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THE USE OF ENZYMATIC TESTS TO ASSESS THE QUALITY OF ARABLE SOILS ALONG MAIN THOROUGHFARES IN LUBLIN

Summary

Communicative enzymatic indicators were used in this study to assess the quality of arable soils along main thoroughfares in Lublin. The study comprised 16 areas located by roads with similar car traffic intensity. Soil samples were collected from the topsoil layer (0-20 cm) of farmlands, at distances of 10, 30, 50 and 100 m from the road verge. The activity of 4 enzymes was measured in the samples: dehydrogenases, acid phosphatase, alkaline phosphatase and urease as well as the total content of heavy metals (Zn, Pb, Cu, Cd) and the total content of 16 polycyclic aromatic hydrocarbons. The research revealed that the activity of dehydrogenases, acid phosphatase and alkaline phosphatase rose gradually as the distance from the road increased. The maximum activity of these enzymes was observed at distances of 50-100 m or 100 m away from the road. The research findings show that unfavourable changes in arable soils located in open areas adjacent to main thoroughfares can be observed at least at a distance of 50 m.
***Key words**: arable soils, enzymatic activity, main thoroughfares*

ZASTOSOWANIE TESTÓW ENZYMATYCZNYCH DO OCENY JAKOŚCI GLEB UPRAWNYCH WZDŁUŻ GŁÓWNYCH TRAS KOMUNIKACYJNYCH LUBLINA

Streszczenie

W pracy zastosowano komunikatywne wskaźniki enzymatyczne do oceny jakości gleb uprawnych położonych wzdłuż głównych tras komunikacyjnych Lublina. Badaniami objęto 16 powierzchni położonych przy drogach o zbliżonym natężeniu ruchu pojazdów samochodowych. Próbki glebowe pobrano z pól uprawnych z warstwy ornej 0-20 cm, z odległości 10, 30, 50 i 100 m od krawędzi jezdni. W pobranym materiale oznaczono: aktywność 4 enzymów: dehydrogenaz, fosfatazy kwaśnej, fosfatazy zasadowej i ureazy oraz całkowitą zawartość metali ciężkich (Zn, Pb, Cu, Cd) i sumaryczną zawartość 16 wielopierścieniowych węglowodorów aromatycznych. W glebach badanych powierzchni aktywność dehydrogenaz, fosfatazy kwaśnej i fosfatazy zasadowej wzrastała stopniowo wraz ze wzrostem odległości od krawędzi drogi. Maksymalną aktywność tych enzymów stwierdzono w odległości 50-100 m lub 100 m od drogi. Wyniki te wskazują, że niekorzystne zmiany stanu biologicznego gleb upranych na terenach otwartych przyległych do tras komunikacyjnych sięgają co najmniej na odległość do 50 m.
***Słowa kluczowe**: gleby uprawne, aktywność enzymatyczna, główne trasy komunikacyjne*

1. Introduction

The protection and monitoring of farmland, especially in endangered areas, such as arable land located along roads, is related with the ecological policy of the state in its broad sense. Its main goal, which is pursued under the sustainable development strategy, is to improve the ecological conditions of human life and the possibility to produce healthy food [21]. The negative effect of intensive car traffic on soils is caused by contamination of the environment with heavy metals, polycyclic aromatic hydrocarbons, deicing products and carbon black dust formed as a result of abrasion of car tyres [7]. Measurements of the content of xenobiotics in soil do not reflect the real ecotoxic danger caused by their presence in the environment. When estimating soil quality it is important to assess the amount of contamination which can be tolerated and will not cause negative consequences to soil organisms and plants. Testing the activity of various enzymes can provide a credible assessment of soil quality and health status. These bioindicators reflect the scale of environment pollution which is dangerous to living organisms without the need to identify many compounds [5]. The aim of the study was to determine changes in enzymatic activity in arable soils located along main thoroughfares in Lublin depending on the distance from the road verge.

