Environ Earth Sci (2016) 75:150
DOI 10.1007/s12665-015-5004-4

ORIGINAL ARTICLE

Biochemical changes in the recreational areas soil caused by the intensity of use

Małgorzata Kawecka-Radomska[1] · Marta Tomczyńska-Mleko[2] · Agnieszka Kamińska[3] · Marta Wesołowska-Trojanowska[4] · Cezary Kwiatkowski[5] · Bartosz Sołowiej[6] · Stanisław Mleko[6]

Received: 29 January 2015 / Accepted: 22 September 2015 / Published online: 6 January 2016

Abstract The aim of this study was to determine the effect of the intensity of selected recreational areas use on biochemical changes within soils. Soil samples were collected from different playgrounds, playing fields and horse farms. Granulometric composition of the soils was determined. Heavy metals concentration, organic carbon concentration, total nitrogen concentration and activities of dehydrogenases, phosphatase and urease were measured at unburdened and burdened sites of the investigated recreational areas. It was found, that the use of the recreations areas triggers the changes in biochemical composition of the soil. Greater burden decreases the enzymes concentration in the soil. For most sites, a positive correlation was found between enzymes and organic carbon concentration and between phosphatase and urease. The degree of heavy metals soils contamination was low and only the samples from one playing field and one horse farm had increased concentration of cadmium. Monitoring of biochemical changes in recreational areas soil (especially playgrounds) is very important to provide safe environment for human leisure time.

Keywords Anthropopression · Enzymes · Goal area · Horse farms · Midfield · Paddock · Penalty zone · Playgrounds · Playing fields · Riding place

Introduction

Anthropopression is a sum of human activities changing the environment. Rational activities tend to restore the functions of ecosystems and landscapes and respect natural

✉ Stanisław Mleko
dairywhey@tlen.pl

Małgorzata Kawecka-Radomska
malgorzata.kaweckaradomska@up.lublin.pl

Marta Tomczyńska-Mleko
martamleko@tlen.pl

Agnieszka Kamińska
agnieszka.kaminska@up.lublin.pl

Marta Wesołowska-Trojanowska
marta.wesolowska-trojanowska@up.lublin.pl

Cezary Kwiatkowski
czarkw@poczta.onet.pl

Bartosz Sołowiej
bartosz.solowiej@up.lublin.pl

1 Institute of Soil Science and Environmental Development, University of Life Sciences in Lublin, Leszczyńskiego 7, 20-069 Lublin, Poland

2 Institute of Plant Genetics, Breeding and Biotechnology, University of Life Sciences in Lublin, Akademicka Street 15, 20-950 Lublin, Poland

3 Department of Mathematics, University of Life Sciences in Lublin, Głęboka Street 26, 20-950 Lublin, Poland

4 Department of Biotechnology, Human Nutrition and Food Commodity Science, University of Life Sciences, Skromna 8, 20-704 Lublin, Poland

5 Department of Herbology and Plant Cultivation Techniques, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland

6 Department of Milk Technology and Hydrocolloids, University of Life Sciences in Lublin, Skromna 8, 20-704 Lublin, Poland

resources (Huang et al. 2013). The total rhizosphere environment is based on an interacting trinity of the soil, the plant and the organism associated with the roots. Soil interfacial interactions in relation to below- and aboveground biodiversity should deserve increasing attention in the future (Huang 2008). Increased levels of human impact create the areas of ecological threats and even ecological disaster in many countries. Therefore, methods not only for preventing from the environment contamination, but also reclamation of degraded areas, are searched for. JESSICA (Joint European Support for Sustainable Investment in City Areas) is an initiative developed in cooperation with the European Commission, European Investment Bank (EBJ), and the Council of Europe Development Bank. Its aim is to support sustainable development of urban areas: the revitalization of degraded areas in cities, renovation of existing playgrounds, and construction of a new sport infrastructure, including playing fields (Dąbrowski 2014). The environment protection is not only the counteracting of the pollution, proper waste management, and rational management of the environmental resources, but also the restoration of degraded areas for living. With a properly conducted reclamation, the wildlife rapidly inhabits degraded areas, and new elements often make the landscape more attractive (Huang et al. 2013). Reclamation of area degraded due to human activities (industrial, technical, municipal, etc.) with a focus on the tourist-recreation development is an unquestionable necessity (Jarva et al. 2014). Human activities change the biochemical composition of municipal areas soil. Total nitrogen in urban soils of Beijing was much lower than that in rural soils of Beijing, which was mainly influenced by natural vegetation coverage and human activities (Xinghui et al. 2013). Soil enzyme activities which are important to organic matter decomposition and nutrients transformation can be affected by soil management practices such as organic fertilization, municipal refuse amendment, natural vegetation or herbicide addition (Monokrousos et al. 2006). The differences in enzyme activities in the soil are likely due to differences in microbiological composition, substrate characteristics and availability or water concentration (Kremer and Hezel 2012). The anthropogenic activities, especially industrial and automotive exhaust emissions, concentrated in the built-up area, constantly increase the heavy metal soil pollution (Li et al. 2014). Human activities in urban areas are concentrated also on recreation. Users of such areas expect clean and safe environment. From the other side, intensity of recreational areas use will likely have an impact on vegetation and soil (Wei-Tsuen et al. 1999, Pan et al. 2011, Jae-Hwan et al. 2014).

The purpose of this study was to determine the effect of the intensity of selected recreational areas use on biochemical changes within soils.

Materials and methods

Sites and soil sampling

The study was carried out in 3 months of the summer 2014: in April, June and September. There were three repetitions of the analysis and there were three samples taken from each site. The soil was taken from up to 20 cm depth (topsoil) using Wegner sticks in accordance with the Polish Norm (1997). The study included: playgrounds, playing fields, and horse farms in Lublin, Poland and the surrounding areas. The following sites were explored (the details are based on the interviews with the teachers, the managers and the players).

- Playground in Dziesiąta housing estate with the burden of an average of 10 h a day in days off school, i.e., on Saturday and Sunday and 3 h daily from Monday to Friday.
- Playground in Turka Borek housing estate with the burden of an average of 8 h a day on Saturdays and Sundays, while 5 h a day from Monday through Friday. Samples from plots designated as burdened (near the slides and near the swings) were compared to those from "0" plots that were not burdened (at the fence). It was also noted that more children used the swings in the playground in Dziesiąta housing estate, while in Turka housing estate—the slides.
- Football playing field in Mętów close to Lublin (natural area without irrigation and fertilization): 3 groups of players of 4 h weekly each.
- Football playing field located at Rusałka Street in Lublin (natural area without irrigation and fertilization): 3 groups of players of 4 h weekly each.
- Football playing field Sport Club "Sygnał", Lublin (well maintained, where grass is regularly cut, as well as fertilization and artificial irrigation are performed) with 20 h of training weekly + matches.
- Football playing field Sport Club "Budowlani", Lublin (well maintained, where grass is regularly cut, as well as fertilization and artificial irrigation are performed) with 40 h of training per week + matches. Analysis of the football game reveals that most players move within the goal area (dimensions 5.5 m × 18.32 m), penalty zone (16.5 m × 40 m), and midfield (about 40 m from the goal) (Kollath 1998). These zones are thus the most burdened places on the playing field. Therefore, on the football fields, samples were taken from the penalty zone, goal area, and midfield, and marked to be burdened, while those from plot "0" as not burdened—samples were taken from the vicinity of playing fields.
- Horse farm (Lubelski Klub Jeździecki)—LKJ.

- Horse farm Bonanza, Lublin. In horse farms, samples from the paddock and horse school were marked as burdened, because horses stay there every day for 6 h (from 8 a.m. to 2 p.m., except from Sundays), plot “0”—not burdened in the case of horse farm Bonanza—it was a wooded area next to the horse paddock, while in the case of LKJ—the area at the fence, where horses are not allowed. In the case of samples collected from the horse farm, plot “0” consisted of a lawn not burdened with the press of horse’s hoofs. The soil burden in the case of horse farm is quite large. Horses are output both in the paddock area, where they not only rest, graze grass, but also trot or gallop, and if there is no training, they can even stay there all day. Horses are trained in the school, there are also conducted the training sessions to prepare riders for the competition, individual lessons of horse riding, or hippotherapy classes.

The soil was taken from up to 20 cm depth (topsoil) using Wegner sticks in accordance with the Polish Norm (1997). Three samples were taken from each site.

Physicochemical properties of the soil, such as granulometric composition, pH and hydrolytic acidity shows Table 1. According to the results the following types of the soil can be assigned: playground in Dziesiąta housing estate—loam; playground in Borek housing estate—loam; playing field in Mętów—sandy loam; Sport Club “Sygnał”—loam; playing field at Rusałka Street—loam; Sport Club “Budowlani” Lublin—sandy loam; horse farm Bonanza—sandy loam, horse farm LKJ—sandy loam. The bedrock for all tested samples was chernozem made from loam and sandy loam. The acidity of the soil measured in KCl (Kaźmierowski 2012) was: slightly acidity, neutral and alkaline. The hydrolytic acidity measured by Kappen method (Kaźmierowski 2012) H_h was from 1.54 cmol(+) kg^{-1} till 1.60 cmol(+) kg^{-1} of the soil and V_H was from 13.66 cmol(+) kg^{-1} till 16.15 cmol(+) kg^{-1} of the soil. Sorption capacity of all tested soils (Lityński et al. 1976) was very strong $T > 9{,}0$ cmol(+) kg^{-1} of the soil.

