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THE EFFECT OF PETROLEUM-DERIVED SUBSTANCES ON CHEMICAL COMPOSITION OF WINTER WHEAT

WPŁYW SUBSTANCJI ROPOPOCHODNYCH NA SKŁAD CHEMICZNY PSZENICY OZIMEJ

Abstract: The aim of the study was to determine the effect of petrol, used engine oil and diesel fuel on the content of calcium, magnesium, iron, potassium and the selected heavy metals in the grain, straw and roots of winter wheat. The effect of bioremediation process on the abovementioned parameters was also determined. The experiment was conducted in 2014 on the area of the Experimental Station of the University of Agriculture in Krakow, situated in Mydlniki. In June 2010, the soil surface was artificially contaminated with petroleum-derived substances in quantity of 6000 mg per 1 kg of dry mass. Half of the objects were subjected to the bioremediation process by adding biopreparation ZB-01. The evaluation of nutrients content was conducted using flame absorption spectrometry. The results of the experiment showed that all used petroleum-derived substances most frequently contributed to the decrease in the content of selected nutrients in the grain of winter wheat. In other organs of plant the content of nutrients and heavy metals due to the presence of petroleum-derived substances in the soil was variable and depended on the type of used substances and on the analysed part of the plant. Application of biopreparation ZB-01 on soil contaminated with engine oil usually caused an increase in the content of analysed nutrients in the roots of plants, but also their decline in the straw. In other objects variables dependencies were noted, most frequently biopreparation had no significant effect on the content of heavy metals in the plants.

Keywords: petroleum-derived substances, bioremediation, nutrients, heavy metals, winter wheat

In recent years, the progressive economy industrialization and the increase of the level of antropopression have led to the intensive growth of petroleum-derived substances consumption, which carries the risk of entering these compounds to the environment. The most vulnerable to contamination are the soils located near petrol stations, garages, seaports, and other areas where the production or distribution of crude

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oil is present [1]. Moreover, heavy agriculture machines are increasingly used, which leads to increase of diesel fuel consumption and therefore may lead to the contamination of cultivated soils. Incorrect transport, storage and inadequate care in the disposal of petroleum-derived substances are the main factors influencing the increase of environmental pollution with these compounds [2–4]. Petroleum-derived substances penetrate into the soil and contribute to its degradation by modifying the physico-chemical and biological properties [5, 6]. The presence of these xenobiotics in the soil results in inhibition of growth and development of many crops, disturbs the uptake of water and nutrients, and modifies the content of heavy metals in plant organs [7–10].

To purify the soil contaminated with petroleum-derived substances most commonly various techniques of bioremediation are used. For this purpose soil microorganisms are applied. They are supposed to reduce the concentration of contaminants to acceptable levels, convert petroleum hydrocarbons into non-toxic compounds or perform mineralization to carbon dioxide and water. Most commonly bacteria and fungi are used, as characterized by a large population size, rapid growth, and moreover, their metabolic products decompose pollutants [11–13].

The aim of the study was to determine the effect of petrol, used engine oil and diesel fuel on the content of selected nutrients (calcium, magnesium, iron, potassium) and heavy metals (cadmium, lead, zinc, nickel, copper, manganese) in the grain, straw and roots of winter wheat.

