Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wroclaw.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2003
Volume 6
Issue 2
Series ENVIRONMENTAL DEVELOPMENT

PALUSZAK Z., OLSZEWSKA H., BREZA-BORUTA B. 2003. EXPERIMENTAL STUDY ON FECAL BACTERIA MOVEMENT IN SOIL AMENDED WITH SLURRY **Electronic Journal of Polish Agricultural Universities**, Environmental Development, Volume 6, Issue 2.
Available Online http://www.ejpau.media.pl

EXPERIMENTAL STUDY ON FECAL BACTERIA MOVEMENT IN SOIL AMENDED WITH SLURRY

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ABSTRACT

The aim of study was to estimate survival, the rate and range of migration of fecal bacteria in soils fertilized with bovine slurry. The research showed that a great majority of fecal bacteria was retained in higher parts of soil profiles. The precipitation, physical and chemical properties of soil, the bacterial population density used in experiment were most important factors that influenced infiltration of fecal microorganisms.

Some microorganisms were quickly transported into deeper layer of the soil profile through mega-and macropores. The contamination of underground water with microorganisms under extreme weather conditions cannot be excluded.

Key words: fecal bacteria, soil, slurry.

INTRODUCTION

Development of animal production and increasing number of large production units result in producing vast amount of animal waste. Its use for agricultural purposes is important from both a sanitary and epidemiological point of view [21]. Slurry that spread over a limited area may contaminate soil and cultivated plants alike. It poses a real risk that soil self-purification ability can be disturbed and pathogens can infiltrate into the ground waters [17]. Slurry contains an excessive amount of 10^9 - 10^{10} bacteria in 1 cm^3 [9] and may be contaminated with pathogens such as enteric bacteria, viruses, fungi, ova and cysts of parasites [2, 26, 28].

A stored slurry does not generate enough heat to prompt self-disinfections and microflora can survive in it for a long time. Having been spread onto the soil, pathogens are gradually inactivated, but some of them remain viable and may move into deeper soil layers and ground waters [17]. The survival time and infiltration rate for enteric bacteria in soils amended with slurry depend on many factors, such as thermal and moisture conditions, kind of soil, its combined physical and chemical properties, biological activity, and the species of microorganisms concerned [1, 3, 17]

The aim of the research was to estimate the risk of contamination of environment with infected slurry by means of evaluating infiltration into forest-meadow chernozem related to soil properties and weather conditions for bacteria *E. coli*, streptococci of group D, and *Salmonella senftenberg*.

EXPERIMENTAL PROCEDURES

The infiltration process of selected faecal bacteria after spreading the cattle slurry onto forest meadow chernozem was studied over two summer and one winter periods. An experimental (D) and a control (K) plot (24 m^2 each) were fertilized with 72 l of cattle slurry. Between them open pits, of parameters 6 by 2.5 m and 160 cm deep, were dug. They enabled horizontal sampling of the studied soil. The slurry spread out onto plot D contained additionally 1l of broth bouillon suspension of *E. coli* and streptococci of D-group (10^8-10^9cfu/cm^3) and 1l of *Salmonella senftenberg* (10^6-10^7 cfu/cm^3).

Soil samples for the studies from both plots were collected from the depths of 12, 25, 43, 70, and 90 cm before spreading the slurry out (sample 0); a week later, and 4 more times at monthly intervals.

Physicochemical soil study

A physicochemical soil study was carried out. Texture for particular genetic soil horizons was estimated with Bouyoucos's method modified by Casagrande and Prószyński [15]. Bulk density and water characterizations were analysed according to methodology provided by Zawadzki [29].

Distribution of soil pores size was determined on the ground of the water characterizations. Filtration coefficients were determined with the laboratory method according to Miatkowski and Ciesliński [18]. Soil pH was estimated in water and in KCl solution. Total carbon, nitrogen, as well as the content of calcium, magnesium, phosphorus and potassium oxides, were determined respectively with Tiurin, Kiejdahl and other methods commonly used in agricultural chemistry [15].

Soil temperature at the depths of 5, 10, 15 and 20 cm was taken and climatic conditions were controlled in the area of study. The air temperature, vapour pressure deficit and insolation were registered and total precipitation was also measured.

Microbial investigation

The number of bacteria in the soil was calculated with NPL method in 100g of soil sample [20]. For *E. coli* equation Mac Conkey bouillon was used (43°C for 24 hours). Then the material was sieved on agar with tergitol and TTC (43°C for 24 hours). The test for decarboxylase of glutamine acid was made to confirm the results. Ability of *E. coli* to utilise lactose with gas deliberation was also tested (44°C for 48 hours).