The weather conditions—temperature and the rain in all three terms of the analysis shows Fig. 1. It was noticed that the hottest month was June and the coldest one was April. The temperature for September was similar to June. The average temperature for June and September was higher than 10 °C and for April was lower than 10 °C. The maximum temperature in June was higher than 25 °C, in September 25 °C and in April was less than 25 °C. The minimum temperature in June was higher than 5 °C, in September 3–4 °C, and in April almost 0 °C. The precipitation in June was over 70 mm, in September over 50 mm and in April 40 mm. Analyzing all these climate conditions the samples of the soil from all the objects were taken at the end of every month.

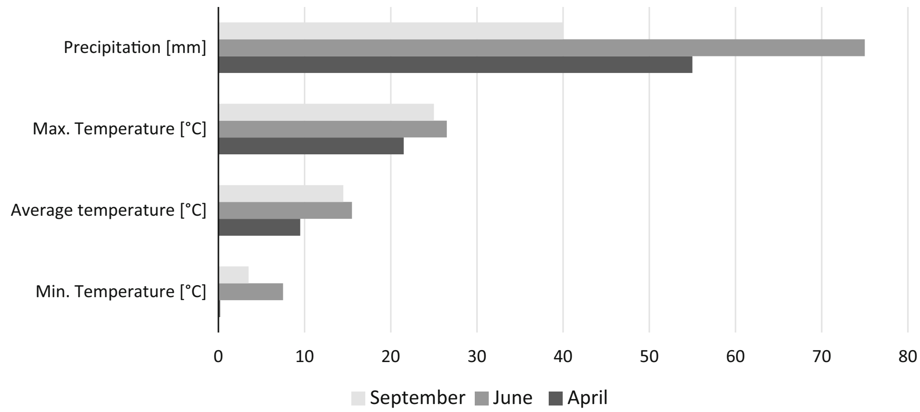
Granulometric composition was determined by the method of Bouycoss and Cassagrande’s with the modification by Prószyński (Ryżak et al. 2009). The samples for

Table 1 Physicochemical properties of the soils

Objects	Granulometric composition (%)				pH			Acidity [cmol(+) kg^{-1}]				
	ϕ 2–0.05 mm	Particles ϕ 0.05–0.002 mm	ϕ ≤ 0.002 mm	Name	In H_2O	In KCl	Name	*H*	*S*	*T*	V_H	*Vs*
Playground Dziesiąta	37	47	16	Loam	6.68	6.09	Slight acid	1.56	9.68	11.24	13.88	86.12
Playground Borek	69	23	8	Sandy loam	6.70	6.12	Slight acid	1.60	9.74	11.34	14.11	85.89
Playing field Mętów	68	23	9	Sandy loam	7.88	7.18	Neutral	1.57	9.72	11.29	16.15	83.85
Sport Club Sygnał	47	42	11	Loam	7.80	7.3	Slightly alkaline	1.58	9.70	11.28	14.01	85.99
Playing field Rusałka	57	32	11	Sandy loam	7.49	7.37	Slightly alkaline	1.54	9.73	11.27	13.66	86.34
Sport Club Budowlani	58	31	11	Sandy loam	7.56	7.24	Slightly alkaline	1.55	9.73	11.28	13.74	86.26
Horse farm Bonanza	53	33	14	Sandy loam	6.12	5.9	Slight acid	1.55	9.71	11.26	13.76	86.24
LKJ	61	33	14	Sandy loam	5.80	5.6	Slight acid	1.59	9.75	11.34	14.02	85.98

H the total amount of hydrogen ion, *S* the total amount of alkaline cations, *T* total sorption capacity of the soil, V_H the degree of saturation of the sorption complex with hydrogen ion, V_s the degree of saturation of the sorption complex with alkaline cations

Fig. 1 Climate conditions in 2014



heavy metals analysis were air-dry, sifted through the plastic strainer with 1 mm mesh diameter and ground in a mortar mill model RM 200 made by RETSCH. The samples weighed 0.5 g and were digested with a mixture of nitric acid and perchloric, transferred to a 25 ml flask, filled up with deionized water into the right volume and filtered through a single filter into tubes and put to PS 950 optical emission spectrometer with inductive coupling plasma (ICP-OES) (Teledyne Leeman Labs, Hudson, USA).

Activities of the following enzymes were determined: dehydrogenases (Thalmann 1968), phosphatase (Tabatabai and Bremner 1969), urease (Zantua and Bremner 1975), organic carbon (ISO 14235 1998), and total nitrogen (ISO 13878 1998).

Data were analyzed by two-way analysis of variance (ANOVA) using STATISTICA 10PL (Statsoft, Warsaw, Poland). Post-hoc Tukey HSD test was used to find significant differences between group means. The mean values were from 3 replicates. In addition, the relationships between analyzed variables were evaluated on the basis of Pearson correlation coefficients. The significance level of $p < 0.05$ was used.

Results

Effect of burden on enzyme concentration

Tables 2, 3 and 4 summarize results from the concentration of dehydrogenase, urease and phosphatase in the soils. It was noted that in the case of samples taken from the playground in Dziesiąta housing estate, dehydrogenase concentration was the highest near the swings, while the lowest in the plot “0”. The highest levels of urease and phosphatase were recorded for plot “0”, the lowest at the slide (Table 2). Samples collected from the playground in Turka Borek housing estate revealed that plot at the slide or near the swings was characterized by significantly higher dehydrogenase concentration, as compared to samples collected from plot “0” with the lowest level of this enzyme. In the case of urease, the lowest value was recorded in sample taken from the slide vicinity, while the significantly higher in the samples taken from the other spots. Referring to phosphatase, the results were similar for all compared objects, although the highest concentration of the enzyme was determined in sample obtained near the swings (Table 2).

In addition the differences in concentration of the enzymes in samples taken from different parts of a play-field were found (Table 3). The lowest concentration of urease was determined in samples collected from Sport Club “Budowlani” Lublin and playing field at Rusałka Street, whilst higher—in samples taken from the school play-field in Mętów and Sport Club “Sygnał”.

The largest concentrations of dehydrogenase were recorded in samples from the penalty zone in Sport Club “Sygnał”, whereas the smallest—from the goal area of Sport Club “Budowlani” and playing field in Mętów. The highest concentration of phosphatase was found in a sample derived from penalty zone in Sport Club Sygnał area, and the lowest—in sample from the penalty zone in playing field in Mętów (Table 3).

It was noticed that the lowest concentration of dehydrogenase for all playing fields was at goal area. For both playing fields in Mętów and Rusałka the highest concentration of urease was noticed in goal area.

In playing field at Rusalka street and Sport Club “Budowlani” the highest concentration of dehydrogenase and phosphatase was observed in June while the lowest concentration of these enzymes in April for samples from all places. In Sport Club “Sygnał” and playing field in Mętów the highest concentration of phosphatase was noticed for all samples in June and the lowest in April except goal area where the highest concentration of phosphatase was observed in September and the lowest in April, although there were no significant differences between the values in this place for all terms. In Sport Club Sygnał the highest concentration of dehydrogenase was noticed in June, the

