ORIGINAL ARTICLE

# Orenburg Region soil and vegetation complex pollution risk evaluation


**I. V. Efremov, V. A. Solopova, E. L. Gorshenina, N. N. Rakhimova, N. V. Eremina, E. E. Savchenkova, V. A. Litvinov, O. V. Chekmareva**

*Department of Health and Wellness, Federal State Educational Institution of Higher Professional Education, Orenburg State University, Orenburg, Russia*



## Abstract

**Aim:** The objective of the present study to find out the heavy metal accumulation in steppe landscapes soils and vegetation. **Materials and Methods:** On imitating modeling basis, the dependence of heavy metals in "soil-plant" system preferential distribution on their subsystems transition intensity was obtained. **Result and Discussion:** On the basis of experimental data system contamination risk analysis, a major percentage of soil trace elements accumulated in the plant root system with lowest pollution elements in aboveground parts. **Conclusion:** Based on the changes in soil-plant absorption capacity, different percentage of heavy metal migrates above and underground part of vegetation. The proposed method of analysis will help in the future environmental pollution risks evaluation studies.



**Key words:** Soil, plants, heavy metals, the pollution risk, absorption


## INTRODUCTION

Soil physical and chemical properties research, carried out in the recent years, has provided considerable experimental material on the heavy metals content - pesticides, nutrients, and other compounds.[1,2] Forecasting changes in the soil qualitative composition, the toxic elements content, are a very topical and difficult task which is solved by the mathematical modeling method. So-called regression mathematical models that are currently used do not completely reveal the mechanisms occurring in the system; therefore, models constructed on the simulation basis are increasingly used.[3] In such models, a significant amount of components that take into account the processes of chemical compounds transformation, diffusion, sorption, and others is typically used. Simulation allows to integrate a significant amount of information about the physical and chemical processes occurring in the system, enabling detailed analysis and dynamic characteristics prediction. However, such bulky models studies are connected with considerable mathematical difficulties. It should be noted that for system complex description, one, two, or three-component model is enough which is much easier to analyze, and at the same time, allows to estimate the main characteristics of the system behavior.[4]

## MATERIALS AND METHODS

The idea of heavy metals in the soil-plant system migration based on probabilistic modeling was used as the main theoretical modeling method.

Let's consider a system consisting of the following components: The soil, the root system, and aboveground plant part. Such system can be attributed to the self-regulating, that is, formed in the course of evolution as a whole system and its individual components. The system component is interrelated.[5]

In the process of the system components, interaction the matter and energy transfer takes place. We define the initial conditions as follows:

1. At the in1itial time it is introduced the initial concentration of the pollutant $C_0$;


**Address for correspondence:**
I. V. Efremov, Federal State Educational Institution of Higher Professional Education, Orenburg State University, Orenburg, Victory Avenue 13, Russia.
E-mail: belova.ores@gmail.com



**Received:** 04-07-2017
**Revised:** 29-07-2017
**Accepted:** 15-08-2017

2. Between the system components, there is material exchange with different intensities:
   $\lambda_1$ - the intensity of a substance from the soil to the root system transition;
   $\lambda_2$ - the intensity of a substance from the plant root system to the aboveground transition;
   $\lambda_3$ - the intensity of the substance from the aboveground plant part into the soil transition.

We characterize the system state by the probability of finding a pollutant in the system component parts:
$P_n$ - The probability of finding a contaminant in the soil;
$P_k$ - The probability of finding a contaminant in the plants root system;
$P_H$ - The probability of finding a contaminant in the aboveground plants parts.

We formulate the task as follows: To determine the pollutant concentration, that is, set in each of the system components, provided by the stationary pollutant intensities transition from one component to another, as time observation tends to infinity.

The total flow of events that display the system in $P_n$ status will proceed with the intensity $\lambda_1$

- The probability that over time Δt, the system will come from the state $P_n$ is ($\lambda_1$.Δt);
- The probability that it will not work ($1-\lambda_1$.Δt).