Azide dextrose broth was used as an enriching medium for selective growth of fecal streptococci. After 48 hours of incubation at 37°C, the material was streaked to agar with esculine and azide (37°C for 48 hours). A serological test to confirm the presumed colony was made (Phadabac-test).

Salmonella was isolated by mean of two media. At the first stage soil samples were blended in 1% peptonic water (24 hours in 37°C), and then the amount of 0.1 ml of material from each test-tube was streaked to selective fluid medium as prescribed by Rappaport (43°C for 24 and 48 hours). Afterwards the material was sieved to a selective agar breeding-ground BPLA according to Kaufmann (37°C for 24 hours). The identification was confirmed by using serological tests with polivalent serum Hm.

Statistic analyses

Microsoft Excel software was used to perform all the statistical analyses. The significance of differences between the count of bacteria and the depth of soil profiles was determined with the Student's t-test. The critical P-value for the t-test was set to 0.05.

RESULTS

Climatic conditions during the research

The results of meteorological observations during the study are presented in Table 1.

The air temperature at the winter period was relatively high for that season of the year. The lowest total monthly precipitation was found in February, whereas the highest in December and amounted to 10.9 mm and27.4 mm, respectively. The values did not deviate much from the average for the region.

Table 1. Mean monthly temperatures of air and soil (°C), air insufficiency (hPa), insolation (hour), and total precipitation (mm) in the area of research

Season of the year	Month	Air temperature (°C)	Soil temperature (^{0}C)				Vapour pressure deficit	Sunshine (hours)	Rainfall (mm)
			Depth (cm)						
			5	10	20	50			
Winter	XI	4.4	4.4	4.6	4.3	5.7	1.2	8.03	25.3
	XII	0.6	0.9	1.1	0.8	2.2	1.1	9.0	27.4
	I	0.4	0.4	0.6	0.3	1.6	1.1	1.1	10.9
	II	2.8	1.4	1.4	1.1	1.7	1.3	1.2	18.9
Summer 1	VI	19.7	21.9	20.9	20.7	19.1	13.8	9.8	31.0
	VII	21.1	23.5	22.8	22.5	21.2	14.6	9.1	27.7
	VIII	21.4	22.4	21.7	21.8	20.9	13.8	7.3	21.7
	IX	13.8	14.7	14.5	14.8	14.8	5.8	4.4	19.5
Summer 2	VI	16.1	18.8	18.4	18.4	17.6	8.2	6.5	63.3
	VII	17.2	19.0	18.4	18.2	17.6	7.4	6.9	91.2
	VIII	16.9	18.6	18.2	18.1	18.1	7.5	8.6	46.8
	IX	12.2	13.7	13.6	14.0	14.0	3.3	3.6	86.4

During the dry summer, the mean monthly temperatures were high. Total precipitation for the first three months was very low - it reached merely 79.8 mm, the value that was almost 100 mm less in comparison to the average calculated over many-years period. That period was also characterized with long insolation time. However, the rainfall in the wet summer reached 201.3 mm, i.e. 35 mm more than the referenced average. For that season air temperature and insolation level were obviously lower in comparison to the dry summer; insolation time of shorter by 3.3 and 2.2 hours were found for July and August, respectively.

Physical and chemical properties of soil

Forest-meadow chernozem is made up of sandy loam on the bed of light loam. Three layers are observed in the soil profile, namely a humus layer (Ap), a browning horizon (B), to the respective depth of 30 cm, and from 30 to 65 cm and the parent rock (C). Results of soil analysis are shown in Table 2.

Table 2. Physicochemical properties of forest-meadow chernozem

1	genetic horizon		Ap		B	C	
2	layer depth cm		0 - 10	10 - 30	30-50	70-80	90-100
3	% volume of pores of the equivalent diameter μm						
	macropores	> 300	2.9	5.0	4.0	3.5	2.8
		300 – 30	5.2	6.0	5.0	6.0	4.1
	mesopores	30 – 5	3.5	4.9	3.9	4.0	3.4
		5 – 0.2	13.0	10.1	9.1	10.0	8.5
	micropores	< 0.2	10.9	10.0	13.0	10.0	14.2
		<5	23.9	20.1	22.1	20.0	22.7
4	textural group		gp		gl	glp	
5	content of fraction of the diameter in mm %: 1.0 – 0.1 0.1 – 0.05 0.05 – 0.02 0.02 – 0.002 < 0.002 razem < 0.02		54 16 8 12 10 22		48 17 8 9 18 27	42 17 9 16 16 32	
6	bulk density g/ cm^3		1.68		1.72	1.78	
7	pH	H_2O	7.6		8.0	8.2	
		KCl	7.3		7.3	7.4	
8	content of C mg/100g		1298		385	170	
9	content of N mg/100g		109		54	28	
10	C/N		11.91		6.63	6.07	
11	total content in mg/100g : CaO K_2O P_2O_5 MgO		42.20 24.32 20.01 10.67		23.60 5.64 8.27 7.70	123.60 2.61 2.76 9.40	
12	Filtration coefficient K10 m/d		0.27		0.39	0.027	