Table 2 Concentrations of enzymes in soil samples taken from playgrounds in 2014

Enzymes	Term	Plot "0"	Near the slide	Near the swings
Playground Dziesiąta				
Dehydrogenase cm^3 H_2 kg^{-1} day^{-1}	April	$3.43 \pm 0.06^{a,B}$	$6.84 \pm 0.02^{b,A}$	$7.96 \pm 0.02^{c,A}$
	June	$3.23 \pm 0.01^{a,A}$	$8.29 \pm 0.01^{b,C}$	$9.06 \pm 0.01^{c,C}$
	September	$3.35 \pm 0.01^{a,B}$	$7.06 \pm 0.01^{b,B}$	$8.01 \pm 0.01^{c,B}$
Urease mg N-NH_4^+ kg^{-1} h^{-1}	April	$1.74 \pm 0.02^{c,A}$	$0.28 \pm 0.03^{a,A}$	$1.08 \pm 0.01^{b,A}$
	June	$2.61 \pm 0.03^{c,C}$	$0.39 \pm 0.03^{a,A}$	$1.17 \pm 0.06^{b,A}$
	September	$2.19 \pm 0.01^{c,B}$	$0.36 \pm 0.02^{a,A}$	$1.15 \pm 0.02^{b,A}$
Phosphatase mmol PNP kg^{-1} h^{-1}	April	$34.31 \pm 0.04^{c,A}$	$21.50 \pm 0.03^{a,A}$	$31.53 \pm 0.25^{b,A}$
	June	$36.51 \pm 0.16^{c,C}$	$24.02 \pm 0.12^{a,C}$	$30.58 \pm 0.17^{b,B}$
	September	$35.53 \pm 0.07^{c,B}$	$23.59 \pm 0.16^{a,B}$	$31.03 \pm 0.09^{b,A}$
Playground Borek				
Dehydrogenase cm^3 H_2 kg^{-1} day^{-1}	April	$5.32 \pm 0.18^{a,B}$	$8.24 \pm 0.11^{c,B}$	$6.17 \pm 0.07^{b,A}$
	June	$3.29 \pm 0.01^{a,A}$	$8.33 \pm 0.02^{c,B}$	$7.32 \pm 0.58^{b,B}$
	September	$3.04 \pm 0.07^{a,A}$	$7.30 \pm 0.04^{b,A}$	$8.89 \pm 0.02^{c,C}$
Urease mg N-NH_4^+ kg^{-1} h^{-1}	April	$1.11 \pm 0.01^{b,A}$	$0.76 \pm 0.01^{a,B}$	$2.02 \pm 0.01^{c,B}$
	June	$1,85 \pm 0.01^{c,C}$	$0.40 \pm 0.01^{a,A}$	$1.04 \pm 0.06^{b,A}$
	September	$1.81 \pm 0.02^{c,B}$	$0.39 \pm 0.02^{a,A}$	$1.09 \pm 0.03^{b,A}$
Phosphatase mmol PNP kg^{-1} h^{-1}	April	$36.22 \pm 0.01^{b,C}$	$35.16 \pm 0.02^{\cdot B}$	$36.73 \pm 0.01^{c,C}$
	June	$32.94 \pm 0.02^{a,B}$	$34.23 \pm 0.02^{b,A}$	$35.10 \pm 0.01^{c,B}$
	September	$32.80 \pm 0.01^{a,A}$	$34.07 \pm 0.14^{b,A}$	$35.03 \pm 0.02^{c,A}$

The same letters within rows (a, b, c) and within columns (A, B, C) indicate homogenous groups ($p < 0.05$)

lowest in April, except the sample from plot "0", where the highest concentration of this enzyme was observed in April and the lowest in June. The highest concentration of urease was observed in June in all samples except penalty zone in playing field in Mętów and playing field at Rusałka street (Table 3).

For the horse farms, the highest dehydrogenase concentration was determined in sample from plot "0" in LKJ, while sample derived from the riding place (b) in LKJ was characterized by the lowest concentration of this enzyme (Table 4). The largest concentration of urease was revealed in sample "0" from LKJ, and the smallest—from riding place (a) in LKJ. Referring to phosphatase—its highest concentration was recorded in a sample from plot "0" in LKJ, whereas the lowest—from riding place (b) in LKJ (Table 4). For horse farm Bonanza the highest concentration of dehydrogenase was found in paddock and significantly lower values at other sites. In case of urease and phosphatase the lowest values were also noted in paddock.

Effect of term on enzyme concentrations

It was noted that in the case of samples taken from the playground in Dziesiąta housing estate at burden place (near the swing and slide), all enzymes concentrations were the lowest in April. In case of urease the differences were not significant. For unburden plot "0" the highest levels of urease and phosphatase were recorded in June, the lowest in April, while the highest concentration of dehydrogenase was found in April and the lowest in June (Table 2). Samples collected from the playground in Turka Borek housing estate revealed that the highest concentrations of all three enzymes were achieved in April, in almost all sites. Only the values of urease taken from plot "0" and dehydrogenase from area near the swings were the lowest in that month (Table 2). The study shows that in case of play-fields, no significant differences in concentration of urease in samples taken at different terms were found (apart from one exception—midfield area in Metów). For most of spots in all playing fields, significant lower concentrations of dehydrogenase and phosphatase were recorded in samples taken in April. For both investigated horse farms the lowest concentration of two enzymes (urease and phosphatase) was in April. Although, in some cases the differences between values were no significant. It is difficult to find a relationship between terms and dehydrogenase concentration.

Effect of burden and term on ammonia concentrations

For playgrounds the highest concentrations of ammonia nitrogen in both cases were obtained from samples collected near swings, while the lowest from plots "0". The

Table 3 Concentrations of enzymes in soil samples taken from playing fields in 2014

Enzymes	Term	Plot "0"	Goal area	Penalty zone	Midfield
Playing field Mętów					
Dehydrogenase $cm^3\ H_2\ kg^{-1}\ day^{-1}$	April	$3.79 \pm 0.01^{c,A}$	$2.59 \pm 0.05^{a,C}$	$4.47 \pm 0.02^{d,A}$	$3.16 \pm 0.05^{b,A}$
	June	$4.07 \pm 0.03^{b,C}$	$2.16 \pm 0.01^{a,A}$	$4.46 \pm 0.06^{d,A}$	$4.32 \pm 0.03^{c,C}$
	September	$3.92 \pm 0.01^{c,B}$	$2.32 \pm 0.01^{a,B}$	$4.51 \pm 0.01^{d,A}$	$3.86 \pm 0.04^{b,B}$
Urease mg $N\text{-}NH_4^+\ kg^{-1}\ h^{-1}$	April	$2.48 \pm 0.01^{c,A}$	$2.53 \pm 0.07^{c,A}$	$1.86 \pm 0.01^{a,A}$	$2.36 \pm 0.01^{b,A}$
	June	$2.53 \pm 0.06^{bc,A}$	$2.60 \pm 0.05^{c,A}$	$1.88 \pm 0.06^{a,A}$	$2.42 \pm 0.01^{b,B}$
	September	$2.51 \pm 0.01^{c,A}$	$2.53 \pm 0.01^{d,A}$	$1.88 \pm 0.01^{a,A}$	$2.40 \pm 0.01^{b,B}$
Phosphatase mol PNP $kg^{-1}\ h^{-1}$	April	$18.12 \pm 0.09^{b,A}$	$18.12 \pm 0.27^{b,A}$	$10.39 \pm 0.25^{a,A}$	$18.76 \pm 0.01^{c,A}$
	June	$20.80 \pm 0.07^{c,C}$	$18.12 \pm 0.12^{b,A}$	$12.31 \pm 0.17^{a,C}$	$22.27 \pm 0.12^{d,C}$
	September	$19.97 \pm 0.03^{c,B}$	$18.13 \pm 0.01^{b,A}$	$11.71 \pm 0.03^{a,B}$	$20.22 \pm 0.08^{d,B}$
Sport Club "Sygnał"					
Dehydrogenase $cm^3\ H_2\ kg^{-1}\ day^{-1}$	April	$9.91 \pm 0.02^{d,C}$	$4.09 \pm 0.01^{b,A}$	$8.90 \pm 0.02^{c,A}$	$4.04 \pm 0.01^{a,A}$
	June	$7.19 \pm 0.01^{c,A}$	$4.67 \pm 0.01^{a,C}$	$10.64 \pm 0.01^{d,C}$	$5.06 \pm 0.01^{b,C}$
	September	$7.59 \pm 0.05^{c,B}$	$4.26 \pm 0.05^{a,B}$	$9.78 \pm 0.02^{d,B}$	$4.98 \pm 0.01^{b,B}$
Urease mg $N\text{-}NH_4^+\ kg^{-1}\ h^{-1}$	April	$6.10 \pm 0.04^{c,A}$	$4.25 \pm 0.05^{b,A}$	$4.24 \pm 0.01^{b,A}$	$2.23 \pm 0.05^{a,A}$
	June	$6.76 \pm 0.05^{d,C}$	$4.51 \pm 0.06^{b,B}$	$4.95 \pm 0.08^{c,C}$	$2.62 \pm 0.06^{a,C}$
	September	$6.44 \pm 0.03^{d,B}$	$4.48 \pm 0.01^{b,B}$	$4.73 \pm 0.02^{c,B}$	$2.44 \pm 0.04^{a,B}$
Phosphatase mol PNP $kg^{-1}\ h^{-1}$	April	$28.09 \pm 0.19^{c,A}$	$19.47 \pm 0.10^{a,A}$	$35.11 \pm 0.18^{d,A}$	$25.27 \pm 0.03^{b,A}$
	June	$29.02 \pm 0.06^{c,C}$	$22.18 \pm 0.13^{a,C}$	$35.95 \pm 0.16^{d,B}$	$27.07 \pm 0.03^{b,B}$
	September	$28.48 \pm 0.14^{b,B}$	$21.33 \pm 0.12^{a,B}$	$35.46 \pm 0.07^{d,A}$	$26.70 \pm 0.02^{c,C}$
Playing field "Rusałka"					
Dehydrogenase $cm^3\ H_2\ kg^{-1}\ day^{-1}$	April	$6.17 \pm 0.01^{c,A}$	$3.45 \pm 0.02^{a,A}$	$7.01 \pm 0.05^{d,A}$	$3.71 \pm 0.04^{b,A}$
	June	$7.23 \pm 0.01^{c,C}$	$4.08 \pm 0.01^{a,C}$	$8.63 \pm 0.01^{d,C}$	$4.26 \pm 0.01^{b,C}$
	September	$7.06 \pm 0.04^{b,B}$	$3.79 \pm 0.04^{a,B}$	$8.08 \pm 0.12^{c,B}$	$3.97 \pm 0.12^{a,B}$
Urease mg $N\text{-}NH_4^+\ kg^{-1}\ h^{-1}$	April	$0.17 \pm 0.02^{a,A}$	$0.41 \pm 0.02^{c,A}$	$0.37 \pm 0.02^{c,A}$	$0.30 \pm 0.03^{b,A}$
	June	$0.11 \pm 0.06^{a,A}$	$0.38 \pm 0.01^{b,A}$	$0.30 \pm 0.04^{b,A}$	$0.24 \pm 0.05^{b,A}$
	September	$0.18 \pm 0.02^{a,A}$	$0.39 \pm 0.04^{c,A}$	$0.37 \pm 0.01^{bc,A}$	$0.31 \pm 0.01^{b,A}$
Phosphatase mol PNP $kg^{-1}\ h^{-1}$	April	$16.05 \pm 0.01^{b,A}$	$21.13 \pm 0.04^{c,A}$	$30.21 \pm 0.09^{d,A}$	$13.17 \pm 0.06^{a,A}$
	June	$16.73 \pm 0.06^{b,B}$	$21.49 \pm 0.05^{c,A}$	$31.16 \pm 0.05^{d,C}$	$13.56 \pm 0.05^{a,C}$
	September	$16.65 \pm 0.02^{b,B}$	$21.49 \pm 0.05^{c,A}$	$30.55 \pm 0.03^{d,B}$	$13.42 \pm 0.01^{a,B}$
Sport Club "Budowlani"					
Dehydrogenase $cm^3\ H_2\ kg^{-1}\ day^{-1}$	April	$5.18 \pm 0.01^{d,A}$	$2.34 \pm 0.02^{a,A}$	$4.48 \pm 0.01^{c,A}$	$3.48 \pm 0.19^{b,A}$
	June	$6.75 \pm 0.01^{d,C}$	$2.97 \pm 0.01^{a,C}$	$5.55 \pm 0.01^{c,C}$	$4.17 \pm 0.01^{b,B}$
	September	$5.86 \pm 0.03^{d,B}$	$2.76 \pm 0.01^{a,B}$	$5.11 \pm 0.01^{c,B}$	$3.94 \pm 0.03^{b,B}$
Urease mg $N\text{-}NH_4^+\ kg^{-1}\ h^{-1}$	April	$0.35 \pm 0.03^{ab,A}$	$0.38 \pm 0.01^{b,A}$	$0.30 \pm 0.04^{ab,A}$	$0.24 \pm 0.07^{a,A}$
	June	$0.36 \pm 0.01^{b,A}$	$0.41 \pm 0.06^{b,A}$	$0.35 \pm 0.01^{ab,A}$	$0.26 \pm 0.01^{a,A}$
	September	$0.36 \pm 0.01^{bc,A}$	$0.38 \pm 0.01^{c,A}$	$0.34 \pm 0.01^{b,A}$	$0.19 \pm 0.01^{a,A}$
Phosphatase mol PNP $kg^{-1}\ h^{-1}$	April	$26.58 \pm 0.28^{d,A}$	$13.25 \pm 0.08^{a,A}$	$15.15 \pm 0.03^{c,A}$	$13.86 \pm 0.19^{b,B}$
	June	$27.31 \pm 0.01^{d,B}$	$14.84 \pm 0.09^{b,C}$	$17.11 \pm 0.01^{c,C}$	$13.29 \pm 0.13^{a,A}$
	September	$27.10 \pm 0.03^{d,B}$	$14.33 \pm 0.03^{b,B}$	$16.85 \pm 0.01^{c,B}$	$13.31 \pm 0.02^{a,A}$