The total probability will be determined from the expression:

$$P_n \cdot (t+\Delta t) = P_n \cdot (t) \cdot (1-\lambda_1 \Delta t)+\lambda_3 \cdot P_H \cdot (t) \cdot \Delta t \quad (1)$$

After conversion, we get:

$$P_n \cdot (t+\Delta t)-P_n(t) = -P_n(t)\, \lambda \Delta t+\lambda_3 P_H(t)\Delta t \quad (2)$$

If Δt→0, we have

$$\frac{dP_П(t)}{dt} = -P_П(t)\lambda_1 + \lambda_3 P_Н(t) \quad (3)$$

Similarly, for the system states $P_k(t)$ and $P_H(t)$, we display the equation:

$$\frac{dP_к(t)}{dt} = -\lambda_2 P_к(t) + \lambda_1 P_П(t) \quad (4)$$

$$\frac{dP_H(t)}{dt} = -\lambda_3 P_H + \lambda_2 P_к \quad (5)$$

The equations 3, 4, and 5 set form Kolmogorov equation system of s, wherein the unknown quantities appear probability $P_n$, $P_k$, and $P_H$. As noted above, they can be interpreted as the probability of finding the pollutants in the root system, the aboveground plants parts and soil. For the transfer of pollution from one environment to another corresponds the various processes such as diffusion, sorption, dry, and wet deposition. Over time, i.e., t→∞ in system components is installed the equilibrium concentration of pollutants in accordance with probabilities $P_n$, $P_k$, and $P_H$.

Let us define the final probabilities $P_n$, $P_k$, and $P_H$ of the following considerations: Final probabilities are independent of time, and therefore,

$$\frac{dP_П}{dt} = 0\,; \frac{dP_к}{dt} = 0\,; \frac{dP_Н}{dt} = 0\,.$$

Then, we have the system:

$$\begin{cases} -\lambda_1 P_П + \lambda_3 P_Н = 0 \\ \lambda_2 P_к + \lambda_1 P_П = 0 \\ -\lambda_3 P_Н + \lambda_2 P_к = 0 \end{cases} \quad (6)$$

The system (6) is redefined, so we eliminate the third equation and replace it by the equation:

$$P_n+P_k+P_H = 1 \quad (7)$$

We obtain:

$$\begin{cases} -\lambda_1 P_П + \lambda_3 P_Н = 0 \\ -\lambda_2 P_к + \lambda_1 P_П = 0 \\ P_П = 1 - P_к - P_Н \end{cases} \quad (8)$$

When pass from the probabilities to concentration, we get:

$$\begin{cases} -\lambda_1 C_П + \lambda_3 C_Н = 0 \\ -\lambda_2 C_к + \lambda_1 C_П = 0 \\ C_П = C_0 - C_к - C_П \end{cases} \quad (9)$$

Solving the system (9), we obtain:

$$C_Н = \frac{\lambda_1\lambda_2 C_0}{\lambda_1\lambda_2 + \lambda_2\lambda_3 + \lambda_3\lambda_1} \quad ; \quad C_к = \frac{\lambda_1\lambda_3 C_0}{\lambda_1\lambda_2 + \lambda_2\lambda_3 + \lambda_3\lambda_1} \quad ;$$

$$C_П = \frac{\lambda_2\lambda_3 C_0}{\lambda_1\lambda_2 + \lambda_2\lambda_3 + \lambda_3\lambda_1} \quad (10)$$

These relations allow for the substance known intensity transition in the system "soil-plant" to determine the distribution of substances in the subsystems. It should be noted that the transitions intensity is determined by the soils and plants properties.[6]

For the purposes of obtained model parameters, identification was carried out experimental studies of soil and plants samples to determine the heavy metals concentrations.

