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Modelling of pollution with lead in shooting ranges of Gaižiūnai Military Ground

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Shooting ranges at the largest Lithuanian military grounds are exploited. These grounds were established more than 100 years ago. The main purpose of this work is to present a pollution migration forecast at a selected prototype, the Gaižiūnai Military Ground, using modelling software. The study metal was lead, i. e. the main compound of old-standard bullets and explosive charges. The simulation relies on the experimental data obtained during complex investigations performed in one of the Lithuanian military grounds. Considering a lead level about 27% higher than the background, one of the small shooting ranges in Gaižiūnai Military Ground was chosen as a prototype for simulation. The aim of the modeling was to simulate pollutant dispersion in areas exploited over a long period of time for military needs, relying on experiential data. In such areas, soil is continually polluted with relatively small amounts of pollutants. Thus, it was a challenge to determine the initial modelling conditions, due to the uncertainties in the load per hour, day, and year. Modelling results allowed making conclusions about the vertical and horizontal dispersion of the pollutant, estimating the risk to groundwater caused by heavy metal pollution.

Key words: soil, pollution, lead, dispersion simulation, shooting ranges

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INTRODUCTION

The aims of the work presented in this paper were to simulate the dispersion of pollutants in the soil and to evaluate the danger to the environment due to such pollution. The simulation relies on the experimental data obtained during complex investigations performed in one of the Lithuanian military grounds (Vasarevičius, Greičiūtė, 2004). From the environmental point of view, such a type of land use has a few particularities: first of all, sudden pollutant emissions (i. e. emissions of big amounts of pollutants within a short period of time) are very rare, if any (Baubinas, Taminskas, 1997–1998). Usually soil pollution in such territories lasts for a long time. On the other hand, the amounts of pollutants reaching the ground are comparably small, resulting in a slow but constant increase of pollutant concentration (Baltrėnas et al., 2001). Various types of land use can be observed on military grounds. Shooting ranges, autodromes, tactical fields, etc. represent the main type of land use (Greičiūtė, Vasarevičius, 2003). The type and distribution of pollutants differ depending on the destination of a particular area and on the time of its use for military needs (Baltrėnas et al., 2001). Besides, the intensity of Lithuanian military ground use varied throughout the last century. According to expectations, the biggest environmental loads these areas had to bear occurred in the times of soviet army possession when no attention was paid to the environmentally safe military ground exploitation (Greičiūtė, Vasarevičius, 2004).

The legacy of Russian occupation still dots the Central and Eastern European landscape. Hundreds of former Soviet military bases pose a considerable threat to human health and the environment. Oil, gas and petrol pollute the soil due to intensive fuelling activities. Old ammunition taints the soil with heavy metals and chemical contamination. This pollution filters through the soil to aquifers, affecting the groundwater supply which is especially hazardous. Lead is the main pollutant at the biggest Lithuanian military grounds. Since the main focus of this investigation lies on future prognosis, data on pollution with heavy metals are presented only very briefly. Since lead is the most common metal in the composition of ammunition, it was chosen for the investigation. Although humans have mined and worked with lead for more than 2500 years, this activity became massive in the 20th century; as a result of the way in which lead has been used in the recent decades, the earth was coated with a fine layer of lead. The most serious worldwide lead contamination has been due to the introduction of lead (in the form of tetraethyl and tetra methyl lead) into gasoline, starting in 1923, with billions of tons of lead released into the atmosphere in the vehicle exhaust. Most of the discharged lead lands on the soil, in water, and on living organisms, particularly the growing along the roadways. Even when lead additives were removed from gasoline in most countries, also in Lithuania, smaller amounts of lead continue to be emitted from automobiles, trucks, and other vehicles. In addition to some natural lead in gasoline, the gradual loss of fine particles of metal, rubber and other components that contain lead contributes to pollution, particularly in urban areas with a high traffic density. Additionally, lead was introduced into the biosphere through burning of coal and through industrial production of metal products (such as steel and brass as well as lead for batteries), and through its addition to paints, solder (now restricted in lead content), and other products. For these reasons, the concentration of lead in Lithuanian soils has increased over the last 40–50 years. This fact should be taken into consideration when analyzing simulation results, as not all the pollution was caused by military activities; anyway, it would be too difficult to determine the ratio between pollution from the atmosphere and by military activities.

Thus, it is very difficult to determine the initial simulation conditions, as it is not clear what amounts of pollutants were getting into soil annually, and even less daily. Due to the fact that the considered pollutants are not liquid but solids like bullets, mines, different wastes, etc., it takes time until the heavy metals present in the composition of ammunition get into the soil in a soluble form (Brady, 1990). That is why the simulation and initial conditions were assumed referring to the investigations performed on Lithuanian military grounds, together with some additional assumptions. As the prototype for simulation, the Gaižiūnai shooting range was chosen. It is one of the small shooting ranges 100 m in length and of the same width. This shooting range is interesting for investigation, as it has an incline on one side, which ends in a water-filled drain. Consequently, if the simulation is successful, it should be possible to observe how deep pollutants spread into the soil, how much time it takes for them to reach the groundwater level, and whether water in the drain is polluted, as the drain falls into a small stream, which in turn discharges into the river Ruklelė, and finally into the Neris, the second biggest river in Lithuania. It is also important to note that during the investigation the highest concentrations of lead and other heavy metals were determined in the soil of this small shooting range.

