Agnieszka **PETRYK**

STUDY OF SOIL CONTAMINATION WITH HEAVY METALS AND COST ESTIMATION OF ITS REMEDIATION ON THE EXAMPLE OF THE CITY TRZEBINIA

Agnieszka **Petryk**, PhD, Eng – *University of Economics in Cracow, Poland*

Correspondence address:
Department of Regional Economics
Rakowicka 27, 31–510 Kraków
e-mail: petryka@uek.krakow.pl

BADANIE ZANIECZYSZCZENIA GLEBY METALAMI CIĘŻKIMI ORAZ SZACUNEK KOSZTU JEJ REKULTYWACJI NA PRZYKŁADZIE MIASTA TRZEBINIA

STRESZCZENIE: Celem artykułu było określenie zawartości metali ciężkich w glebach na terenie silnie zdegradowanym przez przemysł wydobywczy i przetwórczy. Badania przeprowadzono w zachodniej części województwa małopolskiego w mieście Trzebinia. Stwierdzono, że średnia zawartość miedzi w glebie miasta nie przekroczyła wartości dopuszczalnych stężeń tego pierwiastka według regulacji krajowych dla użytków rolnych. Uzyskane wyniki średnich stężeń kadmu, ołowiu i cynku w glebie dla miasta Trzebinia przekroczyły normę krajową wartości dopuszczalnych stężeń tych pierwiastków. Przeprowadzona kalkulacja kosztorysowa wykazała, że koszt zrekultywowania metodą szczegółową (biologiczną) 100 m^2 terenów zdegradowanych zanieczyszczonych metalami ciężkimi w mieście Trzebinia wyniesie 168,69 zł.

SŁOWA KLUCZOWE: metale ciężkie, gleba, rekultywacja, kosztorys

Introduction

Environmental measures taken for several decades are justified in the context of increasingly discernible, negative consequences regarding the impact of toxic heavy metals. This influence directly affects the state of soil, water, air, natural ecosystems and, indirectly, human health and agricultural production[1]. Public awareness of ubiquitous pollution and environmental degradation by substances containing trace elements is gradually increasing[2]. It manifests itself not only in the rapidly increasing number of specialized publications, numerous ongoing research projects, but also in the presence of environmental issues in the public discourse on national and international level, and social actions performed ad hoc[3]. Environmental pollution with heavy metals, although undesirable and expensive, seems to be an inevitable result of advancing globalization processes and industrialization of societies, technologization of industry and agriculture, transport mechanisation, affecting in particular the populations of large cities and large-scale farms[4]. The problem of toxic heavy metals in the soils of Trzebinia is long-term and it is a result of anthropogenic human impact on the environment through various activities (industrial, mining and processing of local raw material). The effects of historical industrialization of Trzebinia region are visible to this day and they are reflected in the state of contamination of soils with heavy metals in the discussed area. There is a need to restore biological and productive value to the soils in the area (remediation), either for agricultural or recreational use. The possibility of their afforestation (biological remediation) is not excluded.

Sources of soil contamination with heavy metals

Pollution and contamination are not identical concepts. The first refers to the presence of foreign substance, which does not cause any visible damage to the environment. Contamination, however, is synonymous with the unmis-

1 B.J. Alloway, D.C. Ayres, *Chemiczne podstawy zanieczyszczenia środowiska,* Warsaw 1999.

2 W. Preżdo, L. Nowakowski, *Chemia środowiska,* university script, Opole 1995.

3 J. Curzydło, *Skażenia motoryzacyjne wzdłuż dróg i autostrad oraz sposoby przeciwdziałania ujemnym skutkom motoryzacji w środowisku*, "Zeszyty Problemowe Postępów Nauk Rolniczych PAN" 1995 no. 418, p. 265–270; B.J. Alloway, D.C. Ayres, op. cit.; P. O'Neil, *Chemia środowiska*, Warsaw 1997; S. Zieliński, *Skażenia chemiczne w środowisku*, second edition revised and supplemented, Wrocław 2007.