The study of Orenburg region soil surface was taken the following samples: Ordinary chernozem, typical, southern, and dark chestnut incompletely developed soils, which make up more than 75% of the region total area. Soil sampling was chosen natural landscape plot size of approximately 100 $m^2$. Sites to be surveyed were selected with uniform soil and vegetation cover, and the most typical for the major agroecological features of the area is soil types and relief elements. From the chosen site, mixed soil sample was taken, consisting of the five-point samples, taken by the envelope method.

The nature and extent of trace elements in the soil profile vertical migration were studied step-by-step along the profile 0-5, 5-10, 10-20, 20-30, 30-40, and 40-50 cm soil of natural ecosystems.

Each layer samples at the sampling point were mixed thoroughly freed from stones, roots, and other impurities. Of the total, weight by the quartering method was selected about 1 kg of the mixed sample. Soils were dried to air-dry condition, ground in a mill, abraded, and sieved through a hole diameter of 0.73 mm. Then, by means of quartering, 50-100 g samples were used for analysis. Plant samples were taken at the same place as the soil samples. The selection of plants was carried out on 10 selected plots of 1m2, placing them along the diagonals of the plot. The combined samples were cut into lengths of 1-3 cm. Then, the quartering method of these samples was isolated an average sample that was dried in an oven at a temperature of 60 ° C to air-dry condition, followed by ashing (liming) at 450-500°C. Sample weight after drying was 100 g. The heavy metals in soil and plants content were determined by spectral analysis emission at the crossed dispersion STE-1 spectrograph.[7]

## RESULTS

Studied area of the soil (depth 30 cm) trace elements analysis showed that in southern chernozem, copper content increased to 50.74 mg/kg and titanium to 3873 mg/kg; in typical, black chernozem chromium to 333 mg/kg; and in ordinary, chernozem silver to - 0.33 mg/kg and zirconium to 201.7 mg/kg. Dark chestnut incompletely developed soil contains the largest zinc amount - 90.69 mg/kg, lead - 18.9 mg/kg, nickel - 150.7 mg/kg, and Mn - 1085 mg/kg.

The changes range in copper concentration in the soil is between 4.2 and 39.6 mg/kg. A significant amount is found in thistle - 38.6 mg/kg (dark chestnut incompletely developed soil). There is a high content of copper in plants growing on the dark chestnut incompletely developed soil.

The zinc content in the plants is in the range from 7.1 to 29.0 mg/kg. The most significant zinc content is in mugwort - 29.0 mg/kg (chernozem ordinary) and chicory - 26.8 mg/kg (dark chestnut incompletely developed soil).

Lead in the aboveground plants parts contained in an amount from 0.3 to 4.2 mg/kg. A significant amount of lead contained in the plants growing on the dark chestnut incompletely developed soil.

The nickel content in the plants is in the range from 5.3 to 15.9 mg/kg. A significant nickel content occurs in salvia and thistle, and the smallest in mugwort.

The chromium content in the plants is in the range from 0.6 to 15.7 mg/kg. A significant amount of chromium contained in thistle - 15.7 mg/kg (chernozem typical), the lowest - in yarrow - 0.5 mg/kg (dark chestnut incompletely developed soil).

The vanadium content ranges from 0.48 to 11.7 mg/kg. A significant amount of vanadium fells on plants growing on chernozem ordinary with it maximum in mugwort.

The titanium quantity in the test plants is from 8.8 to 80.9 mg/kg. The highest titanium concentration is found in chicory - 80.9 (southern chernozem) and mugwort - 79.9 (ordinary chernozem), and the lowest concentration is in mugwort - 7.8 mg/kg (dark chestnut incompletely developed soil).

Molybdenum is found in an amount from 0.28 to 3.77 mg per 1 kg of dry weight with the highest concentration in thistle - 5.8 mg/kg (chernozem typical).