POLLUTION WITH LEAD IN SHOOTING RANGES OF GAIŽIŪNAI MILITARY GROUND

Shooting trainings are usually performed in specially equipped fields called shooting ranges. Depending on the type, they can be isolated by mounds from all sides. Usually only small shooting ranges (about 100 m long)

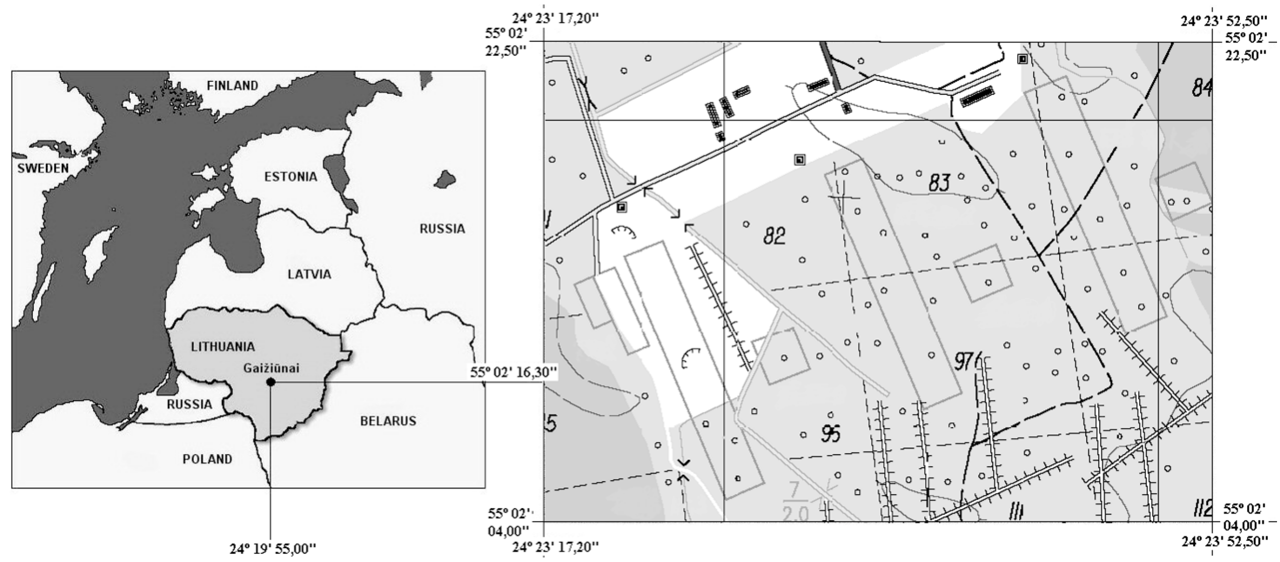

Fig. 1. Location of the Gaižiūnai Military Ground
1 pav. Gaižiūnų karinio poligono geografinė padėtis

are isolated for safety purposes. In bigger ones, walls are mounded every 100 m; targets and pointing fields are equipped on them. The shooting ranges in the Gaižiūnai Military Ground are probably the most frequently used fields. There are three big (600 m long and 100 m wide) and four small (three of them 100 m long and 100 m wide, and one 200 m long and 100 m wide) shooting ranges in the Gaižiūnai Military Ground (Fig. 1).

In 2002, an investigation was performed with the aim to determine soil pollution with heavy metals characteristic of ammunitions. The area of the shooting ranges was divided into segments creating a grid of soil sampling points. The grid covered the totality of the shooting ranges. 24 soil samples were taken in the mounds of the shooting ranges, as the biggest part of bullets is falling there. The sampling fields were subdivided by a mesh. Samples were taken in every cell of the mesh, to secure an even distribution of soil sampling points. Samples were taken from the top layer of soil (0–5 and 10–20 cm deep). Every sample was collected using the principle of the "envelope", when every cell of the mesh was covered by no less than 5 samples. Soil samples were collected with a stainless steel trowel and poured into fabric sacs. The soil samples were dried under laboratory conditions, pulverized and sieved out using a 1.0 mm^2 sieve (Baltrėnas et al., 2001). 20 g of each soil sample was poured over with 100 ml of a solution of concentrated nitric acid (50 ml) and hydrochloric acid (50 ml) and heated for 15 min. The solution was filtered with glass filters and analysed with an atomic absorption spectroscope (210 GP). The error of the method used was 14.5%. In this paper, only results concerning pollution with lead in the territory of the shooting ranges are presented. The level of pollution and its distribution is important when choosing the prototype for simulation and determining the initial conditions.

Lead concentrations of determined in soil samples taken from the Gaižiūnai shooting ranges show that pollution has already reached an unallowable level. The medium concentration of lead was 20.3 mg/kg, while the background concentration of this metal in soils of the Gaižiūnai Military Ground region is 14.7 mg/kg (Fig. 2).