4 L.G. Bondariew, *Pierwiastki śladowe – dobre i złe zarazem*, Warsaw 1989; S.F. Zakrzewski, *Podstawy toksykologii środowiska,* Warsaw 1995.

takable and noticeable occurrence of harmful effects, hindering the proper use of natural resources and constituting a threat to the ecological system, living organisms, human health, inanimate structure, and the beauty of nature[5]. Four factors are present in all cases of contamination: source of contamination, harmful substance, the medium carrying the substance (for example: water, air and soil) and the object exposed to it[6]. There are two types of harmful substances: originally harmful, i.e. producing harmful effects in the form in which they were brought into the environment and secondarily harmful, whose harmfulness is the result of chemical processes in the environment[7]. Another factor degrading the soil environment is any factor that reduces the biological activity of the soil. Anthropopressure as well as climatic and biological conditions are important in the process of degradation[8]. Due to the genesis of degradative processes, one may distinguish: natural, communication, geotechnical, urban, and industrial degradations. Owing to specific properties of the soil, to which these processes are related to, one can enumerate physical, physicochemical, nutritional, toxicological and biological degradations[9]. Soil resistance to degradations depends on its physical and chemical properties: soil pH, its sorption and oxidative capacity, concentrations of soil macro- and microelements, content of humic acids and organic matter[10]. Biochemical processes associated with the presence of microorganisms in the soil are also important. The reduction in the production of biomass, intensive acidification (especially by rainfall of sulphur compounds and the use of fertilizers), the accumulation of phytotoxic substances, deficiency of nutrients for plants and violation of ion balance between them are classified as external signs of soil degradation[11]. Degradation leads to changes in the soil structure, impoverishment of its humus level, reduction in the biological activity of the soil environment, violations of its ion balance, excessive alkalization or salinification of this environment. This results in soil depletion or excess

5 Ibidem.

6 J. Siuta, *Gleba-diagnoza stanu i zagrożenia,* Warsaw 1995.

7 B.J. Alloway, *Heavy metals in soils*, Glasgow 1995; P. O'Neil, op. cit.

8 J. Siuta, op. cit.

9 J. Siuta, *Ochrona i rekultywacja gleb,* Warsaw 1978; Z. Trzyszcz, *Przekształcenie geochemiczne, hydrologiczne i chemiczne pokrywy glebowej w woj. Katowickim,* "Zeszyty Problemowe Postępów Nauk Rolniczych PAN" 1995 no. 418, p. 117–126; R. Turski, S. Baran, *Degradacja, ochrona i rekultywacja gleb,* Lublin 1995; H. Terelak, et al., *Zawartość Cd, Cu, Ni, Pb, Zn i S w glebach woj. krakowskiego i Polski,* Materials from Scientific Conference: Management of areas contaminated by human activity, 1996, p. 69–81.

10 H.C. Buckman, N.C. Brady, *Gleba i jej właściwości*, Warsaw 1971; J. Siuta, *Rekultywacja gruntów,* Warsaw 1998; G.V. Motuzova et al., *Soil contamination with heavy metals as a potential and real risk to the environment,* "Journal of Geochemical Exploration" 2014 no. 144, p. 241–246.

11 A. Karczewska, *Ochrona gleb i rekultywacja terenów zdegradowanych,* Wrocław 2008.

insertion of nutrients into plants, fragmentation of biologically active surface and proper soil as well as drying or waterlogging of soil or decrease in its sorption capacity[12].

In Poland, contamination with heavy metals includes up to 3% of arable land. The toxic presence of heavy metal ions in the soil solution considerably reduces the activity of soil enzymes: dehydrogenase, alkaline phosphatase, acid phosphatase, and urease. The most harmful in this regard is lead, while zinc and copper are the least toxic[13]. Soils showing high content of clay materials and organic matter can accumulate substantial amounts of heavy metals, stopping them in the surface layers, and therefore they are considered to be resistant to chemical contamination. The soil pH and its sorption capacity influence the distribution and mobility of zinc, lead, copper and cadmium in the soil profile and their precipitation. This impact is especially characteristic of acid soils[14]. The course of soil formation and soil profile development are dependent on the type of organic and mineral connections, biodegradation of organic component of the complex, adsorption of the complex on the mineral particle of the soil and the degree of saturation with the metal ion[15]. The greatest concentration of heavy metals is observed in the humic level of soil[16]. The potential for bioaccumulation of metals intensifies their negative impact on the soil environment. Heavy metals take readily soluble forms. This facilitates their bioavailability and migration into waters, and thus accelerates the chemical degradation of soil[17]. In soil, metals adopt non-labile (spare) and labile (movable) forms. The occurrence of a particular form affects the scope of potential harmfulness of metal. In non-labile forms, metal ions bind to the humus and soil minerals and they are occluded on the oxides of manganese and iron. Labile forms are metal ions interchangeably adsorbed by soil col-

12 A. Kabata-Pendias, *Zanieczyszczenia pierwiastkami śladowymi gleb użytków rolnych. Wybrane zagadnienia związane z chemicznym zanieczyszczeniem gleb,* Warsaw 1989; K. Łopata, E. Rudnik, E. Nowak, *Tajemnice gleby. Chroń swoje środowisko,* Warsaw 1997; H. Greinert, *Ochrona gleb,* Zielona Góra 1998; P. Kowalik, *Ochrona środowiska glebowego,* Gdańsk 1999; P. Kowalik, *Ochrona środowiska glebowego,* Warsaw 2001.