Material and methods

The plant material used for the laboratory analysis was obtained from the Experimental Station of the University of Agriculture in Krakow, located in Mydlniki (50°5′5,04″N 19°51′13,47″E). In November 2009, indigenous soil was placed in special containers of 1 m^3 volume each, retaining the natural arrangement of layers. The containers were sunk in the ground so that their upper edge was at the same level as the surface of the soil. All containers had a pipe leading to the surface, enabling the excess of water to be pumped out, and three plastic tubes for suitable soil aeration, which is necessary for the correct course of bioremediation. The soil in the containers was left for eight months without any intervention in order to regain its natural biological functions. In June 2010, the soil surface was artificially contaminated with petrol, used engine oil, and diesel fuel in a quantity of 6000 mg of petroleum-derived substance per 1 kg of dry mass, by pouring it on the soil. After one week, half of the containers were subjected to the bioremediation process by adding biopreparation ZB-01, which was specially produced for this experiment and contained selected prokaryotic organisms, mainly bacteria from the following genera: *Bacillus*, *Pseudomonas*, *Moraxella*, *Stenotrophomonas*, *Acinetobacter*, *Corynebacterium*, *Methylobacterium*, *Alcaligenes*, *Oligella*, *Morganella*. The procedure of bioremediation was repeated in spring 2011. The non-contaminated soil was placed in identical containers and constituted the control treatment. The experiment was set in four repetitions in line with the randomised blocks method. In subsequent years, until 2013 the soil in the containers was left without any intervention to enable natural plant succession. The seeds of the Batuta variety of winter wheat were sown in the containers in mid-October 2013, after earlier preparation of the soil (*ie* loosening and fertilizing). Pre-sowing soil fertilization with ‘azofoska’ was applied providing 5.44 gN, 2.56 gP_2O_5 and 7.64 gK_2O per container.

Plant material used to determine the content of selected nutrients and heavy metals was collected after the wheat harvest in early August 2014. In order to determine the nutrients (calcium, potassium, iron, magnesium) and heavy metal (copper, manganese, nickel, lead, zinc, cadmium) concentrations in plants parts, plant material was cleaned of any patches of deposited aphid honeydew and other surface contaminants, washed in tap, next in distilled water. It was then dried at 105°C. A portion of 0.25 g dried plant material was digested with 5 cm^3 of HNO_3 at 110°C and then diluted to 10 cm^3 with deionized water. Next, the metal content was measured using flame absorption spectrometry (Unicam 939 Solar) [14, 15]. The quality of the analytical procedure was checked using a reference material (Certified Reference Material CTA-OTL-1 Oriental Tobacco Leaves) with the same quantities of samples.

The obtained results were then subjected to analysis by STATISTICA 10.0 software. The significance of differences between the means were tested by two-factor variance analysis, and the means were differentiated by Fisher’s LSD test at $\alpha = 0.05$.

Results

All used petroleum-derived substances contributed to a significant reduction in calcium, magnesium and iron contents in the grain of winter wheat (Table 1). Additionally, used engine oil and petrol resulted in a decrease in potassium content, respectively 920.01 $mg \cdot kg^{-1}$ and 837.22 $mg \cdot kg^{-1}$ compared to the control.

Table 1

The content of some nutrients in grain of winter wheat [$mg \cdot kg^{-1}$]

Object	Ca	Mg	Fe	K
EO 0R	328.17^{bc*}	648.30^{a}	38.73^{abc}	4616.92^{a}
EO R	435.29^{cd}	736.44^{b}	37.30^{ab}	5206.15^{cd}
DF 0R	372.24^{cd}	759.54^{bc}	41.68^{abcd}	5616.57^{d}
DF R	324.24^{bc}	733.63^{b}	48.91^{cd}	5174.31^{bcd}
P 0R	297.24^{b}	762.58^{bc}	32.15^{a}	4699.71^{a}
P R	179.39^{a}	718.28^{b}	47.94^{bcd}	4739.03^{ab}
C 0R	541.28^{e}	843.27^{d}	61.70^{e}	5536.93^{d}
C R	368.24^{c}	803.13^{cd}	50.50^{d}	5025.16^{abc}

EO – soil contaminated with engine oil, DF – soil contaminated with diesel fuel, P – soil contaminated with petrol, C – control soil, 0R – without bioremediation, R – with bioremediation. * Means in columns marked with the same letters do not differ significantly according to LSD test at $\alpha = 0.05$.

Biopreparation ZB-01 applied to the soil contaminated with engine oil resulted to a significant increase in the contents of magnesium and potassium in the grain of analysed plants, while in the case of control caused a decline in calcium, iron and potassium contents. The grain obtained from plants growing in soil contaminated with petrol after the application of the biopreparation was characterized by a higher iron content but a lower calcium content compared to the object in which the bioremediation process was not applied. In the case of diesel fuel, there was no significant effect of using the biopreparation ZB-01 on the level of analysed nutrients in winter wheat grain.