A - humus layer, B - browning horizon, C_{ca} - parent rock, gp – sandy loam; gl - light loam, glp - light loamy sand

The soil with a considerable organic matter content had temperate drainage conditions at a depth between 0 and 50 cm, while from 70 to 100 cm the conditions were found weak and provided suitable base for survival of fecal microorganisms. Bulk density of the soil varied from 1.64 to 1.79 g/cm^3. A filtration coefficient was very low, thus within the parent rock slurry and bacteria infiltration into deeper layers of soil could have been made difficult (Tab. 2).

Infiltration of fecal bacteria into forest-meadow chernozem

Behaviour of fecal bacteria in soil was investigated in 3 periods of time: during mild winter, dry hot summer, and wet summer with air temperatures close to average. Migration of indicator bacteria and their concentration at particular depths of soil profile are presented in Tables 3-5.

Table 3. Number of *E. coli* in 100g of forest meadow chernozem on different depth during dry summer (S_1), wet summer (S_2) and winter (W) on control (C) and experimental (E) plots

Season of the year	Time in weeks	Depth in cm									
		12		25		43		70		90	
		E	C	E	C	E	C	E	C	E	C
W	1	$4.5\cdot10^5$	$9.5\cdot10^3$	$9.5\cdot10^4$	$1.1\cdot10^2$	nw	$1.1\cdot10^1$	$2.5\cdot10^1$	nw	nw	nw
	4	$7.5\cdot10^4$	$2.0\cdot10^3$	$2.0\cdot10^3$	nw	$1.5\cdot10^3$	nw	$4.5\cdot10^1$	nw	nw	nw
	8	$9.5\cdot10^2$	$4.5\cdot10^2$	$4.5\cdot10^3$	nw	nw	nw	nw	nw	nw	nw
	12	$4.5\cdot10^2$	$1.1\cdot10^2$	$2.5\cdot10^1$	$2.0\cdot10^1$	$4.0\cdot10^0$	$1.5\cdot10^1$	nw	nw	nw	nw
	16	$9.5\cdot10^2$	$4.0\cdot10^0$	$2.5\cdot10^1$	$7.0\cdot10^0$	nw	nw	nw	nw	nw	nw
S_1	1	$9.5\cdot10^4$	$4.0\cdot10^3$	$7.5\cdot10^0$	$4.0\cdot10^0$	$1.5\cdot10^1$	nw	nw	nw	nw	nw
	4	$4.0\cdot10^3$	$1.5\cdot10^2$	$7.5\cdot10^2$	$9.5\cdot10^1$	nw	nw	nw	nw	nw	nw
	8	$9.5\cdot10^2$	$4.0\cdot10^1$	$2.5\cdot10^1$	$9.0\cdot10^0$	$4.0\cdot10^0$	nw	nw	nw	nw	nw
	12	$7.5\cdot10^2$	$1.5\cdot10^1$	nw	$7.0\cdot10^0$	nw	nw	nw	nw	nw	nw
	16	$4.0\cdot10^0$	$9.0\cdot10^0$	$9.0\cdot10^0$	nw	$7.0\cdot10^0$	nw	nw	nw	nw	nw
S_2	1	$1.1\cdot10^5$	$2.0\cdot10^3$	$1.1\cdot10^4$	$4.5\cdot10^2$	$2.0\cdot10^2$	$7.0\cdot10^0$	nw	nw	nw	nw
	4	$9.5\cdot10^3$	$4.5\cdot10^2$	$7.5\cdot10^3$	$9.5\cdot10^1$	$4.5\cdot10^2$	$2.5\cdot10^1$	nw	nw	nw	nw
	8	$2.5\cdot10^3$	$7.5\cdot10^1$	$1.5\cdot10^2$	$2.5\cdot10^1$	$1.1\cdot10^2$	$4.0\cdot10^0$	$1.1\cdot10^1$	nw	nw	nw
	12	$7.5\cdot10^2$	$9.5\cdot10^1$	$4.5\cdot10^2$	$7.0\cdot10^1$	$9.0\cdot10^1$	$4.0\cdot10^1$	$1.5\cdot10^1$	nw	nw	nw
	16	$7.0\cdot10^0$	$9.0\cdot10^0$	$4.5\cdot10^1$	$2.5\cdot10^1$	$7.0\cdot10^1$	$7.0\cdot10^0$	nw	nw	nw	nw