13 W. Jarosz, E. Marchwiński, *Wpływ emisji z tras komunikacyjnych na skażenia gleby i żywności,* in: *Ekosystemy żywicielskie i żywność. Zagrożenia i problemy ochrony*, Warsaw 1991; K. Turnau, O. Wenhrynowicz, *Mechanizmy obronne roślin i grzybów w siedliskach skażonych ołowiem*, Materials from the symposium Lead in the environment. Environmental Problems and Methodology, Warsaw 1997.

14 K. Dziadek, W. Wacławek, *Metale ciężkie w środowisku,* cz. 1, *Metale ciężkie (Zn, Cu, Ni, Pb, Cd) w środowisku glebowym,* "Chemia, Dydaktyka, Ekologia, Metrologia" 2005 no. 10(1–2), p. 33–44.

15 F. Woch, *Wademekum klasyfikatora gleb,* Collective work, Second edition supplemented and revised, Puławy 2007; D. Hillel, *Gleba w* środowisku, Warsaw 2012.

16 R. Ciepał, *Przenikanie S, Pb, Cd, Zn, Cu i Fe do biomasy oraz gleby ekosystemu leśnego. Znaczenie bioindykacyjne,* Katowice 1992; J. Curzydło, op. cit.

17 E. Kociołek-Balawejder, E. Stanisławska, *Chemia środowiska,* Wrocław 2012.

loids[18]. The occurrence of two or more toxic metals in soil solution may lead to an antagonistic effect (weakening metal's assimilability and toxicity), a synergic effect (the enhancement of metal's assimilability and toxicity), or an additive effect (strengthening assimilability and toxicity of metal by a neutral element)[19]. An example of the antagonistic effect is the reduction in assimilability and toxicity of cadmium with increased amounts of copper and zinc. The appearance of lead leads to increased assimilability and toxicity of cadmium, which is an example of the synergic effect. The additive effect is created due to an increase in assimilability and toxicity of manganese because of presence iron oxides and hydroxides[20].

Research results

Below there are the research results regarding the content of heavy metals in the soils of the city Trzebinia and the properties of these soils affecting the mobility of heavy metals.

Content of heavy metals in the soil of the city Trzebinia

The average content of cadmium in soil at a depth of 0–20 cm was equal to 5.95 mg/kg, and the median was 5.17 mg/kg. The content of this element ranged from 2.10 mg/kg to 14.90 mg/kg in this soil layer. At a depth of 20–40 cm the average cadmium content was 5.10 mg/kg, with a median of 4.76 mg/kg. In this soil layer, the content of this metal was included in the range of 0,82–15,30 mg/kg.

The average content of lead in soil at a depth of 0–20 cm was equal to 209.77 mg/kg, and the median was 151.77 mg/kg. In this soil layer, the content of the element ranged from 65.65 mg/kg to 845.15 mg/kg. At a depth of 20–40 cm the average lead content was 182.60 mg/kg, and the median was 163.35 mg/kg. In this soil layer, the content of this metal was in the range of 30,87–824,10 mg/kg.

18 T. Chodak, C. Kabała, *Powierzchnia właściwa-złożony parametr charakteryzujący stan środowiska glebowego,* "Zeszyty Problemowe Postępów Nauk Rolniczych PAN" 1995 no. 418, p. 501–506; R. Bednarek, et al., *Badania ekologiczno-gleboznawcze,* Warsaw 2011.

19 E. Gorlach, *Metale ciężkie jako czynnik zagrażający żyzności gleby*, "Zeszyty Problemowe Postępów Nauk Rolniczych" 1995 no. 421a, p. 113–122; K. Cedzyńska, B. Smolińska, *Wpływ metali ciężkich na aktywność enzymatyczną gleby. Obieg pierwiastków w przyrodzie,* Monograph. Vol. III., 2005, p. 541–544; Cz. Jasiewicz, A. Baran, *Przewodnik do wykładów i ćwiczeń z toksykologii*, Cracow 2008.