The silver content in plants ranged from 0.01 to 0.19 mg/kg. The highest concentration is found in thistle - 0.19 mg/kg (chernozem typical), chicory - 0.17 mg/kg, yarrow - 0.16 mg/kg (southern chernozem), salvia - 0.18 mg/kg, and mugwort - 0, 17 mg/kg (ordinary chernozem). The lowest silver content is observed in plants growing on the dark chestnut incompletely developed soil.

Gallium content in all plant species is distributed substantially uniformly from 0.15 mg/kg to 0.94 mg/kg, with the highest concentration in thistle (chernozem typical).

Barium contains in plants at concentrations ranging from 6.8 mg/kg to 59.7 mg/kg. The considerable barium amount is in the salvia (chernozem typical), the lowest is in mugwort (southern chernozem), and the highest barium content occurs in plants on typical black soil.

Zirconium is found in the aboveground plant parts ranging from 4.7 to 12.9 mg/kg. The highest concentration is in the chicory - 12.9 mg/kg on the southern black soil and chicory - 11 mg/kg on chernozem typical.

The manganese content in different plant species is in the range from 20.3 to 77.9 mg/kg. The highest manganese content is observed in chicory (southern chernozem) and lowest in mugwort (chernozem typical).

Data analysis on the trace element content in the aboveground plant part showed that the Cu, Zn, Pb, Cr, V, Ti, Mo, Ag, Ga, Ba, and Mn have great dispersion. A more uniform distribution is observed in Ni and Zr.

Plant root nutrition physiology is based on the principle of ion contact exchange between the colloidal particles and roots. The absorption properties parameters are the absorption capacity (mg per 100 g soil), the environment pH, and the contained in the soil absorbing ions complex ratio. The copper content of the plant root system ranges from 12.9 to 102.7 mg/kg. A significant amount of copper is found in yarrow - 101 mg/kg and mugwort - 77.2 mg/kg (dark chestnut incompletely developed soil), and the lowest content is in mugwort - 11.9 mg/kg (ordinary chernozem). The highest copper content falls on the plants growing on the dark chestnut incompletely developed soil.

The amount of zinc in the root system is in the range from 10.6 to 55.1 mg/kg. The highest zinc concentration is found in chicory - 52.2 mg/kg and yarrow - 54.1 mg/kg (ordinary chernozem). The greatest zinc amount is observed in the plants root system growing on chernozem ordinary.

Lead is contained in the range from 2.0 to 15.3 mg/kg. The highest lead content is in yarrow - 14.3 mg/kg (dark chestnut incompletely developed soil), and the lowest is in salvia - 1.5 mg/kg (dark chestnut incompletely developed soil).

The nickel content in the test plants root system is in the range from 6.6 to 48.9 mg/kg. Significant nickel content is observed in the yarrow - 47.9 mg/kg (dark chestnut incompletely developed soil) and in yarrow - 31.4 mg/kg (ordinary chernozem). The increased nickel content is observed in the root system of plants growing on the dark chestnut soil.

Chromium is found in the plants roots in an amount from 8.4 to 63.5 mg/kg. The highest chromium content is marked in yarrow - 62.5 mg/kg (ordinary chernozem), and the lowest is in salvia - 7.4 mg/kg (ordinary chernozem).

The vanadium concentration in the plant roots lies in the range from 5.7 to 45.0 mg/kg. A significant amount of vanadium is found in the yarrow roots (ordinary chernozem and dark chestnut incompletely developed soils). The highest vanadium concentration is observed in the plants root system growing on chernozem ordinary.

Titanium in plant contains in the range of 31.6 to 222.4 mg/kg. Significant titanium content is in the yarrow roots - 222 mg/kg and thistle - 194 mg/kg (southern chernozem); the lowest is in salvia - 31.6 mg/kg (dark chestnut incompletely developed soil).

The molybdenum content in the plant roots ranges from 3.1 to 19.2 mg/kg. Slight molybdenum content is observed in the salvia roots - 3.1 mg/kg (dark chestnut incompletely developed soil). The highest molybdenum content is observed in the yarrow roots - 19.2 mg/kg (ordinary chernozem).