In seven soil samples lead concentrations varied from 16.3 mg/kg to 24.04 mg/kg and exceeded the background level by 10% to 38%. In other four samples lead concentrations exceeded the background level by 53% to 80%, and the maximum concentration determined was 76.2 mg/kg. These results show that the area of Gaižiūnai Military Ground shooting ranges is polluted by lead. Since the territory is still used for the same purpose, it might be that the pollution will increase, even though a few years ago strict requirements for environmentally safe exploitation were implemented. With the time pollutants will migrate into the soil and can pollute groundwater.

SIMULATION OF LEAD MIGRATION IN SOIL OF SHOOTING RANGES

The simulation was performed using SoilVision Systems Ltd. SVFlux and ChemFlux software. It is obvious that the specific properties of solid and liquid waste migration into soil differ. Liquid pollutants, if spilled on the ground, soak and spread away very quickly; their migration is mainly determined by specific density and soil features. Meanwhile solid wastes stay in the top layer of soil for some time and gradually decompose because of oxidation processes. Products of decomposition travel with seepage water. Thus, when analysing the pollutant transport processes, first of all it is necessary to take into consideration water transport processes and finally the pollutant transport with water. For the simulation of pollutant dispersion, we first need to know how water moves in soil, i. e. to simulate water flux gradients. For this purpose, SoilVision soft-ware includes SVFlux package for working with water fluxes. Generally, SoilVision software includes several related packages. For example, AcuMesh is a module which forms the structure of the modeled object, the so-called grid. Different parameters are assigned to each cell of the grid, and discrete values are obtained for each segment of the object. FlexPDE is a calculation module: all the graphical and digital information is comprised here. Results are visualized in the graphic form. These two packages (AcuMesh and FlexPDE) are essential working tools, together with other SoilVision simulation packages. The other two packages, SVFlux and ChemFlux, are connected in a way that ChemFlux needs graphics and simulated gradient files from SVFlux. The water gradient file is simulated using

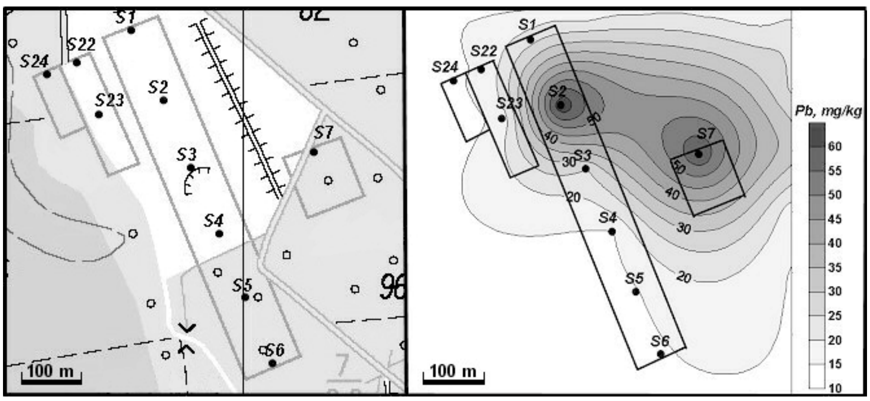

Fig. 2. Shooting ranges and lead concentrations in Gaižiūnai Military Ground (S1–S7, S22–S24 – soil sampling points). One of the small shooting ranges chosen as a prototype for simulation is marked as point S7

2 pav. Gaižiūnų karinio poligono šaudyklos ir tyrimo metu jose nustatytos švino koncentracijos (S1–S7, S22–S24 – dirvožemio ėminių taškai). Viena mažųjų šaudyklų, kuri buvo pasirinkta kaip prototipas modeliavimui, pažymėta S7 tašku

SVFlux. To do so, boundary conditions of the flow have to be established considering a definite object. The first step of simulation is to describe the medium of an object. Relying on experimental data, two soil types were chosen and described. A proper selection of medium parameters and coefficients is of highest importance, as medium features determine water (together with pollutants) movement peculiarities and speed. The top layer of the soil selected for simulation consisted of silt and fine sands with organic matter (such soil prevails in the area of Gaižiūnai Military Ground). The deeper layer of the soil is composed of silt loam with sand and organic content, and is therefore less permeable.

For description of both types of soil, the following features and coefficients were used:

• k_{sat} – saturated hydraulic conductivity of soil layer:

– for the top layer of soil (silt and fine sand with organic matter):

k_{sat} = $1 \cdot 10^{-3}$ *cm/s = 315.6 m/year;*

– for a deeper layer of soil (silt loam with sand and organic content):

k_{sat} = *5E-04 cm/s = 158 m/year.*

• Saturated volumetric water content (VWC):

– for the top layer of soil (silt and fine sand with organic matter): 0.305;

– for a deeper layer of soil (silt loam with sand and organic content): 0.433.