20 M. Gębski, W. Stepski, S. Mercik, *Ocena metod oznaczania metali ciężkich w glebie w oparciu o ich zawartości w roślinach*, "Zeszyty Problemowe Postępów Nauk Rolniczych" 2000 no. 472, p. 267–273.

The average zinc content in soil at a depth of 0–20 cm was equal to 2795.47 mg/kg, and the median was 616.44 mg/kg. In this soil layer, the scope of element content ranged from 165.85 mg/kg to 2091.81 mg/kg. At a depth of 20–40 cm the average zinc content was 715.20 mg/kg, and the median was 512.81 mg/kg. In this soil layer, this metal had content in the range of 108,20–1892,10 mg/kg.

The average copper content in soil at a depth of 0–20 cm was equal to 22.82 mg/kg, and the median was 19.47 mg/kg. In this soil layer, element content range is from 4.86 mg/kg to 54.62 mg/kg. At a depth of 20–40 cm average copper content was 18.85 mg/kg, the median 12.75 mg/kg. In this soil layer, the metal had content in the range of 3,22–59,69 mg/kg.

Soil properties affecting the mobility of heavy metals

The average percentage content of organic matter in soil for a depth of 0–20 cm was 4.28%, and the median 4.08%. Matter content for this depth is in the range of 2,00–8,10%. For a depth of 20–40 cm the average content of organic matter in soil was equal to 2.92% and the median 2.95%. In this soil layer, matter content shaped in the range of 1,05–6,05%.

Average electrolytic conductivity of soil at a depth of 0–20 cm was equal to 206.05 μS, and the median was 214,00 μS. The conductivity in this soil layer took the range of values 57,00–390,00 μS. For a depth of 20–40 cm average electrolytic conductivity was lower and it amounted to 174,64 μS, and the median was 163,90 μS. The range of value concerning the electrolytic conductivity of the soil in the analysed layer amounted to 57,00–370,00 μS.

The average pH of the soil determined in water regarding the 0–20 cm layer was 6.54 and the median was 6.70, and it took acid reaction. The pH values ranged from 5.90 to 7.10, that is, from acidic to slightly alkaline reaction. For a depth of 20–40 cm, the average value of soil pH specified in water was 6.74, and the median was 6.80, which corresponds to acid reaction, like the soil reaction in the layer 0–20 cm. The pH range for the depth of 20–40 cm ranged from 6.70 to 7.60, hence from acid to alkaline reaction, similarly to the 0–20 cm layer of soil. The average value of soil pH determined in KCl for the 0–20 cm layer was 6.24, and the median of 6.40, showing acid reaction. Range of the pH varied from 5.20 to 6.80, which is in the range of acid reaction. For a depth of 20–40 cm, the average value of soil pH determined in KCl was 6.39, median was 6.50. Thus, it was acid reaction, such as in a layer of 0–20 cm. At a depth of 20–40 cm soil pH value ranged from 5.10 to 7.20, included in the range from acid to slightly alkaline reaction, in contrast to the 0–20 cm layer, in which soil only showed the acid reaction.

The granulometric composition of Trzebinia soils is dominated by clay and sandy soils. The average percentage content of sand fraction was 72.39%, silt 18.22%, clay 9.39%.

Methods and criteria for remediation of soils contaminated with heavy metals

Land remediation relies on restoring their utility or natural value through execution of necessary procedures. Methods for remediation of soils contaminated with heavy metals are based on immobilization of metals in soil or in their mobilisation and removal from soil. Immobilisation effect of heavy metals in the solid phase of soil is achieved by modifying the pH and its sorption capacity. The basic procedure limiting the mobility of metals is deacidification of soils by liming. Mobilisation and removal can be achieved by phytoextraction, which involves the use of plants for the removal of heavy metals from the soil. Biomass from such lands, rich in heavy metals, is regarded as hazardous waste[21].

The decision about the direction of remediation is undertaken on the basis of the following factors that can be grouped into:

- economic,
- formal and legal – the direction of remediation must be consistent with the local development plan,
- technical,
- hydrogeological,
- cultural,
- social[22].

According to the Act of 21 August 1997 *on real estate management*, every property, regardless of the type, location and purpose, has a value that can be referred to as[23]:

- market value,
- replacement value,
- cadastral value,
- hypothetical bank value – or another kind of value provided by separate regulations.

For the valuation of real estate one uses comparative, income or cost approach. Table 1 shows the classification of property valuation.

