critical one, then even a small anthropogenic load (H_i) can lead to the intensive development of the degradation processes. Second, when the anthropogenic load exceeds the permissible scales. In order to make a more detailed assessment of the ecological risk, it is required to consider the regional ecosystem ability to self-regeneration, distance of the ecosystems from the sources of impact, duration of the impact produced by the anthropogenic load, etc. Then the risk of disturbance of the i^{th} component of the ecosystem resistance (P_i) is expressed as a function of the kind

$$P_i = f(r, K_i^K, H_i, L, t),$$

where K_i^K – critical condition of the i^{th} component of the ecosystem; r – distance of the ecosystems from the sources of impact; t – time required for the ecosystem to reach the critical condition; L – ability of the ecosystem to self-regenerate after the negative impact of the anthropogenic load H_i.

Results of investigations

Use of the agricultural lands and ploughness of the Danube areas of Odesa region are characterized, on the average, by such indicators: 66.2% – the level of the agricultural land use; 87% – ploughness of the territories. It was established that the integral index of the land condition I_{z_st} varies from 3 to 3.17 and corresponds to the *2nd* group of the sites (3 < I_{z_st} < 3.3) where the soil condition is assessed as "unsatisfactory". According to the expert assessment, the physical degradation of soils is manifested, above all, in excessive density almost across 38.4 % of the ploughed area of the region while the total area of the degraded soil reaches 98,000 ha. Being a factor characterizing degradation of the ground layer and ecological hazard, erosion is assessed, above all, by intensity of soil wash and the volumes of the ground substrate transfer, which varies from 10-15 to 20-25 t/ha. Assessment of soil pollution was performed with the use of the data obtained from 645 tests. Evaluations of the soil ecosystem resistance disturbance in have shown the "high" level (P_s^c = 0.25).

As regards assessment of the ecological risks when handling useless plant protection chemicals (UPPC), it was determined that in the territory of the Danube regions there are 6 warehouses containing UPPC or 1.08% of the total number of such warehouses in Odesa region. The volume of stored UPPC therein amounts to 27.8 t or 2.1% of their total volume in the regional warehouses. These warehouses have no certificates and their condition is unsatisfactory. Assessment of soil pollution was accomplished by comparing the measured concentrations of pollutants (cadmium, copper, zinc, manganese, cobalt, arsenic, lead, mercury, DDT, DDE, DDD, γ-HCCH/lindane, geptachlorine) with the MACs and with sanitary standards (Serbov et al., 2021).

Assessment of the ecological condition and calculations of the ecological risk levels for soils at the UPPC warehouse locations have proved the following: 1) the ecological condition of soil near Desantne village and Stari Troyany village, and Utkonosivka village and Novokalanchak village is determined as "satisfactory", and the ecological risk level as "high" (P_s^c = 0.25-0.3); 2) the ecological condition of soil near village Novoselivka and village Vasylivka, and Kirnychki village, Ostrovne village, Glavani village Kamyanske village and the area between villages Dilen and Novoselivka is determined as "medium", and the ecological risk level as "considerable" (P_s^c = 0.35-0.4); 3) the ecological condition of soil near Shevchenkove village and Zadunaivka village was determined as "bad", and the ecological risk level as "high" (P_s^c = 0.6-0.65).

Conclusions

The determined integral index of the land condition I_{z_st} within the boundaries of the Ukrainian Danube region varies from 3 to 3.16 and meets the requirements of the *2nd* group of objects while the quality condition of lands is assessed as "unsatisfactory". The risk of the soil ecosystem disturbance level that exceeds the criterion is assessed as "high" (P_s^c = 0.25). The ecological condition of soils at the locations where UPPCs are stored meets, predominantly, the "medium" category requirements. The ecological risk level varies between "high" and "considerable" (P_s^c = 0.25-0.4). However, near the UPPC warehouses in Shevchenkove village and in Zadunaivka village the maximum levels of the environmental pollution were recorded. The general ecological condition of soils in the mentioned areas is assessed as "bad" and the ecological risk level is "high" (P_s^c = 0.6-0.65).

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