For compiling the geometry of the Gaižiūnai Military Ground shooting range, real parameters were available. The length of the object was 120 m (i. e. 100 m is the length of shooting range, and 20 m is the distance to the drain and part of its trench). A rise of 2 m reflects the target zone of the shooting range. It seems to be very high in such scale (120 m length and 10 m height), but actually it is just a mound with a 2 m wide platform on the top. The depth of the object was 10 m. As mentioned before, this shooting range is crossed by a drain at the left border.

The boundary conditions are assigned particularly for each region of the object. As in the first stage of simulation the variable was water but not pollutants, there were two types of boundary parameters: head and normal flux. The head is given in meters. This parameter can be defined as the height of water column, or in other words it is the height of the saturated soil layer. When setting this condition, it is necessary to take into account the inclination of the object surface and the depth of groundwater. Relying on geological data, in the territory of Gaižiūnai Military Ground (Jonava district) the depth to groundwater is about 0.5–2 m. In the study object, in the left there is an inclination of the surface, which ends in a drain with water. Hereby the head is given in the left part of the object and is equal to 5.5 m. The second boundary condition is given as a normal flux, i. e. water flux into soil through the surface (with rain water mainly). In Lithuania, the annual level of precipitation is 500–700 mm/year (average 625 mm/year). It was assumed that each segment of the surface length gets 625 mm precipitation per year. This value is set in the section of boundary conditions, and the distribution of water flux gradients was calculated. From this point, the further simulation of pollutant migration is possible.

The medium features of the object were described by SVFlux package, but the parameters influencing the flow of water flux were of main importance. The change of pollutant concentration in time can be described by the advection-dispersion equation:

$$\frac{\partial C}{\partial t} = D_L \frac{\partial^2 C}{\partial x^2} - v_x \frac{\partial C}{\partial x}, \quad (1)$$

where C is pollutant concentration in water, t is time, v is pore water flow velocity, x is distance, D_L is the hydrodynamic dispersion coefficient.

$$D_L = D_e + \alpha_L v, \quad (2)$$

with D_e as the effective diffusion coefficient, and α_L the dispersion. The term $v_x \frac{\partial C}{\partial x}$ represents the advective transport, and $D_L \frac{\partial^2 C}{\partial x^2}$ represents the dispersive transport. The usual assumption is that v and D_L are equal for all solute species, so that C can be the total dissolved concentration for an element.

To simulate migration of the pollutant, it is necessary to take into consideration the longitudinal and transverse dispersion, diffusion, etc. These parameters are assigned particularly for each type of the soil, as they depend on particular soil features. Referring to a number of laboratory and field tests, it has been many times proven that transverse and longitudinal dispersion is directly proportional to distance (Stianson, Thode, 2004). It has been empirically deduced that α_L (coefficient of longitudinal dispersion) is equal to 10% and α_T (coefficient of transverse dispersion) to 1% of distance. Relying on such presumption, α_L is equal to 1 m and α_T to 0.1 m. The diffusion coefficient for the upper soil layer was equal to 0.0221 m^2/year and for the deeper layer 0.0625 m^2/year. One of the main values needed as an input for the simulation (necessary when describing boundary conditions) is the amount of the pollutant that gets into the soil during a particular period of time. It is very difficult to determine this value for the areas which were used for a very long time and the pollution was not always constant. To solve this problem, a few presumptions were made:

• soil of the Gaižiūnai shooting range is polluted only with lead and its compounds;

• only the top layer of soil is polluted;

• the land use of the Gaižiūnai Military Ground for military purposes as shooting ranges was started 100 years ago;

• there had been no soil pollution with heavy metals in the territory before. Therefore the concentrations of heavy metals are supposed to be the same as the background concentration (background concentration of lead is 14.7 mg/kg).

As is seen in Fig. 1, the maximum concentration of lead in one part of the shooting range was 60 mg/kg and in the opposite part 40 mg/kg. If subtracting the value of background concentration, the remaining amount of lead (respectively 45.3 mg/kg and 25.3 mg/kg) can be treated as pollution due to harmful military activities. Assuming a time span of 100 years, approximate values of pollutants that were annually getting into the soil, i.e. 0.452 mg/kg/year in the target zone and 0.253 mg/kg/year in the rest part of the shooting range can be assumed as necessary input data.

Two simulation scenarios were developed.

The first scenario relies on the presumption that from the very installation of the shooting range the pollution was a constant process (i. e., a constant amount of pollutant gets into soil every year). As military activities will continue in the future, the pollution continues too. The simulation results "after 100 years" show the current situation and further – the pollution level and distribution after another 10, 20, 50 years.

Boundary conditions were described as follows: "$c_0 + 0.253*t$" – in the area of the shooting range, except target zone, and "$c_0 + 0.453*t$" – in the target zone (where c_0 is the initial (background) concentration of lead (14.7 mg/kg for lead in soils of Jonava region), and t is the time).

The second scenario relies on the presumption that from the very installation of the shooting range its pollution was a constant process, but with continuing military activities in the future, the territory of shooting ranges is no more polluted (because of applied environmental means for a safe exploitation of the shooting ranges). The modelling results showing the dispersion of pollutants after 100 years are the same as in the first scenario. Further results show tendencies of pollutant spread when the territory is no more polluted.