The same letters within rows (a, b, c, d) and within columns (A, B, C) indicate homogenous groups ($p < 0.05$)

highest concentration of ammonia nitrogen was noticed in June for all samples except playground in Borek—near the slide, where the highest concentration of ammonia nitrogen was observed in April, although there were no significant differences between the terms in all samples near the slide (Table 5). The ammonia nitrogen level in horse farms soil samples was significantly higher for riding places and paddock, rather than for plot "0". The highest concentration of ammonia nitrogen was found in June and the lowest in April for all samples (Table 6). For the school play-field in Mętów, the highest ammonium nitrogen concentration was determined in sample from plot "0", while the lowest

Table 4 Concentrations of enzymes in soil samples from horse farms LKJ and Bonanza in 2014

Enzymes	Term	Plot "0"	Riding place "a"	Riding place "b"	Paddock
LKJ					
Dehydrogenase cm^3 H_2 kg^{-1} day^{-1}	April	$11.58 \pm 0.10^{d,C}$	$6.20 \pm 0.02^{c,A}$	$3.08 \pm 0.01^{a,A}$	$5.30 \pm 0.01^{b,A}$
	June	$10.93 \pm 0.03^{d,A}$	$6.32 \pm 0.02^{c,B}$	$3.71 \pm 0.33^{a,B}$	$5.50 \pm 0.03^{b,B}$
	September	$11.12 \pm 0.01^{d,B}$	$6.31 \pm 0.03^{c,B}$	$3.71 \pm 0.02^{a,B}$	$5.48 \pm 0.07^{b,B}$
Urease mg N-NH_4^+ kg^{-1} h^{-1}	April	$9.57 \pm 0.19^{c,A}$	$0.52 \pm 0.02^{a,A}$	$1.15 \pm 0.02^{b,A}$	$1.10 \pm 0.01^{b,A}$
	June	$9.66 \pm 0.15^{d,A}$	$0.61 \pm 0.01^{a,B}$	$3.15 \pm 0.05^{b,C}$	$3.40 \pm 0.02^{c,C}$
	September	$9.61 \pm 0.14^{d,A}$	$0.59 \pm 0.01^{a,B}$	$2.16 \pm 0.01^{b,B}$	$2.78 \pm 0.01^{c,B}$
P	April	$31.42 \pm 0.29^{d,A}$	$11.72 \pm 0.04^{b,A}$	$7.04 \pm 0.04^{a,A}$	$23.91 \pm 0.05^{c,A}$
Phosphatase mmol PNP kg^{-1} h^{-1}	June	$32.96 \pm 0.10^{d,B}$	$11.81 \pm 0.08^{b,A}$	$7.45 \pm 0.03^{a,C}$	$24.06 \pm 0.19^{c,A}$
	September	$32.88 \pm 0.07^{d,B}$	$11.83 \pm 0.01^{b,A}$	$7.28 \pm 0.03^{a,B}$	$24.15 \pm 0.03^{c,A}$
Horse farm Bonanza					
Dehydrogenase cm^3 H_2 kg^{-1} day^{-1}	April	$7.01 \pm 0.01^{b,A}$	$7.00 \pm 0.01^{b,C}$	$6.90 \pm 0.03^{a,B}$	$8.14 \pm 0.04^{c,A}$
	June	$7.19 \pm 0.03^{b,C}$	$6.62 \pm 0.03^{a,B}$	$6.57 \pm 0.07^{a,A}$	$8.40 \pm 0.03^{c,B}$
	September	$7.11 \pm 0.01^{c,B}$	$6.50 \pm 0.02^{a,A}$	$6.68 \pm 0.03^{b,A}$	$8.21 \pm 0.09^{d,A}$
Urease mg	April	$4.54 \pm 0.06^{b,A}$	$6.44 \pm 0.03^{c,A}$	$6.66 \pm 0.01^{d,A}$	$1.48 \pm 0.02^{a,A}$
N-NH_4^+ kg^{-1} h^{-1}	June	$4.89 \pm 0.01^{b,C}$	$7.37 \pm 0.02^{c,C}$	$7.40 \pm 0.03^{c,B}$	1.68 ± 0.03^{aB}
	September	$4.77 \pm 0.01^{b,B}$	$7.28 \pm 0.01^{c,B}$	$7.35 \pm 0.04^{c,B}$	$1.56 \pm 0.04^{a,A}$
Phosphatase mmol PNP kg^{-1} h^{-1}	April	$21.47 \pm 0.13^{b,A}$	$21.13 \pm 0.19^{b,A}$	$21.16 \pm 0.05^{b,A}$	$10.49 \pm 0.10^{a,A}$
	June	$23.71 \pm 0.03^{c,C}$	$22.16 \pm 0.17^{b,B}$	$22.16 \pm 0.01^{b,B}$	$11.80 \pm 0.06^{a,C}$
	September	$22.20 \pm 0.02^{d,B}$	$22.09 \pm 0.02^{c,B}$	$21.85 \pm 0.03^{b,B}$	$11.11 \pm 0.01^{a,B}$

The same letters within rows (a, b, c, d) and within columns (A, B, C) indicate homogenous groups ($p < 0.05$)

Table 5 Concentrations of ammonia nitrogen and organic carbon in samples from playgrounds in 2014