All petroleum-derived substances used in the experiment resulted in a significant increase in the cadmium content in winter wheat grain (Table 2). Engine oil also contributed to the increase in the content of manganese by nearly 4 mg · kg^{-1} compared to the control, while diesel fuel – an increase in the contents of lead and nickel (33 mg · kg^{-1} and 0.19 mg · kg^{-1} respectively). Grain of plants growing in soil contaminated with petrol was characterized by lower content of zinc (nearly 17 mg · kg^{-1}) than the grain of plants obtained from control.

Table 2

The content of some heavy metals in grain of winter wheat [mg · kg^{-1}]

Object	Cd	Pb	Zn	Ni	Cu	Mn
EO 0R	0.37^{c*}	3.04^{bcd}	56.01^{cd}	0.17^{bc}	5.17^{bcd}	21.46^{b}
EO R	0.35^{c}	6.18^{cd}	56.61^{d}	0.23^{d}	5.62^{cd}	21.31^{b}
DF 0R	0.45^{d}	7.42^{de}	53.52^{bcd}	0.31^{e}	5.87^{d}	19.14^{ab}
DF R	0.33^{c}	8.50^{e}	50.85^{bc}	0.31^{e}	5.56^{cd}	25.98^{c}
P 0R	0.21^{b}	3.29^{a}	42.09^{a}	0.14^{abc}	4.04^{a}	20.33^{ab}
P R	0.25^{b}	3.99^{ab}	48.40^{abc}	0.18^{cd}	4.60^{abc}	19.00^{ab}
C 0R	0.09^{a}	4.29^{abc}	59.01^{d}	0.12^{ab}	4.90^{abcd}	17.51^{a}
C R	0.21^{b}	4.29^{abc}	45.74^{ab}	0.09^{a}	4.31^{ab}	19.65^{ab}

Symbols as in Table 1. * Means in columns marked with the same letters do not differ significantly according to LSD test at $\alpha = 0.05$.

Used biopreparation usually had no significant effect on the content of selected heavy metals in wheat grain and only in object contaminated with engine oil it contributed to an increase in nickel content, in the object contaminated with diesel fuel – an increase in manganese content, but a decrease in cadmium content, while in control – an increase in cadmium content, but a decrease in the content of zinc.

All applied xenobiotics caused a significant increase in the iron content in wheat straw (Table 3). Straw of plants growing in soil contaminated with diesel fuel was additionally characterized by almost 520 mg · kg^{-1} higher calcium content compared to the control. Petrol contributed to a significant increase in the content of potassium in the straw simultaneously decreasing calcium and magnesium contents.

The use of the biopreparation on soil contaminated with petrol most often resulted in a significant decrease in content of selected nutrients in the analysed part of the plant (a decrease in the contents of magnesium and iron in the object contaminated with engine oil, a decrease in calcium, iron and potassium contents in the object contaminated with diesel fuel, a decrease in iron and potassium contents in the object contaminated with petrol and a decrease in calcium content in the control). However, it

Table 3

The content of some nutrients in straw of winter wheat [mg · kg^{-1}]

Object	Ca	Mg	Fe	K
EO 0R	2838.84^{bc}	512.57^{cd}	376.03^{e}	17956.08^{bc}
EO R	3000.18^{c}	462.14^{ab}	269.04^{d}	26830.23^{d}
DF 0R	3081.05^{c}	519.50^{d}	133.30^{c}	18120.88^{bc}
DF R	2136.00^{a}	486.26^{abcd}	57.03^{a}	12341.05^{a}
P 0R	2169.03^{a}	455.77^{a}	360.30^{e}	41934.27^{e}
P R	2145.74^{a}	612.64^{e}	127.02^{c}	15802.75^{ab}
C 0R	2561.82^{b}	509.02^{bcd}	89.24^{b}	14681.78^{ab}
C R	2031.50^{a}	465.45^{abc}	78.55^{ab}	19931.02^{c}

Symbols as in Table 1. * Means in columns marked with the same letters do not differ significantly according to LSD test at $\alpha = 0.05$.

was noted, that biopreparation applied to the soil contaminated with engine oil caused a significant increase in potassium content in straw (by 8874.15 mg · kg^{-1}), while in the case of soil contaminated with petrol – an increase in magnesium content (by 156.87 mg · kg^{-1}), and in the case of control – an increase in potassium content (by 5249.24 mg · kg^{-1}).