Boundary conditions for such a case are as follows: if $t <= 100$, then $c_0 + 0.253*t$ else c_0 – in the territory of the shooting range, and if $t <= 100$, then $c_0 + 0.453*t$ else c_0 – in the target zone.

SIMULATION RESULTS AND DISCUSSION

Modelling with SVFlux allowed calculating the distribution of water flux gradients which are determined by flow. Calculating the values of head and pressure (atmospheric pressure), it is possible to get the distribution of gradients. The pressure is increasing from top to bottom (the smallest values are on the surface and the biggest at a depth of 10 m), and is equal to 0 in the middle of the object. Because of that, water flow has two directions: first of all, water flows down from the surface until it reaches the zero pressure line, while water from the lower layers spurts up with the upward flow direction. Consequently, besides the zero pressure line, the two streams with different flow directions would collide. The final direction of flow gradients is determined by the head. If influenced by it alone, the stream would flow from the high to the low pressure zone. Only on evaluating the influence of both head and atmospheric pressure it is possible to form a distribution of flow gradients. As expected, flow gradients in the surface are pointed down, but then, due to the influence of the head, the direction changes. The size of the gradient is different in particular regions of an object (i. e. in different layers of soil). Gradient values are noticeably bigger in the upper layer of soil and smaller in the deeper one. Such distribution can be explained by soil features: the upper layer of soil mainly consists of sand and has a high permeability, while the deeper layer of soil consists mainly of silt loam and is not that permeable, and the water stream can hardly flow (Fig. 3).

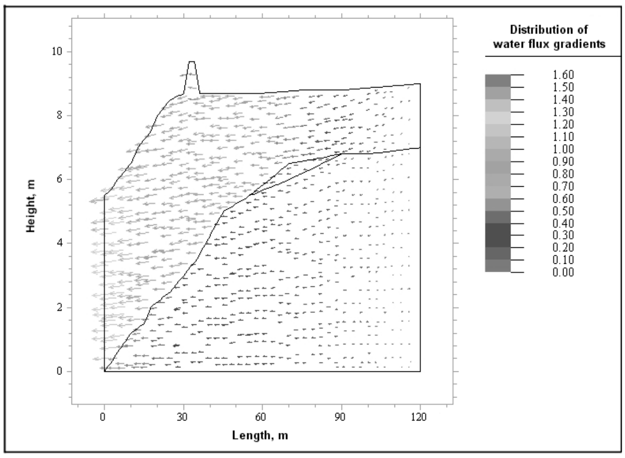

Fig. 3. Distribution of **s**imulated flow gradients
3 pav. Sumodeliuotų tėkmės gradientų pasiskirstymas

As described above, the simulation was performed at some time intervals: pollutant dispersion was observed after 1, 5, 10, 20, 40, 60, 80 and 100 years after the beginning of pollution (the start of shooting range exploitation). After that, the results of two modelling scenarios were estimated: when the pollution continues and when it stops.

The results of the simulation revealed that after one year of intensive exploitation, concentrations of lead in the whole territory of the shooting range were equal to background, but in the target zone the maximum lead concentration reached 15.18 mg/kg. The factor of time is of main importance: as mentioned before, ammunitions that fall into the ground are affected by oxidation, and it takes more than 1 or 2 years. Only after their decomposition pollutants get into the soil together with rain water. It can be expected that with time the level of pollution will considerably increase.

The direction of pollutant migration could already be seen after 5 years of exploitation of the shooting range. It was directed to the incline, towards the drain. Comparing the results after the first two periods, we see that in the first case bigger concentrations of lead were determined only on the surface and at the depth of 1 m. After 5 years, the influence of pollutant migration is already noticeable at a depth of 2 m in the territory of the shooting ranges and reaches a depth of 4–5 m in the target zone. At such depth lead concentrations are almost equal to background (transcendence is 3–5%), while in the surface the maximum lead concentration in the target zone can be observed. After 5 years of shooting range exploitation, pollutants spread only in the upper sandy soil layer, without reaching the deeper silt loam soil. Having in mind that silt loamy soils are less porous and permeable than sandy ones, it is very likely that the deeper soil layer will slow down pollutant migration. Such presumption was approved by results obtained in the case of 10 years of shooting range pollution. After this period of time, pollutant concentrations increased in all the affected zones but didn't move much in depth, resulting in an almost unpolluted deeper layer of soil. It changed after 20 years of pollution: in this case, pollution by lead is already spread in depth and in width. Maximum lead concentration in the surface of the target zone and in the area from the target zone to the drain exceeds the background concentration by 38%, while in the remaining part of the shooting ranges lead concentration is 20 mg/kg (26% bigger than the background). Modelling results have shown that after 20 years of territory use for military purposes soil layers to the depth of 5 m are influenced by pollution, while the deeper layers (to the depth of 10 m) are not yet affected. Such situation changes rapidly after 40 years of pollution. The results show only a little part of soil layer which was not yet polluted. The pollution level, even in the less permeable silt loam soil layer, reaches 22 mg/kg. Lead concentration at the groundwater level (2 m deep) throughout the whole territory of the shooting ranges is 24 mg/kg (38% more than the background), and even 31 mg/kg in the target zone and drains downhill. Such results show the situation to be quite dangerous, as pollution of groundwater is very probable, especially when after 60 years of territory pollution lead concentration at the groundwater level was 39 mg/kg (i. e. 60% more than background) (Fig. 4).