Objects	Term	Plot "0"	Near the slide	Near the swings
Ammonia nitrogen ($mg\ kg^{-1}$)				
Playground Dziesiąta	April	$71.01 \pm 0.12^{a,A}$	$71.13 \pm 0.12^{a,A}$	$74.28 \pm 0.46^{b,A}$
	June	$71.12 \pm 0.06^{a,A}$	$71.85 \pm 0.07^{b,B}$	$74.44 \pm 0.05^{c,A}$
	September	$71.06 \pm 0.01^{a,A}$	$71.36 \pm 0.14^{b,A}$	$74.26 \pm 0.06^{c,A}$
Playground Borek	April	$71.13 \pm 0.12^{a,A}$	$72.84 \pm 0.07^{b,A}$	$74.25 \pm 0.06^{c,A}$
	June	$72.18 \pm 0.05^{a,B}$	$72.70 \pm 0.05^{b,A}$	$74.352 \pm 0.05^{c,A}$
	September	$72.11 \pm 0.08^{a,A}$	$72.62 \pm 0.07^{b,A}$	$74.28 \pm 0.05^{c,A}$
Organic carbon (%)				
Playground Dziesiąta	April	$0.98 \pm 0.01^{a,A}$	$1.60 \pm 0.01^{c,C}$	$1.43 \pm 0.01^{b,C}$
	June	$2.09 \pm 0.02^{c,C}$	$1.02 \pm 0.02^{b,A}$	$0.89 \pm 0.02^{a,A}$
	September	$1.52 \pm 0.01^{c,B}$	$1.34 \pm 0.02^{b,B}$	$1.16 \pm 0.02^{a,B}$
Playground Borek	April	$0.98 \pm 0.01^{a,A}$	$1.60 \pm 0.01^{c,A}$	$1.44 \pm 0.01^{b,A}$
	June	$0.97 \pm 0.01^{a,A}$	$1.61 \pm 0.01^{c,A}$	$1.44 \pm 0.01^{b,A}$
	September	$0.98 \pm 0.01^{a,A}$	$1.63 \pm 0.03^{c,A}$	$1.44 \pm 0.01^{b,A}$

The same letters within rows (a, b, c, d) and within columns (A, B, C) indicate homogenous groups ($p < 0.05$)

from the goal area (Table 7). For other playing fields ammonium nitrogen concentration was very similar for all sites (few significant differences were noted), and it is difficult to find any relationship. For all the samples, except the penalty zone in Sport Club "Sygnał", the highest concentration of ammonia nitrogen was found in June.

Table 8 shows the concentration of heavy metals in investigated soil samples. In this study, despite the fact that the test objects were close to the road, soil samples were characterized by a low concentration of heavy metals—soil pollution level 0, group of soil b, class B and C. Only the samples from the playing field in Sport Club "Sygnał" and

Table 6 Concentrations of ammonia nitrogen and organic carbon in samples from horse farms in 2014

Objects	Term	Plot "0"	Riding place "a"	Riding place "b"	Paddock
Amonia nitrogen (mg kg^{-1})					
Bonanza	April	$74.53 \pm 0.22^{a,A}$	$74.83 \pm 0.02^{b,A}$	$74.88 \pm 0.01^{b,A}$	$74.90 \pm 0.01^{b,A}$
	June	$75.09 \pm 0.07^{a,B}$	$75.18 \pm 0.01^{a,C}$	$75.17 \pm 0.02^{a,B}$	$75.73 \pm 0.07^{b,C}$
	September	$75.01 \pm 0.11^{a,B}$	$75.01 \pm 0.01^{a,B}$	$75.19 \pm 0.01^{a,B}$	$75.15 \pm 0.01^{a,B}$
LKJ	April	$74.17 \pm 0.04^{a,A}$	$74.88 \pm 0.03^{d,A}$	$74.66 \pm 0.04^{c,A}$	$74.41 \pm 0.09^{b,A}$
	June	$74.27 \pm 0.12^{a,A}$	$75.09 \pm 0.07^{b,B}$	$75.30 \pm 0.12^{b,C}$	$75.17 \pm 0.12^{b,C}$
	September	$74.23 \pm 0.10^{a,A}$	$74.93 \pm 0.07^{b,A}$	$75.08 \pm 0.01^{d,B}$	$74.81 \pm 0.07^{bc,B}$
Organic carbon (%)					
Bonanza	April	$0.82 \pm 0.01^{a,A}$	$1.79 \pm 0.01^{c,C}$	$1.80 \pm 0.01^{c,C}$	$1.20 \pm 0.01^{b,C}$
	June	$0.82 \pm 0.04^{a,A}$	$0.81 \pm 0.03^{a,A}$	$1.48 \pm 0.01^{c,A}$	$1.08 \pm 0.01^{b,A}$
	September	$0.85 \pm 0.01^{a,A}$	$1.30 \pm 0.01^{c,B}$	$1.66 \pm 0.02^{d,B}$	$1.14 \pm 0.01^{b,B}$
LKJ	April	$2.46 \pm 0.01^{d,C}$	$2.40 \pm 0.01^{c,C}$	$0.86 \pm 0.01^{b,A}$	$0.64 \pm 0.01^{a,A}$
	June	$1.84 \pm 0.01^{b,A}$	$0.60 \pm 0.03^{a,A}$	$0.96 \pm 0.02^{d,C}$	$0.80 \pm 0.02^{c,C}$
	September	$2.16 \pm 0.01^{d,B}$	$1.51 \pm 0.05^{c,B}$	$0.91 \pm 0.01^{b,B}$	$0.72 \pm 0.01^{a,B}$

The same letters within rows (a, b, c, d) and within columns (A, B, C) indicate homogenous groups ($p < 0.05$)

Table 7 Concentrations of ammonia nitrogen and organic carbon in samples from playing fields in 2014

Objects	Term	Plot "0"	Goal area	Penalty zone	Midfield
Ammonia nitrogen (mg kg^{-1})					
Playing field Mętów	April	$72.45 \pm 0.19^{c,A}$	$71.18 \pm 0.05^{a,A}$	$71.60 \pm 0.15^{b,A}$	$72.32 \pm 0.15^{c,A}$
	June	$73.63 \pm 0.12^{d,C}$	$71.37 \pm 0.25^{a,A}$	$72.25 \pm 0.05^{b,B}$	$73.13 \pm 0.12^{c,B}$
	September	$73.18 \pm 0.06^{d,B}$	$71.28 \pm 0.01^{a,A}$	$72.02 \pm 0.02^{b,B}$	$72.89 \pm 0.01^{c,B}$
Sport Club Sygnał	April	$73.49 \pm 0.22^{b,A}$	$72.62 \pm 0.30^{a,A}$	$73.29 \pm 0.16^{b,A}$	$72.28 \pm 0.16^{a,A}$
	June	$73.53 \pm 0.05^{b,A}$	$73.21 \pm 0.07^{a,B}$	$73.26 \pm 0.06^{a,A}$	$73.16 \pm 0.07^{a,C}$
	September	$73.39 \pm 0.01^{b,A}$	$72.91 \pm 0.07^{a,AB}$	$73.18 \pm 0.01^{b,A}$	$72.93 \pm 0.09^{a,B}$
Playing field Rusałka	April	$70.64 \pm 0.07^{ab,A}$	$70.40 \pm 0.19^{ab,A}$	$70.67 \pm 0.24^{b,C}$	$70.21 \pm 0.10^{a,A}$
	June	$71.35 \pm 0.05^{a,C}$	$71.20 \pm 0.12^{a,B}$	$71.41 \pm 0.07^{a,B}$	$71.15 \pm 0.14^{a,B}$
	September	$71.10 \pm 0.01^{b,B}$	$70.87 \pm 0.04^{b,B}$	$70.12 \pm 0.01^{a,A}$	$70.94 \pm 0.20^{b,B}$
Sport Club Budowlani	April	$73.22 \pm 0.09^{a,A}$	$73.47 \pm 0.23^{ab,A}$	$73.34 \pm 0.07^{a,A}$	$73.74 \pm 0.12^{b,A}$
	June	$73.55 \pm 0.13^{a,B}$	$73.59 \pm 0.12^{ab,A}$	$73.52 \pm 0.02^{a,B}$	$73.81 \pm 0.06^{b,A}$
	September	$73.52 \pm 0.01^{ab,B}$	$73.57 \pm 0.01^{b,A}$	$73.46 \pm 0.02^{a,B}$	$73.77 \pm 0.04^{c,A}$
Organic carbon (%)					
Playing field Mętów	April	$0.61 \pm 0.01^{a,C}$	$2.15 \pm 0.01^{d,A}$	$0.90 \pm 0.01^{b,A}$	$1.79 \pm 0.01^{c,A}$
	June	$0.35 \pm 0.02^{a,A}$	$2.70 \pm 0.03^{b,C}$	$3.94 \pm 0.03^{d,C}$	$3.69 \pm 0.02^{c,C}$
	September	$0.48 \pm 0.01^{a,B}$	$2.43 \pm 0.02^{b,B}$	$2.42 \pm 0.01^{b,B}$	$2.71 \pm 0.05^{c,B}$
Sport Club Sygnał	April	$0.01 \pm 0.01^{a,A}$	$1.80 \pm 0.01^{c,A}$	$1.60 \pm 0.01^{b,A}$	$1.80 \pm 0.01^{c,C}$
	June	$1.19 \pm 0.02^{a,C}$	$2.81 \pm 0.03^{d,C}$	$1.90 \pm 0.01^{c,C}$	$1.38 \pm 0.02^{b,A}$
	September	$0.60 \pm 0.01^{a,B}$	$2.31 \pm 0.02^{d,B}$	$1.75 \pm 0.01^{c,B}$	$1.59 \pm 0.01^{b,B}$
Playing field Rusałka	April	$2.16 \pm 0.01^{d,C}$	$1.64 \pm 0.01^{b,A}$	$1.51 \pm 0.01^{a,C}$	$1.68 \pm 0.01^{c,C}$
	June	$0.89 \pm 0.02^{a,A}$	$1.98 \pm 0.03^{d,C}$	$1.40 \pm 0.01^{c,A}$	$1.22 \pm 0.02^{b,A}$
	September	$1.52 \pm 0.02^{b,B}$	$1.81 \pm 0.01^{c,B}$	$1.45 \pm 0.02^{a,B}$	$1.46 \pm 0.02^{a,B}$
Sport Club Budowlani	April	$1.80 \pm 0.01^{d,C}$	$1.53 \pm 0.01^{c,C}$	$0.99 \pm 0.01^{b,A}$	$0.60 \pm 0.01^{a,A}$
	June	$0.63 \pm 0.01^{a,A}$	$1.04 \pm 0.02^{b,A}$	$1.05 \pm 0.02^{b,B}$	$1.41 \pm 0.02^{c,C}$
	September	$1.22 \pm 0.01^{b,B}$	$1.28 \pm 0.01^{c,B}$	$1.03 \pm 0.01^{a,B}$	$1.00 \pm 0.03^{a,B}$