The engine oil led to an increase in the content of most analysed heavy metals in winter wheat straw (lead, zinc, nickel and manganese) (Table 4). Diesel fuel on the one hand, caused an increase in the nickel content by almost 0.3 mg · kg^{-1}, but on the other hand, also led to a decline in zinc content by more than 10 mg · kg^{-1}. Petrol caused a significant lead level increase, but also a decrease in the contents of zinc and manganese. Used petroleum-derived substances had no significant effect on the contents of cadmium and copper in the straw of analysed plants.

Table 4

The content of some heavy metals in straw of winter wheat [mg · kg^{-1}]

Object	Cd	Pb	Zn	Ni	Cu	Mn
EO 0R	0.89^{a}	15.71^{de}	79.53^{c}	0.73^{bcd}	7.94^{a}	41.10^{d}
EO R	1.01^{a}	9.35^{bc}	83.21^{c}	0.90^{e}	9.83^{b}	34.73^{cd}
DF 0R	0.93^{a}	6.62^{ab}	36.80^{a}	0.83^{de}	8.26^{a}	21.84^{b}
DF R	1.00^{a}	10.59^{bc}	47.22^{a}	0.86^{de}	7.69^{a}	53.10^{e}
P 0R	0.81^{a}	17.13^{e}	41.28^{a}	0.65^{abc}	7.63^{a}	13.38^{a}
P R	0.96^{a}	12.37^{cd}	38.49^{a}	0.77^{cde}	8.35^{a}	32.42^{c}
C 0R	0.79^{a}	5.07^{a}	58.08^{b}	0.54^{a}	7.91^{a}	27.97^{bc}
C R	0.90^{a}	6.87^{ab}	65.79^{b}	0.61^{ab}	7.81^{a}	58.57^{e}

Symbols as in Table 1. * Means in columns marked with the same letters do not differ significantly according to LSD test at $\alpha = 0.05$.

Biopreparation application on soil contaminated with diesel fuel, petrol and on control soil led to a significant increase in manganese content in the straw of winter wheat compared to the objects in which the bioremediation process was not applied. Moreover, the straw obtained from plants growing in soil contaminated with used engine oil after applying the biopreparation was characterized by the higher nickel and copper contents, in turn, lower lead content (as in the object contaminated with petrol) than the objects without the application of biopreparation.

Both diesel fuel and petrol caused an increase in iron content in the roots of winter wheat compared to the control (Table 5). However, used engine oil caused an almost twofold decrease in the content of this nutrient in the analysed part of plant. The roots of plants growing in soil contaminated with diesel fuel were also characterized by a higher content of magnesium, while the roots of plants growing in soil contaminated with petrol contained significantly less calcium and magnesium (673.07 mg · kg^{-1} and 56.26 mg · kg^{-1} respectively) in relation to the control.

Table 5

The content of some nutrients in roots of winter wheat [mg · kg^{-1}]

Object	Ca	Mg	Fe
EO 0R	3108.15^{b}	440.64^{b}	641.81^{a}
EO R	3772.83^{c}	498.44^{c}	1366.23^{c}
DF 0R	3199.68^{b}	551.48^{d}	1547.91^{d}
DF R	3003.90^{b}	496.79^{c}	1068.37^{b}
P 0R	2438.89^{a}	392.94^{a}	1459.01^{cd}
P R	2606.69^{a}	431.13^{ab}	1112.94^{b}
C 0R	3111.96^{b}	449.20^{b}	1118.94^{b}
C R	3265.60^{b}	447.91^{b}	1478.92^{cd}

Symbols as in Table 1. * Means in columns marked with the same letters do not differ significantly according to LSD test at α = 0.05.