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21 A. Karczewska, op. cit.

22 A. Ostręga, *Sposoby zagospodarowania wyrobisk i terenów po eksploatacji złóż surowców węglanowych na przykładzie Krzemionek Pogórskich w Krakowie,* doctoral dissertation, Cracow 2004.

23 Ustawa z dnia 21 sierpnia 1997 roku o gospodarce nieruchomościami (Dz.U. 2010 nr 102 poz. 651 z późn. zm.).

Table 1. Classification of methods for real estate valuation

Approach	Method	Technique
Comparative	Comparing pairs	-
	Statistical analysis of the market	
	Correcting the average price	
Income	Investment	Simple capitalization Discounted cash flows
	Profits	
Cost	Restoration costs	Detailed Merged elements Indicator
	Replacement costs	
	Liquidation costs	Detailed Indicator
Mixed	Residual	-
	Liquidation costs	
	Estimated indicator of land	

Source: A. Janik, *Wielokryterialna metoda wyceny wartości terenów zdegradowanych*, "Zeszyty Naukowe Politechniki Śląskiej. Seria: Organizacja i zarządzanie" 2012 no. 62, p. 57–79.

Determination of the restoration value according to the cost approach requires identifying the value of land as the expenditure value that must be covered for the purchase of land with the same function and characteristics similar to the land on which the buildings are constructed. The list of difficulties affecting the quality of degraded lands, due to anthropogenic activities, is shown in table 2.

Table 2. Difficulties affecting the quality of valuation concerning properties degraded by anthropogenic activities

Approach	Difficulties
Comparative	• lack of data for comparisons • incomplete information on land prices
Income	• it is not possible to apply in the case of abandoned areas
Cost	• inability to obtain market information about the costs of full restoration • in the case of high pollution levels, e.g. with heavy metals, land's value can be negative in value

Source: A. Jadach-Sepioł, *Możliwości zarządzania wartości nieruchomości*, in: W. Rydzik (ed.), *Aspekty prawne i organizacyjne zarządzania nieruchomością,* Cracow 2009.

Commonly for the valuation of costs that need to be covered to restore degraded soils to their utility value, one uses, among others, professional standards of real estate appraisers – Standard IV *Dotyczy wpływu czynników środowiskowych na wycenę nieruchomości (Eng. Concerning the impact of environmental factors on real estate valuation*.) Standard IV takes into account the costs of restoring the property to its state before contamination, providing outlays on the removal of contaminated soil, e.g. using the techniques of remediation[24].

Estimate price calculation using the detailed method for remediation of soils contaminated with heavy metals in Trzebinia – cost estimate approach

Cost estimate value of the outlays was determined by Council of Ministers Regulation of 21 September 2004 *w sprawie wyceny nieruchomości i sporządzania operatu szacunkowego (Eng. – on the property valuation and preparation of the appraisal report)* (§35.1 paragraph 2. point 2.) with the use of the detailed technique, which specifies the restoration costs on the basis of the necessary amounts to execute the construction works and unit prices of these works. Cost estimate made by means of the detailed method was used to determine the remediation price of areas degraded by heavy metals. Detailed calculation is based on calculating the estimate price as the sum of products: the amount of fixed premeasured units, units of material outlays and their prices, and appropriately added indirect costs and profit, including the value-added tax (VAT)[25]. The value of individual material outlays (labour, materials, work of equipment and means of technological transport) indispensible to make an estimate, adopted on the basis of Catalogue of Standard Prices and Rates[26] (tab. 0215, 0216). Unit standards of material outlays, unit prices of production factors, indirect costs, calculation profit and VAT were taken into account[27]. Remediation cost of $100m^2$ will amount to 168,69 zl (table 3). Calculated costs include the cost of remediation by detailed biological method, involving the reconstruction of soils using agrotechnical methods (mechanical cultivation of the soil), and seeding legumes and grasses. This requires a series of procedures, including arrangement of the

24 Rozporządzenie Rady Ministrów z dnia 21 września 2004 roku *w sprawie wyceny nieruchomości i sporządzania operatu szacunkowego* (Dz.U. nr 207, poz. 2108 i 2109).

25 R. Cymerman, *Wycena nieruchomości a ochrona środowiska (ekologiczne uwarunkowania wyceny nieruchomości),* "Nieruchomości" 2000 no. 7.

26 Katalog Nakładów Rzeczowych nr 2–21. Tereny zieleni tab. 0215-Wysiew nawozów mineralnych lub wapna nawozowego, tab.0216-Uprawa gleby przy zastosowaniu nawozów zielonych.