The same letters within rows (a, b, c, d) and within columns (A, B, C) indicate homogenous groups ($p < 0.05$)

Table 8 Concentrations of PTEs (mg kg^{-1}) in selected soil samples and class of pollution

Objects	Cd	Zn	Pb	Cr	Cu	Ni	Soil pollution level of PTE's	Class
mg kg^{-1}								
Sport Club Budowlani	0.32 ± 0.001	37.5 ± 0.001	26.0 ± 0.001	25.5 ± 0.001	–	13.9 ± 0.002	0	B
Playground Dziesiąta	0.39 ± 0.001	28.1 ± 0.001	25.1 ± 0.002	27.1 ± 0.001	0.23 ± 0.001	12.2 ± 0.001	0	B
Sport Club Sygnał	3.81 ± 0.002	66.6 ± 0.002	30.0 ± 0.001	17.0 ± 0.001	2.78 ± 0.001	10.9 ± 0.001	0 (Cd III)	C
Playing field Mętów	0.32 ± 0.001	18.3 ± 0.001	20.2 ± 0.001	16.1 ± 0.002	–	7.07 ± 0.001	0	C
Horse farm Bonanza	0.28 ± 0.001	24.6 ± 0.002	21.5 ± 0.001	12.8 ± 0.001	–	9.23 ± 0.001	0	B
LKJ	1.11 ± 0.002	71.0 ± 0.001	22.0 ± 0.002	12.6 ± 0.001	1.34 ± 0.001	7.38 ± 0.002	0 (Cd I)	B

Soil particle have been analyzed up to a diameter of 1 mm

LKJ horse farm had increased concentration of cadmium—soil pollution level of Cd I for LKJ and III for Sport Club Sygnal (Kabata-Pendias and Piotrowska 1995).

For playground in Borek the highest concentration of organic carbon was found near the slide and significantly lower values at other sites. The highest concentration of organic carbon was found in playground in Dziesiąta in June in plot "0" and the lowest also in playground in Dziesiąta in June near the swings (Table 5). The lowest concentration of organic carbon was found in sample collected from the plot "0" in playing field in Mętów in June and in Sport Club "Sygnał" in April. The highest concentration of organic carbon was found in midfield of playing field in Mętów in June (Table 7). For playing fields and horse farms it is difficult to find a relationship between burden of the spot and organic carbon concentration. The highest concentration of organic carbon was found in plot "0" in LKJ in April and the lowest in riding place a also in LKJ, in June (Table 6).

Discussion

The study suggests that soil at sport playing fields was characterized by a particle size distribution corresponding to the loose and weakly loamy sands, in which the percentage of sand grain of 2–0.05 mm diameter was, respectively, 94 and 89 %, the share of dusty fraction of 0.05–0.002 mm grain diameter ranged from 3 to 7 %, while the proportion of clay fraction having a grain size less than 0.002 mm amounted from 2 to 3 %. In the study upon the recreational objects, soils were characterized by a particle size distribution corresponding to light, sandy, and common loam, in which the share of sand ranged from 69 to 37 %, dust fraction ranged from 47 to 23 %, and clay fraction amounted from 8 to 16 %. Policht-Latawiec (2008) has shown that reducing the proportion of sand in relation to dust-loamy soil in the granularity composition of soil for building the playing fields leads to better soil permeability. It can be concluded that loamy soils are better and cheaper to use for football playing fields than sandy soils, which were described by Policht-Latawiec (2008). Kopeć and Głąb (2006) summarized that alluvial soil with granularity composition of ordinary dust becomes highly compacted and physically degraded under pressure, it is not conducive to the root growth and does not properly supplies water and nutrients to plants.

Perhaps a greater burden near the swings in one case and near the slide in the other, may affect the dehydrogenase concentration in the soil. In both cases, the lowest dehydrogenase activity values were recorded in plot "0", where children did not play at all. Considering the urease: its concentration was the highest in the plot "0", where there was no burden. Near the swings and the slide, where the burden was greater, concentration of urease was significantly lower than in plot "0". Concentration of phosphatase in soil samples taken from the playground in Dziesiąta housing estate was the highest in plot "0". Significantly lower values were obtained in samples collected near the swings, while samples taken near the slides were characterized by the lowest concentration of phosphatase. In the case of playground in Borek Turka housing estate, the highest concentrations of this enzyme were recorded in the sample collected by the swings, where the burden was smaller than in the case of sample from near the slide, where the burden was the greatest.

The study shows that in the case of the horse farms, the soil samples taken from the unburdened plot "0" revealed the highest concentration of dehydrogenase. In the case of urease and phosphatase enzymes, their highest activities were recorded for LKJ horse farm in samples collected from the plot "0", that was unburdened. Decrease in these enzymes concentrations was observed in samples derived from the paddocks. Elevated urease level was determined in samples from place "b" as compared to those collected in place "a". For phosphatase enzyme, the results were adverse—higher enzyme concentration was found in place "a" rather than in "b". In conclusion, it can be seen that dehydrogenase activity depends on the burden of a given site and time, for which the horses remain on that area. In the case of other enzymes, such relationship was not found. Dehydrogenases are considered to be a good and adequate measure of microbial oxidative activities in soil, indicating microbiological redox-systems (Wolińska and Stępniewska 2012). Theses enzymes transfer hydrogen from organic substrates to inorganic acceptors, what influence the biological oxidation of the organic matter (Zhang et al. 2010). High burden influences a decrease in dehydrogenases concentration. In such places soil restoration is needed. It is a slow process and Haiyan et al. (2013) noticed that soil carbon components in the two grasslands progressively changed after the grazing had been excluded. It was concluded that degradation of natural pasture followed by extensive cultivation with little attention to conservation practices has led to decline in soil quality (Ayoubi et al. 2014). Despite government regulations that require some horse farms to implement nutrient management plans and encourage them to adopt best management practices (BMPs), the current use of BMPs by farm operators is limited (Fiorellino et al. 2013). Best management practices involves the lowest herbicide implementation rates, storage of manure on an impervious surface, use of a sacrifice lot within a pasture, rotational grazing, managing roof runoff, and lime application. Appropriate stocking density, use of rotational grazing, and correct manure management is also needed (Fiorellino et al. 2013).

It was noted that in playing field in Mętów midfield in playing field in Mętów revealed the lowest dehydrogenase activity. In the case of urease, samples from the goal area in playing field in Mętów contained its largest amounts. Considering the phosphatase activity in the playing field at Rusałka Street, its largest concentration was found in sample from the penalty zone, while in the playing field in Mętów, the highest concentrations of phosphatase were recorded in samples derived from the midfield. In conclusion, it can be stated that for the same weekly burden of both playing fields and without additional fertilization and irrigation of the area, samples collected from penalty zones were characterized by the highest dehydrogenase concentrations. For playing fields, the penalty zones were frequently visited by footballers, and thus these were the most burdened areas. The goal areas were equally often used by players and the highest concentration of urease was determined in samples collected from these areas in both uncared playing fields. In addition, it is interesting that much higher values of urease in the test soil samples were found in playing field in Mętów than in the case of that at Rusałka Street. The highest concentrations of all three tested enzymes (dehydrogenase, phosphatase, and urease) in the playing field of Sport Clubs "Sygnał" and "Budowlani" were achieved in samples from the plot "0", where there was no the area burden and from penalty zone in Sport Club Sygnał. The authors found that for horse farms there was very high concentration of ammonia nitrogen in the place of manure storage directly on the ground—to 56.8 mg/100 g in a 30–50 cm depth soil layer and 74.0 mg/kg in the soil samples collected from the depth of 0–20 cm (additional results not shown in any table). For other investigated samples, the concentration of ammonium nitrogen was not much different from one another in all soil samples regardless of the area burden, time during which children, players, or horses were present at a given area, or treatments used for various recreational areas. It can be concluded that the ammonium nitrogen concentration in the test samples was small and did not constitute a threat for human organism.