Biopreparation ZB-01 in the case of the object contaminated with engine oil caused a significant increase in calcium, magnesium and iron contents in plant roots. In the object contaminated with diesel fuel the most frequently inverse relationship was reported (a decrease of magnesium and iron contents after applying the biopreparation). Most often, biopreparation did not affect significantly the content of the analysed components in the case of control and object contaminated with petrol and only led to a decrease in iron content in plants growing in soil contaminated with petrol and increase the content of this element in the control object.

Both engine oil and diesel fuel caused a significant increase in the contents of cadmium, lead, zinc and manganese in the roots of analysed plant (Table 6). Both xenobiotics, also led to a decrease in copper content compared to the control (over 2 mg · kg^{-1}). Moreover the roots of plants growing in soil contaminated with engine oil were characterized by a significantly higher content of nickel (by 0.38 mg · kg^{-1}). There was no significant effect of petrol on the contents of selected heavy metals in the roots of winter wheat.

Table 6

The content of some heavy metals in roots of winter wheat [mg $\cdot$ kg^{-1}]

Object	Cd	Pb	Zn	Ni	Cu	Mn
EO 0R	1.95^{c}	14.01^{cde}	127.30^{d}	1.29^{b}	12.24^{a}	130.31^{b}
EO R	1.96^{c}	17.06^{e}	144.02^{e}	1.33^{b}	13.31^{ab}	169.47^{cd}
DF 0R	1.90^{c}	15.72^{de}	115.12^{d}	1.18^{ab}	11.94^{a}	181.92^{d}
DF R	2.22^{d}	14.13^{cde}	80.47^{bc}	1.14^{ab}	14.30^{bc}	169.52^{cd}
P 0R	1.38^{a}	11.31^{abc}	59.24^{a}	1.21^{ab}	13.02^{ab}	96.04^{a}
P R	1.59^{b}	9.83^{a}	66.58^{a}	0.97^{a}	15.00^{bc}	98.31^{a}
C 0R	1.43^{ab}	10.17^{ab}	71.09^{ab}	0.91^{a}	14.56^{bc}	97.71^{a}
C R	1.64^{b}	13.00^{bcd}	88.18^{c}	1.07^{ab}	16.33^{c}	151.04^{c}

Symbols as in Table 1. *Means in columns marked with the same letters do not differ significantly according to LSD test at $\alpha = 0.05$.

Application of the biopreparation on the soil contaminated with engine oil and on control soil led to a significant increase in the contents of zinc and manganese in plant roots. In the case of soil contaminated with diesel fuel, it was noted, that the use of biopreparation increased the contents of cadmium and copper in the analysed parts of plant, in turn, the zinc content dropped. In the object contaminated with petrol, most often, used bioremediation process did not affect significantly the content of heavy metals in the roots of winter wheat and only caused an increase in cadmium content by 0.21 mg $\cdot$ kg^{-1} compared to the object, in which the biopreparation was not used.