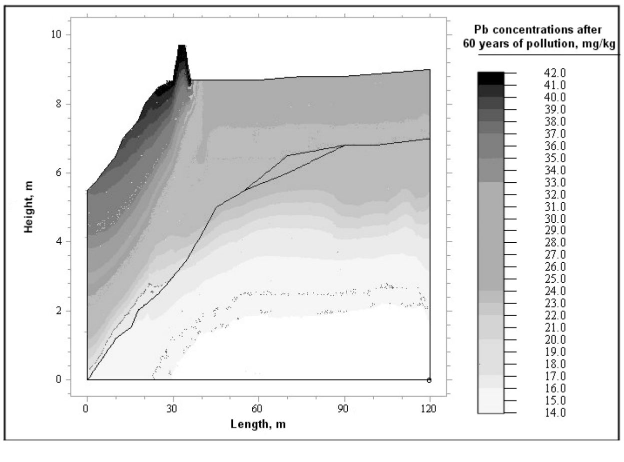

Fig. 4. Distribution of lead concentrations in the territory of a small shooting range after 60 years of continuous pollution
4 pav. Švino koncentracijų pasiskirstymas mažosios šaudyklos teritorijoje po 60 nuolatinio teršimo metų

After 80 years of territory exploitation, lead concentrations are bigger than background in all the analysed cross-sections of the shooting ranges. After 20 more years, lead concentration in the surface of the whole shooting range territory measures up the level of 42 mg/kg (i. e. 65% more than the background). Such pollution was determined at a depth of 2 m where pollutants can easily reach and pollute water, as the groundwater level is just at the same depth. It is very likely that the biggest part of pollutants gets into the drain and can be carried with water flow, reaching natural streams and rivers. Distribution of lead concentrations after 100 years of shooting range exploitation (it shows the present situation in the Gaižiūnai Military Ground shooting ranges) is the starting point for comparison of two scenarios: when the shooting range is further used for military needs and polluted at the same intensity, and when the pollution stops (Fig. 5).

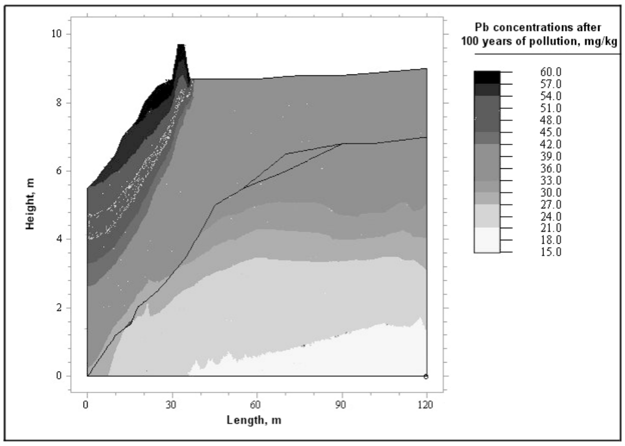

Fig. 5. Distribution of lead concentrations in the territory of a small shooting range after 100 years of continuous pollution
5 pav. Švino koncentracijų pasiskirstymas mažosios šaudyklos teritorijoje po 100 nuolatinio teršimo metų

As the results have shown, if the Gaižiūnai Military Ground shooting range is further used for military trainings, the tendencies of pollutant migration are almost the same, but the concentrations are bigger. After 120 years, on the whole territory of the shooting range surface and down to 2.5 m in depth, lead concentration will be 45 mg/kg (i. e. 67% more than background), while in the target zone and drains downhill it varies from 63 to 72 mg/kg. Comparing with the results of the second scenario when the territory is no more polluted, lead concentration after 110 years is already much smaller, its maximum reaching only 31 mg/kg (52% more than the background). In this case, the maximum lead concentrations were estimated at a depth of 5 m in the territory of the shooting ranges and at a depth of 10 m in the target zone. Such tendencies allow us to conclude that pollutants not only spread, but also diminish because of natural soil cleanup features, and as a result the lead concentrations decrease. Comparing the results of both scenarios, we see that after 120 years of shooting range exploitation the maximum lead concentration is 72 mg/kg (in the surface), while when pollution stops after 100 years, only a 27.5 mg/kg maximum concentration is determined (at a depth of 6–7 m). After 30 additional years, results calculated by the first scenario showed the maximum lead concentrations of 84 mg/kg (i. e. 82% more than the background) in the surface of the target zone and drains downhill (Fig. 6).

The obtained results after the same period by the second scenario were slightly smaller: maximum lead concentration was 24.5 mg/kg at a depth of 9–10 metres (Fig. 7).