Terelak (2005) reported that soils in arable lands in Poland contain following average quantities of Cd, Cu, Ni, Pb, and Zn in the topsoil: 0.21, 6.5, 6.2, 13.6, and 32.4 mg/kg. About 80 % of arable land soils in the country are characterized by natural (0 degree), while 17.6 % elevated (I degree) concentrations of heavy metals. In this study the degree of heavy metals soils contamination was low. According to Polish norms presented in The Official Regulation of the minister of environment only the samples from the playing field in Sport Club "Sygnał" and LKJ horse farm had increased concentration of cadmium, which is classified into the third, the lowest class of contamination (Polish Minister of Environment 2002). Nevertheless, higher cadmium concentration in samples collected from playing field in Sport Club "Sygnał", is quite interesting—its concentration is almost 4 times higher as compared to other samples, as well as to those from LKJ horse farm, in which cadmium level was almost by 1 mg/kg higher than in other samples. The issue of heavy metals concentration in soil, especially at playgrounds, is very important. According to Costa et al. (2012) Cr and Ni in the soil pose a serious risk to children due to their daily outdoor activities and particular behavior. Children are more expose to the topmost part of the ground via dusting and hand-to-mouth ingestion. Thus, the focusing of studies on the topmost layer provides an overview of concentration levels in the most easily accessible part of the soil. Studies on the topmost layer could also enable a preliminary assessment of the amount and extent of dust-related, diffuse contamination in urban soil (Jarva et al. 2014). Children, playing in industrial areas, public parks, kindergarten playgrounds, and commercial areas, are more susceptible to soil lead toxicity. Bio accessibility was affected by use scenario type, level of contamination, soil pH, soil type, and speciation (Ren et al. 2006). Nielsen and Kristiansen (2005) found, that the exposure of a child to lead from soil is a combination of direct exposure from the soil and indirect exposure through indoor dust. They removed topsoil (upper 15 cm) from footpaths and other intensively used areas with bare soil, and replaced it with uncontaminated soil on top of perforated landscape cloth. Eventually, these areas were covered with wood chips. The interventions had effectively reduced the potential exposure to lead from the most intensively used areas of the playgrounds (Nielsen and Kristiansen 2005). Costa et al. (2012) found, that chromium and nickel are above the regulations in soils of the volcanic complex and in a public garden near the railway. Li et al. (2014) concluded, that among the different heavy metals, Hg changed mostly with the variation of distance to build-up area. Tahmasbian et al. (2014) found the lowest quantities of analyzed trace elements in green-lands and parks with strict vehicle traffic rules on one hand and the highest amounts in highways, industrial areas and city center with the highest traffic load. The urban soils were highly enriched with heavy metals, such as Hg, Pb and Cd and demonstrated more heavy metal contaminated, in comparison with the suburban soils (Zhen-ang et al. 2011). Dehydrogenase activity in the soil is influenced, among others, by catalysts and inhibitors. The role of activators and inhibitors may be played by heavy metals, including nickel (Kuziemska 2012). The literature data (Wyszkowska and Wyszkowski 2004) indicate the negative impact of increased nickel amounts on the biological activity of the soil by reducing the activity of dehydrogenases, urease, as well as alkaline and acidic phosphatase. Present study revealed the lowest concentrations of dehydrogenase and urease in samples derived from the playing field in Sport Club “Budowlani” Lublin, where the highest nickel level (13.9 mg/kg of soil) was recorded, although achieved values for nickel in any tested objects did not exceed the obligatory limits. It is important to mention, that the term “heavy metals” is not entirely satisfactory from a chemical viewpoint. More accurate and wide expression is “potentially toxic trace elements—PTEs”, as not every trace element is a metal and they are toxic only above specific concentrations (Duffus 2002; Hooda 2010).

Organic carbon is widely considered the most important governing factor in soil quality interrelationships that are expressed in improved biological activities, plant available nutrients and functional soil structure, including high aggregate stability and low bulk density (Kremer and Hezel 2012). Zhou and Hang (2014) claim that the concentration of organic carbon in the soil depends on the temperature, soil moisture, and nitrogen concentration. Concentration of organic carbon differed significantly in samples taken both from the playing fields, as well as from horse farms. These results suggest enzyme activity is affected by changes in organic carbon because the latter served as a precursor for enzyme synthesis (increases soil microbial biomass, which is an enzyme source), and played a vital role in enzyme physical stabilization. In addition, phosphatase, urease and arylsulfatase were more significantly affected by changes in soil electric conductivity than in soil pH. This may be because salt stress was a limiting factor for plants and microorganisms (which are the main source of enzymes) in these soils (Chen et al. 2013).

For all analyzed objects the concentration of dehydrogenase and phosphatase mostly depended on the temperature. Significant lower values of them were obtained in April were the average temperature was close to 0 °C, except playground in Borek where the highest concentrations of all three enzymes were achieved in that month.

Table 9 presents correlations between enzymes, nitrogen and organic carbon concentration for the soil from all investigated sites separately. For most sites, a positive correlation was found between enzymes and organic carbon concentration. Literature data (Aon and Colaneri 2001; Chodak and Niklińska 2010) indicate a positive dependence between soil enzymes activities vs. organic carbon concentration in the soil. Higher organic carbon concentration can provide more substrate to increase microbial biomass and higher enzyme production (Yuan and Yue 2012). This dependence is confirmed in majority of studied objects, although in the case of samples from playing field Budowlani and the horse farms, a negative correlation was noted. For most sites a negative correlation was found between nitrogen and organic carbon concentration. A positive correlation was found for cared playing ground Borek and it could be caused by the fertilization process. For most sited, there was statistically significant correlation between all three enzymes concentration (Table 9). Very similar correlation was found by Chen et al. (2013) and they concluded, that the fact that phosphatase, urease and arylsulfatase activity was significantly inter-correlated suggests, that these enzymes have similar origin and persistence in soil.

Conclusions

Chemical and biochemical changes of studied objects depend on human activities. Use of the recreations areas triggers the changes in chemical and biological composition of the soil. Greater burden decreases the enzymes concentration in the soil. The concentration of some enzymes in soil depended on climate conditions. As higher temperature was observed as more dehydrogenase and urease increased. For most sites, a positive correlation was found between enzymes and organic carbon concentration and between all three enzymes. In this study, the degree of heavy metals soils contamination was low and only the samples from one playing field and one horse farm had increased concentration of cadmium. Monitoring of

Table 9 Correlations between enzymes, nitrogen and organic carbon

	Dehydrogenase	Urease	Phosphatase	Nitrogen	Organic carbon
Playground Dziesiąta					
Dehydrogenase	1.00				
Urease	−0.76*	1.00			
Phosphatase	−0.61*	0.96*	1.00		
Nitrogen	−0.52*	0.43*	0.22	1.00	
Organic carbon	0.72*	−0.17	0.07	−0.41*	1.00
Playground Borek					
Dehydrogenase	1.00				
Urease	−0.72*	1.00			
Phosphatase	0.45*	−0.03	1.00		
Nitrogen	0.88*	−0.67*	0.27	1.00	
Organic carbon	0.54*	0.06	0.34	0.56*	1.00
Playing field Mętów					
Dehydrogenase	1.00				
Urease	−0.66*	1.00			
Phosphatase	−0.33	0.87*	1.00		
Nitrogen	−0.05	−0.22	−0.08	1.00	
Organic carbon	0.58*	0.14	0.50*	−0.24	1.00
Playing field Sygnał					
Dehydrogenase	1.00				
Urease	0.55*	1.00			
Phosphatase	0.87*	0.22	1.00		
Nitrogen	−0.45*	−0.43*	−0.25	1.00	
Organic carbon	0.64*	0.70*	0.47*	−0.41*	1.00
Playing field Rusałka					
Dehydrogenase	1.00				
Urease	−0.22	1.00			
Phosphatase	0.60*	0.50*	1.00		
Nitrogen	−0.35	0.08	−0.02	1.00	
Organic carbon	0.17	−0.04	−0.08	−0.33*	1.00
Sport Club BKS					
Dehydrogenase	1.00				
Urease	0.03	1.00			
Phosphatase	0.79*	0.31	1.00		
Nitrogen	−0.22	0.24	0.08	1.00	
Organic carbon	−0.24	−0.52*	−0.44*	−0.37*	1.00
Horse farm LKJ					
Dehydrogenase	1.00				
Urease	0.87*	1.00			
Phosphatase	0.83*	0.81*	1.00		
Nitrogen	0.75*	0.75*	0.42*	1.00	
Organic carbon	−0.74*	−0.68	−0.74	−0.55*	1.00
Horse farm Bonanza					
Dehydrogenase	1.00				
Urease	−0.93*	1.00			
Phosphatase	−0.99*	0.91*	1.00		
Nitrogen	−0.23	0.38	0.06	1.00	
Organic carbon	0.36	−0.22	−0.34	−0.07	1.00

Statistical significance of correlations is marked with stars ($p < 0.05$)

biochemical changes in recreational areas soil (especially playgrounds) is very important to provide safe environment for human leisure time.