Discussion

In conducted experiment petroleum-derived substances caused a decrease in calcium content in winter wheat grain and petrol also caused a decrease in the content of this nutrient in straw and roots of plants. Wyszkowski and Wyszkowska [8] showed, on the basis of their studies, that the engine oil causes a decrease in calcium content in the aerial parts of oats and maize. The dose of xenobiotic and used organic and mineral fertilization have the major effect on the strength of this interaction. These authors also showed that the engine oil usually causes a decrease in magnesium content and the doses above 6 g $\cdot$ kg^{-1} also contribute to the decrease in potassium content in plants, which corresponds to results of the present experiment, particularly with regard to the grain of winter wheat. Wyszkowski et al [7] found that the engine oil in small doses (1.696 g $\cdot$ kg^{-1}) increases the contents of calcium, magnesium and potassium in the aerial parts and roots of yellow lupine. The discrepancies may be due to the fact of different plant species used in both experiments as well as the other types of soil used as the substrate, which may also have a significant effect on nutrient uptake by plants and was emphasized by these authors. Wyszkowski and Ziolkowska [16] showed that petrol and engine oil may cause a decrease in magnesium content in the aerial parts of oats. In our experiment, petrol also caused a decrease in the content of this micronutrient in all analysed parts of plant, while diesel fuel – the decline in winter wheat grain. The authors also showed that petrol contributes to a significant increase in potassium content in oats, which was also confirmed in our experience (petrol resulted in a significant decrease in potassium content in winter wheat straw). Wyszkowski and Ziolkowska [17] found that a dose of petrol and engine oil amounting to 5 $cm^3 \cdot kg^{-1}$ results in a decrease in calcium and magnesium contents in the aerial parts of yellow lupine and maize. Petroleum-derived substances usually cause an increase of soil density, which leads to clogging of soil pores and, consequently, contributes to disturbances of water and nutrient uptake by plants. This substances may also block the transport of substances in plant cells, which may contribute to the limited growth and development of plants [18].

Rusin et al [10] found that engine oil and diesel fuel cause an increase in the contents of lead and manganese in leaves of broad bean. In our experiment mentioned substances also most often contributed to the increase in heavy metals content in the analysed parts of winter wheat. These authors also showed that diesel fuel can increase nickel content, engine oil – increase zinc content, while petrol – decrease zinc content in leaves, which also corresponds to the results of our experiment. Furthermore, Nwachi et al [19] showed that petroleum-derived substances cause an increase in lead content in the leaves of *Vernonia amygdelina*, *Talinum triangulare, Manihot esculenta* i *Xanthotosoma sagittifolium.* Many authors emphasize that the petroleum-derived substances contribute to the increase of heavy metals level in the soil [20–22], which may also explain the increase of their content in plant organs.

Available scientific literature provides scarce information about the effect of supported bioremediation on the content of nutrients and heavy metals in plants growing in soil contaminated with petroleum-derived substances. Nanekar et al [23] showed that adding an extra microorganisms (bioaugmentation) to the soil contaminated with petroleum-derived substances decreased the amount of total petroleum hydrocarbons in the soil, and also resulted in lowering lead content while increasing manganese content. In the present experiment, the application of ZB-01 biopreparation on the soil contaminated with both used engine oil and petrol decreased the lead content in winter wheat straw, and for all analysed objects caused an increase in manganese content in some parts of plant. Rusin et al [10] also showed that the use of biopreparation ZB-01 on soil contaminated with petrol contribute to the decline in lead content and most often to increase in manganese content in the leaves of broad bean. Microorganisms are often used for the purification of soil contaminated with petroleum-derived substances, which is associated with their ability to adapt to adverse conditions and the use of harmful compounds for their growth and development, which increases the rate of decomposition [12, 13].

Wyszkowski and Ziolkowska [16] demonstrated that the addition of compost, bentonite and calcium oxide to soil contaminated with engine oil and petrol modifies the content of nutrients in plants. All substances introduced into the soil most often contributed to increase in calcium and magnesium contents in spring oilseed rape, however, the bentonite may cause a decrease in calcium and magnesium contents, while calcium oxide – calcium content increase, but also decline in magnesium content in oats. Compost most often contributed to the increase in magnesium content in yellow lupine and an increase in calcium content in maize [17]. In the present experiment the effect of ZB-01 biopreparation was also variable and resulted both an increase and a decrease in the content of selected nutrients, which was dependent on the type of xenobiotic, and on the analyzed part of plant. Many authors emphasize that biostimulation of the soil and its proper aeration are determining factors in improving the soil purification from petroleum-derived substances [24, 25]. Moreover composted municipal organic wastes cause a decrease in content and phytotoxicity of petroleum hydrocarbons by up to 80% [26]. The addition of organic substances into the soil contaminated with other substances (*eg* heavy metals) may contribute to the increase in nutrient content in winter wheat grain [27].