The silver concentration in the plants roots varies from 0.2 to 17.9 mg/kg. A significant silver amount is observed in the yarrow roots (dark chestnut incompletely developed soil), and the smallest is in salvia (dark chestnut incompletely developed soil).

The gallium content in the plant root system ranges from 1.7 to 14.5 mg/kg, with the highest concentration in mugwort - 14.5 mg/kg (southern chernozem) and thistle - 12.8 mg/kg (dark chestnut incompletely developed soil).

Barium is found in the plants roots in an amount from 20.0 to 142.6 mg per 1 kg of dry weight with the highest concentration in salvia- 142.6 mg/kg and yarrow - 102 mg/kg (chernozem typical and common, respectively) with the lowest in chicory (dark chestnut incompletely developed soil).

Zirconium is found in plants in a range from 7.4 to 33.3 mg/kg. The maximum zirconium content is observed in yarrow - 31 mg/kg (ordinary chernozem).

The manganese amount is noted in the range from 33.4 to 148.7 mg/kg. A significant amount of manganese is observed in yarrow - 147.7 mg/kg (dark chestnut incompletely developed soil) and thistle - 110 mg/kg (ordinary chernozem).

In the result of the theoretical modeling of the interaction in the system "soil-plant," equations system have been proposed to evaluate the system components contamination risk. According to substances transitions intensity in the system "soil-plant," the main distribution of substances in the subsystems is determined.

Maximum contamination probability of aboveground plants parts with copper is observed in thistle - 0.31 (dark chestnut incompletely developed soil). For other soil-plant systems, the possibility of thistle contamination by copper is much less. Minimum risk of copper plant contamination is marked for salvia on chernozem southern and yarrow on chernozem typical.

Great risk of mugwort zinc contamination is 0.07 per ordinary chernozem.

The risk of lead contamination is at the maximum in chicory - 0.07 (southern chernozem) and the minimum in salvia - 0.0006 (southern chernozem).

Maximum mugwort nickel contamination probability on chernozem ordinary is 0.031. Minimum is in yarrow on chernozem typical - 0.0006, whereas on ordinary chernozem is 0.025.

The risk of chromium, vanadium, titanium, and gallium contamination of the aboveground plants parts is very low.

The greatest molybdenum contamination risk is observed in the typical black earth in the salvia, thistle, and chicory.

Maximum silver contamination risk occurs in chicory - 0.4 and yarrow - 0.37 (southern chernozem) in other types of soil chicory contamination risk is in more than 10 times lower.

The risk of contamination with gallium, zirconium, and barium of the aboveground plant part is statistically insignificant (<0.01).

The highest value of manganese contamination risk occurs in the aboveground thistle part - 0,022 (ordinary chernozem).

The risk of the root system contamination by trace elements is calculated by the formula (10). Significant copper contamination probability is observed in the salvia root system on the southern black soil - 0.95.

The maximum and minimum probability of the root system contamination is marked at the chicory on chernozem ordinary - 0.65 and on typical black soil - 0.07.

Chance of lead accumulation in roots is observed in salvia on the southern black soil - 0.98. Other types of soil are spread on the lead contamination risk which ranges from 0.1 to 0.96.

The maximum nickel contamination risk occurs in yarrow −0.69 and the minimum in salvia - 0.02, which grows on the dark chestnut incompletely developed soil.

Chance of chromium, vanadium, and titanium accumulation in roots has considerable variation, as follows:
- The chromium accumulation from 0.06 to 0.96;
- The vanadium accumulation from 0.02 to 0.96;
- The titanium accumulation from 0.02 to 0.54.

Significant potential for molybdenum roots contamination is observed in mugwort and salvia in the southern chernozem - 0.99.

The highest value of silver contamination risk is seen in salvia, thistle - 1.0 (southern chernozem), thistle, chicory, mugwort, and yarrow - 1 (dark chestnut soils). The analysis results show that molybdenum and silver are very rapidly accumulated in the plants root system.