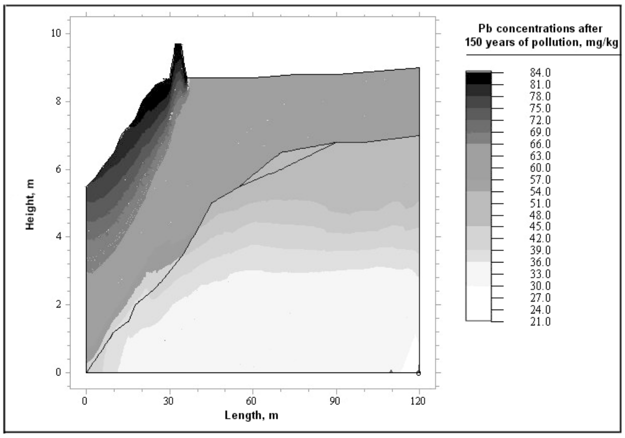

Fig. 6. Dispersion of lead concentrations in the territory of a small shooting range after 150 years of continuous pollution
6 pav. Švino koncentracijų pasiskirstymas mažosios šaudyklos teritorijoje po 150 nuolatinio teršimo metų

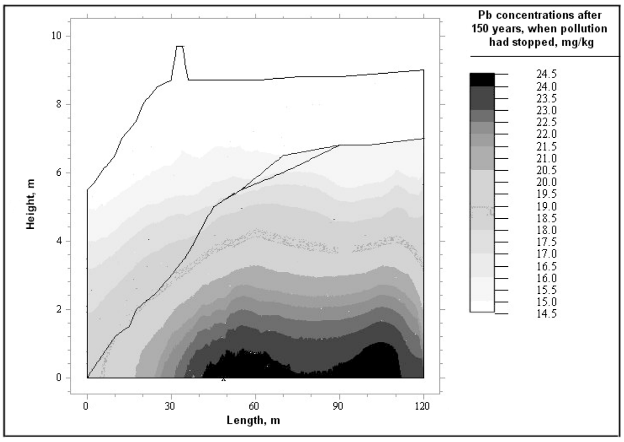

Fig. 7. Dispersion of lead concentrations in the territory of a small shooting range after 150 years; pollution was stopped after 100 years of exploitation
7 pav. Švino koncentracijų pasiskirstymas mažosios šaudyklos teritorijoje po 150 m., iš kurių teritorija buvo eksploatuojama 100 metų

Thus, if in the beginning of pollution the biggest lead concentrations were determined downhill, when the pollution stops the concentrations in this zone decrease rather than in the left part of the shooting range. It is quit understandable, as the surface of the territory and downhill consists of sandy soil with good permeability features. In this layer water moves faster, carrying the pollutants, and the processes of pollution and cleanup are faster too. As the results have shown, the deeper layer of soil is harder to pollute, but if this has occurred, it takes time for the soil to be restored naturally.

CONCLUSIONS

Pollutant dispersion in soil depends mainly on the velocity of water flow and its direction. Peculiarities of water flow depend on the soil features: sandy soils are porous, and water is able to move faster without many obstacles. Dense soils, like clay, silt loam, etc. are hardly permeable. The flow of water flux is also dependent on soil suction. As expected, simulation results have shown rather bigger flow gradients in a surface consisting of a sandy soil layer. Water flux flow in soils is created because of pressure and head distribution: the flow is directed from the high to the low-pressure zone.

The simulation results have shown that the most polluted territory of the Gaižiūnai Military Ground is the target zone as well as the drains downhill.

According to the simulation results, after 40 years of the shooting range exploitation the maximum determined lead concentration exceeds the background values twice. After 60 years of territory use for military needs, lead concentrations twice bigger than background were estimated at a depth of 2 m, at the level of groundwater, showing a danger of groundwater pollution. After 100 years of shooting range pollution (i. e. in the present situation), the maximum lead concentration was already 60 mg/kg (75% more than the background), and almost all the analysed cross-sections were polluted.

If the exploitation and pollution of the shooting range would last 50 years more, the maximum lead concentration would reach 84 mg/kg. The most polluted territory would be the target zone and downhill, i. e. in such case it is possible that not only groundwater but also the water in the drain would be polluted. It is very dangerous, as the polluted drain water flows into natural streams which are connected with rivers.

If after 100 years of exploitation of the shooting range the pollution of this territory stops, the level of pollution would decrease more than twice within 20 years, and the maximum lead concentration would reach only 27.5 mg/kg. After 150 years of territory use for military activities, considering a stop of pollution after 100 years, the maximum lead concentration would be 24.5 mg/kg, i. e. not much above the background. Such results allow us to conclude that for the total cleanup of the site 60 years would be enough.