Conclusions

1. All used petroleum-derived substances, most often, contributed to a significant reduction in selected nutrients content in the grain of winter wheat. In other plants' organs the nutrient content due to the presence of petroleum-derived substances in the soil was variable and depended on the type of the compound and on the analysed part of plant. Diesel fuel caused an increase in calcium content in the straw, and iron and magnesium contents in the roots, petrol – a decrease in calcium and magnesium contents in the straw and in the roots, but also an increase in the potassium content in the roots, while engine oil – a decrease in iron content in the roots. Moreover all used substances led to the increase in iron content in the straw of analysed plants.
2. The effect of petroleum-derived substances on the content of heavy metals in plants was also variable. Engine oil and diesel fuel caused an increase in the contents of cadmium, lead, zinc and manganese in the roots and an increase in the cadmium content in grain and nickel in straw but also led to a reduction in copper content in the roots. Petrol contributed to the increase in cadmium content in the grain and lead in the straw, but also to a decline in the zinc content in the grain and straw, and manganese in the straw.
3. Application of ZB-01 biopreparation on soil contaminated with engine oil, most often, caused an increase in content of the analysed nutrients in the roots of plants, but also their decline in the straw. In the case of soil contaminated with diesel oil biopreparation, most often, caused a decrease in their content in both straw and roots, in the case of soil contaminated with petrol – a decrease in calcium content in the grain, the decline in iron content in the roots and straw, but also an increase in calcium content in the grain and magnesium in the straw, while in control - a decrease in calcium content in the grain and straw, as well as iron in the grain and roots.
4. ZB-01 biopreparation usually had no significant effect on the content of heavy metals in plants, but most often affect an increase in the manganese content in all plant organs. In the case of other heavy metals biopreparation effect was also dependent on the type of metal and the analysed part of the plant.

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WPŁYW SUBSTANCJI ROPOPOCHODNYCH NA SKŁD CHEMICZNY PSZENICY OZIMEJ

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Abstrakt: Celem przeprowadzonych badań było określenie oddziaływania benzyny, przepracowanego oleju silnikowego i oleju napędowego na zawartość wapnia, magnezu, żelaza i potasu oraz wybranych metali ciężkich w ziarnie, słomie i korzeniach pszenicy ozimej. Dodatkowo określono oddziaływanie procesu bioremediacji na wyżej wymienione cechy. Doświadczenie zostało przeprowadzone w 2014 r. na obszarze Stacji Doświadczalnej Uniwersytetu Rolniczego w Mydlnikach, położonych niedaleko Krakowa. Jest to obszar, który w czerwcu 2010 r. został sztucznie zanieczyszczony substancjami ropopochodnymi w ilości 6000 mg na kg s m. gleby. Połowa z obiektów została poddana procesowi bioremediacji z użyciem preparatu ZB-01. Ocena zawartości składników pokarmowych w liściach roślin została przeprowadzona przy użyciu metody płomieniowej absorbcji atomowej. Na podstawie przeprowadzonych badań stwierdzono, że wszystkie zastosowane substancje ropopochodne najczęściej przyczyniały się do spadku zawartości wybranych składników pokarmowych w ziarnie pszenicy ozimej. W pozostałych organach roślinnych zawartość składników pokarmowych, jak również metali ciężkich spowodowana obecnością ropopochodnych w glebie była zmienna i zależała od rodzaju zastosowanego związku i od analizowanej części rośliny. Zastosowany biopreparat ZB-01 na glebę zanieczyszczoną olejem silnikowym najczęściej powodował wzrost zawartości analizowanych składników pokarmowych w korzeniach roślin, ale także ich spadek w słomie, w pozostałych obiektach odnotowano zmienne zależności, najczęściej nie miał on jednak istotnego wpływu na zawartość metali ciężkich w roślinach.

Słowa kluczowe: substancje ropopochodne, bioremediacja, składniki pokarmowe, metale ciężkie, pszenica ozima