Great probability for gallium contamination of roots is observed in mugwort on southern chernozem (0.99) and the thistle in the dark brown soil.

The maximum barium contamination risk is observed in yarrow - 0.76 (ordinary chernozem) and its minimum in chicory - 0.1 (dark chestnut incompletely developed soil).

Zirconium is slightly accumulated in plants root system. The maximum contamination risk occurs in yarrow - 0.42 (ordinary chernozem), and the plants growing on chernozem typical have minimal zirconium contamination risk.

The maximum manganese contamination risk occurs in yarrow - 0.42 (dark chestnut incompletely developed soil), and minimum is in chicory- 0.03 (southern chernozem).

The risk of soil contamination by trace elements was calculated using the formula (10).

For the soil-plant systems:
- The soil is dark chestnut + salvia, and then, the risk of soil contamination with copper is high - 0.38;
- The soil is dark chestnut + mugwort, yarrow, and then, copper contamination risk is minimal.

Great probability for soil contamination is marked on chernozem typical - 0.89 if chicory, mugwort, and red clover are accounted for a large proportion of all vegetation.

The lead soil contamination risk is less than the risk of this element root system contamination. At the same time, if an ordinary chernozem and dark chestnut grow salvia, mugwort, and yarrow, the soil contamination risk may reach from 0.4 to 0.5.

The risk of soil contamination by chromium ranges from 0.05 (yarrow on dark chestnut soil) to 0.95 for the salvia growing on dark chestnut soils and chernozem ordinary.

The nickel soil contamination risk is high for all types of soils and plants. Hence, for the soil-plant systems, dark chestnut incompletely developed soil + salvia, thistle, and chicory - the risk is almost 100%.

Titanium, vanadium, gallium, barium, zirconium, and manganese accumulate little in plants, and these elements contamination risk is high for all tested soil types.

The greatest molybdenum pollution risk is observed in the soil-plant system such as the dark chestnut incompletely developed soil + salvia - 0.21.

The maximum silver contamination risk is marked on the dark chestnut incompletely developed soil, if a large vegetation percentage falls on the salvia, having a low absorption capacity.

## DISCUSSION

The content and trace elements in soils distribution depend on the direction and soil-forming process development degree and the trace elements in the landscape behavior. The trace elements nature in the soil cover distribution is determined by the humus content, particle size distribution, the environment reaction, redox conditions, absorption capacity, and carbon dioxide content. Gross forms of trace elements, being in chemical compounds with other elements and an integral part, are inactive. Minerals found in soluble or absorbed state are available for plants.

Data general analysis showed uneven trace elements in the soil profile migration in the result of the soil-forming process that there is profile elements redistribution. In the humus horizon of the investigated soils, there is observed zinc and phosphorus accumulation.

Black earth is considered to be the best trace-element composition soils, a kind of standard. However, in the detailed study, it was found that this is not true. In certain geochemical conditions, even fertile black soil may lack or excess certain minerals or their mobile forms. For example, compared with the average Clark, normal content in the soil (a term coined by Vinogradov A.P.), southern chernozem has a deficit of trace elements such as beryllium, vanadium, cobalt, lithium, copper, tin, titanium, chromium, zirconium, and molybdenum; ordinary chernozem lacks barium, beryllium, vanadium, yttrium, cobalt, lithium, manganese, copper, nickel, niobium, tin, titanium, phosphorus, and chromium; typical chernozem - beryllium, vanadium, cobalt, lithium, manganese, copper, tin, titanium, phosphorus, and zirconium; dark chestnut incompletely developed soil-barium, beryllium, vanadium, yttrium, cobalt, lithium, tin, titanium, phosphorus, and zirconium.