2. Materials and Methods

The study comprised 16 areas located by roads with similar car traffic intensity. All of them are situated near Lublin, i.e. Turka – national road No. 82, Zemborzyce Tereszyńskie – national road No. 19, Kazimierzówka – road No. S-12, Ciecierzyn – regional road No. 835 (Figure 1). In September 2015 soil samples were collected from the topsoil layer (0-20 cm) of farmlands, at distances of 10, 30, 50 and 100 m from the road verge. Due to the close relationship between soil enzyme activity and soil quality the fields selected for the study were located on soils of very good wheat complex [11]. They were characterised by similar granulometric composition of dusts [17] and acidity (pHKCl = 6.4-6.8). This procedure minimised the influence of other factors (soil properties and typology, different car traffic intensity) than the distance from the road verge and enabled better assessment of the range of the influence of traffic routes on the biological state of arable soils. The ac-

tivity of the following enzymes was measured: dehydrogenases (ADh) [25], acid phosphatase (APhacA), alkaline phosphatase (APhal) [24] and urease (AU) [28]. These enzymes play a significant role in transforming soil organic matter and exhibit noticeable reactions to environmental factors. In order to assess the degree of soil contamination from car traffic the total content of heavy metals (Zn, Pb, Cu, Cd) was measured with a Leeman Labs (PS 950) apparatus by means of emission spectrometry with argon ICP excitation. The total content of 16 polycyclic aromatic hydrocarbons (Σ16PAHs) was measured with the HLPC method with UV detection (254 nm). Soil samples (30g) were extracted with dichloromethane in an ultrasonic bath. The extracts were purified by means of the SPE technique [16]. The soil sample subjected to analysis was a mean of 5 samples collected from each area. Statistical analysis was conducted using the Statistica package [22].

Source: Authors' compilation / Źródło: opracowanie własne

Fig. 1. Location of study areas

3. Results and Discussion

There were considerable variations in the activity of the topsoil enzymes under analysis. The intensity and tendency of variations depended on the distance of the research area from the road verge and the type of enzyme under study (Table 1). In all of the soil areas under study the activity of dehydrogenases, acid phosphatase and alkaline phosphatase grew significantly as the distance from the road increased. The maximum activities of these enzymes were observed at the distances of 50 and 100 m away from the road verge. Only in Kazimierzówka the maximum activities were observed at the distance of 100 m. The enzymatic activity in the soil areas situated in close neighbourhood of roads (10 and 30 m away from the verge) was weaker because of greater inflow of heavy metals and PAHs from exhaust gases and road dust into the soil. The data presented by many authors [2, 3, 4, 14, 15, 19, 26, 27] confirm particular sensitivity of dehydrogenases and phosphatases to the soil environment contamination with heavy metals and PAHs. The enzymatic activity can be used as an indicator of contamination of the soil environment with heavy metals and PAHs.

Table 1. Enzymatic activity of soils

Locality / No road	Distance from road [m]	DhA	PhacA	PhalA	UA
Ciecierzyn / 835	10	1.98b	2.92a	1.94a	14.94b
	30	3.16c	4.39b	2.88b	10.09a
	50	5.22d	9.55c	6.04c	9.22a
	100	5.08d	9.74c	5.89c	9.97a
Kazimierzówka /S-12	10	1.24a	2.11a	1.43a	10.32a
	30	1.89b	3.18ab	1.89ab	15.18b
	50	2.93c	4.73b	3.16b	17.89bc
	100	4.41d	9.65c	6.09c	20.94c
Turka / 82	10	1,88b	3.16a	2.12a	18.22bc
	30	2.94c	4.67b	3.13b	14.16b
	50	4.27d	8.84c	5.93c	10.81a
	100	4.33d	9.02c	6.06c	11.03a
Zemborzyce Tereszyńskie / 19	10	1.92b	2.56a	1.64a	20.63c
	30	2.99c	3.83b	2.51b	17.20bc
	50	4.49d	9.46c	6.35c	11.54a
	100	4.42d	9.12c	6.18c	11.62a

DhA – Dehydrogenases in cm^3 $H_2 \cdot kg^{-1} \cdot d^{-1}$,
PhacA – Acid Phosphatase and PhalA – Alkaline Phosphatase in mmol $PNP \cdot kg^{-1} \cdot h^{-1}$,
UA – Urease in mg $N\text{-}NH_4^+ \cdot kg^{-1} \cdot h^{-1}$;
Values followed by the same letter in a column were not significant at $p < 0.05$, 't'- test.

Source: own work / Źródło: opracowanie własne

The study revealed a gradual decrease in the content of heavy metals and polycyclic aromatic hydrocarbons in the soil as the distance from the road verge increased (Tables 2 and 3). Numerous data from reference publications show that these contaminations are accumulated near roads [1, 7, 8, 12]. In our study the content of Zn and Cu in the soil samples exceeded the geochemical background value only at the shortest distance from the road (10 m), whereas the content of Pb exceeded the value also at the distance of 30 m from the road verge. As far as cadmium is concerned, the soil samples from all the areas under study were characterised by higher content of this metal than the chemical background value (Table 2). It is a very negative effect because cadmium is a metal which is most easily accumulated in plant tissues and thus, it is included in the trophic chain. Cadmium and lead are the elements causing the greatest threats to agricultural production and human health [7].