References

Aon MA, Colaneri AC (2001) Temporal and spatial evolution of enzymatic activities and physico-chemical properties in an agricultural soil. Appl Soil Ecol 18:255–270

Ayoubi S, Emami N, Ghaffari N, Honarjoo N, Sahrawat KL (2014) Pasture degradation effects on soil quality indicators at different hillslope positions in a semiraid region of western Iran. Environ Earth Sci 71:375–381

Chen L, Jian-Ming X, NengFei D, Qing-Lin F, Bin G, YiCheng L, Hua L, Ningyu L (2013) The effect of long-term reclamation on enzyme activities and microbial community structure of saline soil at Shangyu, China. Environ Earth Sci 69:151–159

Chodak M, Niklińska M (2010) Effect of texture and tree species on microbial properties of mine soils. Appl Soil Ecol 46:268–275

Costa C, Reis AP, Ferreira da Silva E, Rocha F, Patinha C, Dias AC, Sequeira C, Terroso D (2012) Assesing the control exerted by soil mineralogy in the fixation of potentially harmful elements in the urban soils of Lisbon, Portugal. Environ Earth Sci 65:1133–1145

Dąbrowski M (2014) Engineering multilevel governance? Joint European Support for Sustainable Investment in City Areas (JESSICA) and the involvement of private and financial actors in urban development policy. Reg Stud 48(12):2006–2019

Duffus JH (2002) "Heavy metals"—a meaningless term? Pure Appl Chem 74:793–807

Fiorellino NM, Wilson KM, Burk AO (2013) Characterizing the use of environmentally friendly pasture management practices by horse farm operators in Maryland. J Soil Water Conserv 68(1):33–40

Haiyan W, Decao N, Hua F, Jian K (2013) Experimental investigation on soil carbon, nitrogen, and their components under grazing and livestock exclusion in steppe and desert steppe grasslands, Northwestern China. Environ Earth Sci 70:3131–3141

Hooda PS (2010) Introduction. In: Hooda PS (ed) Trace elements in soils. Blackwell Publishing, Oxford, UK, pp 3–8

Huang PM (2008) Impacts of physicochemical-biological interactions on metal and metalloid transformations in soils: and overview. In: Violante A, Huang PM, Gadd GM (eds) Physico-chemical processes of heavy metals and metalloids in soil environments. John Wiley & Sons Inc, New York, pp 3–52

Huang PM, Wang S-L, Tzou Y-M, Huang Y, Weng B, Zhuang S, Wang MK (2013) Physicochemical and biological interfacial interactions: impacts on soil ecosystem and biodiversity. Environ Earth Sci 68:2199–2209

ISO 13878 (1998) Soil quality—determination of total nitrogen concentration by dry combustion. International Organization for Standarization, Geneva, Switzerland

ISO 14235 (1998) Soil quality—determination of organic carbon by sulfochromic oxidation. International Organization for Standarization, Geneva, Switzerland

Jae-Hwan Ch, Hae-Kag L, Kyung-Rae D, Yong-Jin J, Woon-Kwan Ch, Dong-Kyoon H, Min-Hye K (2014) A study on the measurement and analysis of radioactivity concentration and the ambient dose rate in soil on the playgrounds of elementary schools in the Gwangju area. Environ Earth Sci 71:2391–2397

Jarva J, Ottesen RT, Tarvainen T (2014) Geochemical studies on urban soil from two sampling depths in Tampere Central Region, Finland. Environ Earth Sci 71:4783–4799

Kabata-Pendias A, Piotrowska M (1995) Basis for assessing chemical contamination of soils. Heavy metals, sulfur and PAHs. Environmental Monitoring Library, Warsaw

Kaźmierowski C (2012) Soil science. Ex 6 pH and acidity UAM Poznań:1–8

Kollath E (1998) Football. The technique and tactics. MARSHAL Wroclaw: ss 144

Kopeć S, Głąb T (2006) The influence of soil compaction on yielding of selected species of grass. Zesz Nauk UP Wrocław Roln 545:141–146

Kremer J, Hezel LH (2012) Soil quality improvement under an ecologically based farming system in northwest Missouri. Renew Agric Food Syst 28(3):245–254

Kuziemska B (2012) Dehydrogenase activity in soil contaminated with nickel. Ochr Środow Nat 52:103–112

Li J, Pu L, Zhu M, Liao Q, Wang H, Cai F (2014) Spatial pattern of heavy metal concentration in the soil of rapid urbanization area: a case of Ehu Town, Wuxi City, Eastern China. Environ Earth Sci 71:3355–3362

Lityński T, Jurkowska H, Gorlach E (1976) Agricultural chemical analysis PWN: ss 149

Monokrousos N, Papatheodorou EM, Diamantopoulos JD, Stamou GP (2006) Soil quality variables in organically and conventionally cultivated field sites. Soil Biol Biochem 38:1282–1289

Nielsen JB, Kristiansen J (2005) Remediation of soil from lead-contaminated kindergartens reduce the amount of lead adhering to children's hands. J Expo Sci Environ Epidemiol 15:282–288

Pan J, Yu L (2011) Effects of Cd or/and Pb on soil enzyme activities and microbial community structure. Ecol Eng 37:1889–1894

Policht-Latawiec A (2008) The study of water permeability of the soil composite dust and clay, sand and peat substrate. Acta Sci Pol Formatio Circumiectus 7(4):21–30

Polish Minister of Environment (2002) Official regulation of soil quality standards. Dziennik Ustaw 165:1359

Polish Norm (1997) Analysis of the chemical-agricultural soil—sampling PN-R-04031

Ren HM, Wang JD, Hang XL (2006) Assesment of soil lead exposure in children in Shenyang, China. Environ Pollut 144:327–335

Ryżak M, Bartmiński P, Bieganowski A (2009) Methods for determining size distribution of mineral soils. Acta Agrophys Monogr 175(4)

Tabatabai MA, Bremner JM (1969) Use of p-nitrophenyl phosphate for assay of soil phosphatase activity. Soil Biol Biochem 1:301–307

Tahmasbian I, Nasrazadani HS, Sinegani AAS (2014) The effects of human activities and different land—use on trace element pollution in urban topsoil of Isfahan (Iran). Environ Earth Sci 71:1551–1560

Terelak H (2005) Heavy metals and sulfur in the soils of the Polish agricultural land. Probl Ekol 9(5):259–264

Thalmann A (1968) Zur Methodik der Bestimmung der Dehydrogenase Aktivität in Boden mittels Triphenyltetrazoliumchlorid (TTC). Landwirt Forsch 21:249–258

Wei-Tsuen S, Kun-Yu Ch, Chang-Sheng J, Jung-Der W (1999) Long-term effect of increased lead absorption on intelligence of children. Arch Environ Health 54(4):297–301

Wolińska A, Stępniewska Z (2012) Dehydrogenase activity in the soil environment. Biochem Genet Mol Biol 14:183–210

Wyszkowska J, Wyszkowski M (2004) Influence of soil pollution by nickel on enzymatic activity. Zesz Probl Post Nauk Rol 505:518–522

Xinghui X, Xiuli Z, Yunjia L, Haiyang D (2013) Levels and distribution of total nitrogen and total phosphorous in urban soils of Beijing, China. Environ Earth Sci 69:1571–1577

Yuan B, Yue D (2012) Soil microbial and enzymatic activities across a chronosequence of Chinese Pine plantation development on the Loess Plateau of China. Pedosphere 22:1–12

Zantua MI, Bremner JM (1975) Comparison of methods of assaying urease activity in soils. Soil Biol Biochem 7:291–295

Zhang N, He X, Gao Y, Li Y, Wang H, Ma D, Zhang R, Yang S (2010) Pedogenic carbonate and soil dehydrogenase activity in response to soil organic matter in Artemisia ordosica Community. Pedosphere 20:229–235

Zhen-ang C, Sheng-ying Q, Zheng-yu B, Neng-you W (2011) Contamination and distribution of heavy metals in urban and suburban soils in Zhangzhou City, Fujian, China. Environ Earth Sci 64:1607–1615

Zhou X, Hang Y (2014) Temporal dynamics of soil oxidative enzyme activity cross a simulated gradient of nitrogen deposition in the Gurbantunggut Desert, Northwestern China. Geoderma 213:261–267