It may be noted that there is considerable differentiation in the trace element distribution in the certain territories soil. Each element is characterized by considerable variability in the distribution of large limits, depending on the humus content, pH, particle size distribution, carbonate, and other factors, which in turn depend on the vegetation characteristic of the area. Thus, it can be noted that the same plants growing on various types of soils form various soil-plant system, characterized by special physical and chemical properties.

Elements come into the plant and soil biota and are not accumulated approximately in the proportion in which they are found in the soil. Of the many elements, the organisms carrying "biological sorting" selectively absorb substances they need.

Nickel, chromium, titanium, molybdenum, and silver contents analysis showed that the same type of soil is marked their maximum and minimum concentrations. It is due to the fact that the trace elements in plants accumulation are influenced by their individual characteristics. In addition, the trace elements in plants content are influenced by soil factors such as, for example, the copper in the salvia concentration on the dark chestnut incompletely developed soil is 6 times higher than in the southern chernozem.

Data analysis on the trace element content in the plants root system showed that all the elements being analyzed are unevenly distributed. For example, a significant amount of copper is accumulated in the root system.

As seen from the results, some soil-plant systems with one and the same plant are characterized by maximum risk value and other soil-plant systems with the same plant by minimal. This is due to the influence of soil factors specific to each soil type on the trace elements in plants accumulation.

Comparative soil and plant systems with heavy metals contamination risk analysis showed that the lowest risk is inherent in the aboveground plants parts.

## CONCLUSIONS

The plant contamination risk data analysis showed that most of the trace elements contained in the soil are accumulated in the plants root system and only a small percentage, in the aboveground plants parts.

The elements come into the plant and soil biota and are accumulated there not in the proportion in which they are in the soil, they selectively absorb substances they need. The content of different kind trace elements such as Cu, Zn, Pb, Cr, V, Ti, Mo, and Ba, in the aboveground plants part, is characterized by a large range of values. A more uniform distribution is observed in Ni, Zr, Ga, Mn, and Ag. The large concentration spread in plants root system is observed in all the analyzed elements.

As a result of interaction, simulation processes in the "soil-plant" system on the proposed equations system has been evaluated the system components contamination risk. These contamination risks showed that the lowest pollution elements have aboveground plants part, and other elements such as zirconium, titanium, and gallium have the ability to be accumulated in soil and almost not be absorbed by plants.

Thus, the presented method of Orenburg region soil and vegetation complex pollution modeling allows to objective trace the various chemical elements in the "soil-plant" system migration according to the changes in absorption capacity. Based on the above, we can conclude the proposed method prospects and its application possibilities in the environmental pollution risks evaluation.

## REFERENCES


1. Sharma RK, Agrawal M, Marshall F. Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. Ecotoxicol Environ Saf 2007;66:258-66.
2. Ogundiran MB. Assessment and Chemical Remediation of Soil Contaminated by Lead-Acid Battery Waste in Lalupon, Oyo State, Nigeria. PhD Dissertation. Ibadan, Nigeria: University of Ibadan; 2007.
3. Smical AI, Hotea V, Oros, V, Juhasz J, Pop E. Studies on transfer and bioaccumulation of heavy metals from soil into lettuce. Environ Eng Manage J 2008;7:609-15.
4. Brunetti C, Ferdinando M, Fini A, Pollastri S, Tattini M. Flavonoids as antioxidants and developmental regulators: Relative significance in plants and humans. Int J Mol Sci 2013;14:3540-55.
5. Efremov IV. Biophysical monitoring and ecological status 'soil-plant' system under anthropogenic impact. Nizhny Novgorod: Science; 2011. p. 247.
6. Efremov IV. Soil-Plant Systems Modelling. Moscow: Publishing LCI; 2008. p. 152.
7. Efremov IV, Kuzmin ON. Research and evaluation of heavy metals in the 'soil-plant' system migration properties. Agrarian Russia; Moscow: Agriculture, 2011, p. 107. Available from: http://agros.folium.ru/index.php/agros/article/view/443/365


**Source of Support:** Nil. **Conflict of Interest:** None declared.