In the soil samples under study the total content of PAHs decreased regularly and statistically significantly as the distance from the road verge increased (Table 3). According to the classification system suggested by Maliszewską-Kordybach [13], soil located at the distances of 10 and 30 m from the road should be classified as minimally contaminated, whereas soil located at the distances of 50 and 100 m from the road verge should be classified as uncontaminated. Soils located in the closest neighbourhood of roads are contaminated with PAHs not only because of the direct effect of emission from engines but also due to the indirect effect of vehicle use, such as abrasion of car tyres and road works. Tyres are usually filled with carbon black. As a result of abrasion it is emitted to the environment together with the PAHs it includes [1]. Polycyclic aromatic hydrocarbons can be accumulated by crops [20] and cause a serious threat to human health due to their mutagenic and carcinogenic properties.

Table 2. The content of heavy metals in investigated arable soils

Locality / No road	Distance from road	Zn	Pb	Cu	Cd
	[m]	[mg·kg^{-1}]			
Ciecierzyn / 835	10	35	13.8	7.9	0.37
	30	27	11.0	6.8	0.33
	50	18	9.1	5.2	0.26
	100	16	8.2	4.9	0.25
Kazimierzówka / S-12	10	39	21.1	8.4	0.44
	30	30	16.3	6.5	0.37
	50	28	9.4	5.4	0.31
	100	24	9.2	5.2	0.27
Turka / 82	10	32	18.7	7.8	0.32
	30	26	16.2	6.6	0.29
	50	16	9.7	5.7	0.25
	100	15	9.5	5.3	0.24
Zemborzyce Tereszyńskie / 19	10	33	19.4	7.5	0.30
	30	23	16.8	4.9	0.29
	50	19	9.8	3.8	0.25
	100	17	9.3	2.5	0.24
Geochemical background		30	9.8	7.1	0.18

Source: own work / Źródło: opracowanie własne

Table 3. The content of 16 polycyclic aromatic hydrocarbons (Σ16PAHs) content in investigated arable soils

Locality / No road	Content of 16 PAHs [μg·kg^{-1} s.d.]			
	Distance from road [m]			
	10	30	50	100
Ciecierzyn / 835	412d	294c	132b	67a
Kazimierzówka / S-12	598d	332c	152b	78a
Turka / 82	531d	268c	139b	63a
Zemborzyce Tereszyńskie / 19	542d	272c	124b	62a

Values followed by the same letter in a column were not significant at $p < 0.05$, 't'- test.

Source: own work / Źródło: opracowanie własne

As far as urease is concerned, there was not a definite regularity related with a gradual increase in the enzyme activity as the distance from the road grew longer. Kazimierzówka was the only locality where this regularity was observed (Table 1). In the other areas under study the greatest urease activity was measured in the closest neighbourhood of roads (10 m away from the road verge). Urease is resistant to external factors and under extreme conditions its activity increases [23]. High urease activity in soils under pressure of anthropogenic contamination was also observed in other studies [3, 9, 10]. The availability of the substrate, i.e. urea, is the only factor limiting urease activity. Being an extracellular enzyme, it is synthesised only in the presence of the substrate [6]. Urea (the final product of metabolism of proteins in land animals and humans) in roadside soil can be found in different sources, such as: animal excreta, food waste, fragments of tissues and cells of the soil micro-, meso- and macrofauna, plant debris and cells of microorganisms. Urease activity can be used to assess the scale of anthropogenisation of the soil environment [18].

4. Conclusions

1. Car traffic, which pollutes the environment with heavy metals and PAHs, has negative influence on the enzymatic activity in roadside soils.
2. Dehydrogenase and phosphatase activities in the arable soils under study were significantly stimulated as the distance from the road verge increased. Simultaneously, there was a decrease in the content of heavy metals and polycyclic aromatic hydrocarbons.
3. Unfavourable changes in the biological state of arable soils located in open areas adjacent to roads can be observed at least at a distance of 50 m.
4. Measurements of dehydrogenase and phosphatase activity enable determination of the influence of car traffic on the quality and health status of soils in the neighbourhood of main thoroughfares.

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