27 K. Jóźwiak-Jaworska, *Podstawy kosztorysowania w architekturze krajobrazu,* Warsaw 2012.

Table 3. Estimate price calculation using the detailed method for remediation of soils contaminated with heavy metals in Trzebinia

No. item	Description of work, expenditures	UOM	The amount of work, standards	Price	R (estimated value of labour)	M (estimated value of construction materials)	S (estimated value of the work of construction equipment)	Total
	SCOPE OF REMEDIATION WORKS							
	1.1. LIMING- KNR 2-21 table 0215							
	Sowing of mineral fertilizers or lime fertilizer							
		m^2	**100,00**					
	Labour							
	Gardeners - group I (analogy)	r-g	0,6637	15,00	9,96			
	Materials							
	Agrofoska (analogy)	t	0,0051	1 230,96		6,28		
	Equipment							
	Wheeled tractor 25-28 KM (1)	m-g	**0,0132**	**87**			**1,15**	
	Harrow	m-g	**0,0094**	**39,27**			**0,37**	
	Fertilizer seeder (fertilizer spreader)	m-g	**0,0038**	**34,34**			**0,13**	
	Total running costs				9,96	6,28	1,65	17,88
	Indirect costs 65% R+S				6,47		1,07	7,54
	Profit 11% R+S+Kp (R+S) (Kp - Eng. indirect costs)				1,81		0,30	2,11
	Total heading				**18,23**	**6,28**	**3,02**	**27,53**
	1.2. SEEDIND LEGUMES KNR 2-21 table 0216							
	Cultivation of the soil by using green manure							

	m²	**100**					
Labour							
Gardeners - group I (analogy)	r-g	0,0238	15	0,357			
Gardeners - group II (analogy)	r-g	0,2626	15	3,939			
Materials							
potassium salt 38-42%	t	0,002	1453,6		2,91		
superphosphate 17,5%	t	0,002	1361,6		2,72		
saletrzak 20,5%	t	0,001	1214,4		1,21		
Seeds of legumes	t	0,0025	24800		62,00		
Equipment							
Wheeled tractor 25-28 KM (1)	m-g	0,139	87			12,09	
Harrow	m-g	0,052	39,27			2,04	
Ploughing plough	m-g	0,0867	44,2			3,83	
Total running costs				4,30	68,84	17,97	91,11
Indirect costs 65% R+S				2,79	44,75	11,68	59,22
Profit 11% R+S+Kp (R+S) (Kp - Eng. indirect costs)				0,78	12,50	3,26	16,54
Total heading				7,87	126,09	32,91	166,86
Total: Remediation works							
Total running costs				14,25	75,12	19,62	108,99
Purchase costs 0%				0	0,00	0	0,00
Indirect costs 65% R+S				9,26	0,00	12,75	22,01
Profit 11,4% R+S+Kp(R+S) (Kp - Eng. indirect costs)				2,59	0,00	3,56	6,15
Total				26,10	75,12	35,93	**137,15**
Together with VAT 23%				**32,10**	**92,40**	**44,19**	**168,69**

land surface. The duration of remediation depends on the type of wasteland, physicochemical properties of the substrate and the type of farming[28].

Conclusions

1. Considering the obtained results regarding average concentrations of cadmium, lead and zinc in the soil of Trzebinia, it should be stated that they exceeded the allowable concentrations of these elements according to national regulations (Dz.U. 2002) for farmlands, both at a depth of 0–20 cm and 20–40 cm. The statement about soil pollution with the aforesaid elements in Trzebinia is eligible.
2. The obtained results of soil pollution with zinc, cadmium and lead show a connection with activities from the past (industrial, agricultural, mining and processing local raw materials) in the rural administrative units of Trzebinia.
3. Analysing the obtained results of the average copper content in the soil of Trzebinia, it must be concluded that they have not exceeded the permissible concentrations of this element according to national regulations (Dz. U. 2002) for farmlands (<150 mg/kg s.m), both at depth 0–20 cm and 20–40 cm. Therefore, the soils of Trzebinia have not been contaminated with copper.
4. Standards for soil and land quality were exceeded in the area of the Trzebinia city. Taking into account cost-benefit analysis, soil remediation should be carried out.
5. The performed estimate calculation showed that the cost of remediation by detailed biological method regarding 100 m^2 of degraded lands will amount to 168,69 zl.

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28 A. Karczewska, op. cit.

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