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DIRVOŽEMIO TARŠOS ŠVINU MODELIAVIMAS GAIŽIŪNŲ POLIGONO ŠAUDYKLOSE

S a n t r a u k a

Straipsnyje aprašyto darbo tikslas – remiantis empiriniais duomenimis sumodeliuoti teršalų sklaidą teritorijose, kurios ilgą laiką buvo naudojamos kariniams tikslams. Toks teritorijų panaudos tipas turi savą specifiką: pirmiausia retai pasitaiko ūmūs teršalų išmetimai (t. y. didelių teršalų kiekių išmetimai per trumpą laiką), nors tokių atvejų per ilgametį karinių poligonų eksploatavimą pasitaikydavo. Kalbama apie nuolatinį teršimą sąlyginai nedidelėmis teršalų koncentracijomis.

Trijų didžiausių Lietuvos poligonų eksploatavimas yra prasidėjęs daugiau nei prieš 100 metų. Visuose šiuose poligonuose yra skirtingos paskirties teritorijų, iš kurių bene svarbiausios ir intensyviausiai naudojamos šaudyklos, autodromai, tankodromai, taktiniai laukai. Analizei pasirinktos Gaižiūnų poligono šaudyklos, taip pat vienas būdingiausių karinei veiklai sunkiųjų metalų – švinas. Dėl tam tikros šaudyklų eksploatavimo specifikos sunku nustatyti pradines modeliavimo sąlygas, nes nėra aišku, kokie teršalų kiekiai patekdavo į dirvožemį per metus ar juo labiau – per dieną. Be to, karinėse teritorijose teršiama ne tiek skystomis medžiagomis, kiek kietais kūnais – kulkomis, minomis, atliekomis ir pan. Taigi praeis nemažai laiko, kol ištirpę teršalai (sunkieji metalai) pateks į dirvožemį. Uždavinio problema ir pradinės sąlygos buvo aprašytos remiantis Lietuvos kariniuose poligonuose atliktais tyrimais ir tam tikromis prielaidomis. Modeliavimo uždavinio prototipu buvo pasirinkta nedidelė, 100 m ilgio ir pločio, Gaižiūnų karinio poligono šaudykla.

Modeliavimo rezultatai rodo, kad, kaip ir galima buvo tikėtis, labiausiai teršiama šaudyklos taikinių zona bei šalia esančio griovio šlaitas: čia jau po 40 metų nuolatinio teršimo sumodeliuotos švino koncentracijos fonines viršija du kartus. Pagal modeliavimo rezultatus, po 60 metų teršimo švino koncentracijos, dvigubai viršijančios fonines, bus jau 2 m gylyje, t. y. grės tarša gruntiniams vandenims. Jei šaudykla būtų nuolat teršiama 150 metų, būtų pasiekta maksimali 84 mg/kg švino koncentracija (taikinių zonoje bei griovio šlaite) ir, tikėtina, būtų teršiami gruntiniai vandenys. Jei po 100 metų šaudyklos eksploatacijos teršimas liautųsi, po 20 metų tarša sumažėtų daugiau nei perpus. Dar po 30 metų maksimali švino koncentracija tesiektų 24,5 mg/kg.

Кристина Грейчюте, Саулюс Васарявичюс

МОДЕЛИРОВАНИЕ ДИСПЕРСИИ СВИНЦА В ПОЧВЕ СТРЕЛЬБИЩА ПОЛИГОНА ГАЙЖЮНАЙ

Резюме

Цель работы, описанной в статье, – смоделировать дисперсию загрязняющих веществ на территориях, которые долгие годы использовались для военных целей. Использование таких территорий имеет определенную специфику, поэтому они долгие годы подвергались непрерывному загрязнению, иногда концентрации загрязняющих веществ были невелики.

Эксплуатация трех крупнейших военных полигонов Литвы началась раньше, чем 100 лет тому назад. Самые важные и чаще всего используемые территории военных полигонов – это стрельбища. Для анализа были выбраны стрельбища полигона в Гайжюнай и один из самых характерных для военного дела металлов – свинец. Из-за специфики эксплуатации стрельбищ трудно установить условия моделирования, так как не произведены замеры уровня загрязненности почвы загрязняющими веществами в год или тем более в день. Более того, военные территории загрязняются не жидкими веществами, а попадающими в почву пулями, минами и т. п. Поэтому, до того момента, когда загрязняющие вещества в жидкой форме попадают в почву, проходит немало времени. Для описания проблемы и условий модели было сделано несколько предположений на основе результатов проведенного на военных полигонах Литвы исследования. Для прототипа модели было выбрано маленькое (длиной 100 м и шириной 100 м) стрельбище военного полигона в Гайжюнай.

Результаты проведенного моделирования показали, что уже через 40 лет эксплуатации стрельбища концентрации свинца дважды превысят фоновые. Через 60 лет концентрации свинца, дважды превышающие фоновые, установлены в почве уже на глубине 2 м. При непрерывном загрязнении стрельбища в течение 150 лет концентрация свинца в почве достигнет 84 мг/кг и возникнет серьезная тревога за грунтовые воды. После 100 лет прекратив эксплуатацию стрельбища, через 20 лет загрязненность свинцом снизилась бы более чем в 2 раза, а спустя 30 лет она составляла бы лишь 24,5 мг/кг.