Table 4. Number of group D streptococci in 100g of forest meadow chernozem at different depth during dry summer (S_1), wet summer (S_2) and winter (W) on control (C) and experimental (E) plots

Season of the year	Time in weeks	depth in cm									
		12		25		43		70		90	
		E	C	E	C	E	C	E	C	E	C
W	1	$6.5\cdot10^5$	$2.5\cdot10^3$	nw	$9.5\cdot10^2$	$9.5\cdot10^1$	$7.0\cdot10^0$	$2.5\cdot10^1$	nw	$4.0\cdot10^0$	nw
	4	nw	nw	nw	$9.5\cdot10^1$	nw	nw	nw	nw	nw	nw
	8	$2.5\cdot10^4$	$9.5\cdot10^1$	$3.0\cdot10^2$	$2.5\cdot10^1$	nw	$4.0\cdot10^0$	nw	nw	nw	nw
	12	$4.5\cdot10^3$	$9.5\cdot10^1$	$2.0\cdot10^2$	$4.5\cdot10^1$	nw	$7.5\cdot10^0$	$4.0\cdot10^0$	nw	$4.0\cdot10^0$	nw
	16	$4.5\cdot10^3$	$7.0\cdot10^0$	$7.0\cdot10^0$	nw	$2.5\cdot10^1$	$4.0\cdot10^0$	nw	nw	nw	nw
S_1	1	$4.5\cdot10^4$	$2.0\cdot10^3$	$1.5\cdot10^2$	$9.5\cdot10^1$	$2.5\cdot10^1$	$7.0\cdot10^0$	$7.0\cdot10^0$	nw	nw	nw
	4	$1.5\cdot10^3$	$2.0\cdot10^2$	$9.5\cdot10^1$	$1.5\cdot10^2$	nw	$4.0\cdot10^0$	$4.0\cdot10^0$	nw	nw	nw
	8	$7.5\cdot10^2$	$7.0\cdot10^0$	$2.5\cdot10^1$	$1.1\cdot10^1$	nw	nw	nw	nw	nw	nw
	12	$9.5\cdot10^1$	$4.5\cdot10^1$	$9.5\cdot10^1$	$2.5\cdot10^1$	nw	nw	nw	nw	nw	nw
	16	$9.0\cdot10^0$	$7.0\cdot10^0$	nw	nw	nw	nw	nw	nw	nw	nw
S_2	1	$6.5\cdot10^5$	$8.5\cdot10^3$	$2.5\cdot10^4$	$1.5\cdot10^2$	$4.0\cdot10^2$	$7.5\cdot10^1$	$7.5\cdot10^1$	nw	nw	nw
	4	$1.1\cdot10^4$	$6.5\cdot10^2$	$7.5\cdot10^3$	$7.5\cdot10^1$	$7.5\cdot10^2$	$2.5\cdot10^1$	$2.5\cdot10^1$	nw	nw	nw
	8	$9.5\cdot10^3$	nw	$1.1\cdot10^4$	$9.5\cdot10^1$	$4.5\cdot10^1$	$7.0\cdot10^0$	$1.1\cdot10^0$	nw	nw	nw
	12	$7.5\cdot10^3$	$9.5\cdot10^1$	$9.5\cdot10^2$	$4.0\cdot10^0$	$1.1\cdot10^2$	nw	$7.0\cdot10^0$	nw	nw	nw
	16	$1.1\cdot10^2$	$7.0\cdot10^0$	$2.5\cdot10^2$	$7.0\cdot10^0$	$9.0\cdot10^1$	nw	nw	nw	nw	nw

Table 5. Number of *Sallmonella* in 100g of forest meadow chernozem on different depth during dry summer (S_1), wet summer (S_2) and winter (W) on experimental (E) plots

Season of the year	Time in weeks	Depth in cm				
		12	25	43	70	90
W	1	$9.5 \cdot 10^3$	$7.5 \cdot 10^3$	nw	nw	nw
	4	$6.5 \cdot 10^2$	$2.5 \cdot 10^2$	nw	nw	nw
	8	$7.0 \cdot 10^1$	$7.0 \cdot 10^1$	$9.0 \cdot 10^0$	nw	nw
	12	$1.1 \cdot 10^2$	$9.0 \cdot 10^0$	nw	nw	nw
	16	$4.0 \cdot 10^0$	nw	nw	nw	nw
S_1	1	$9.5 \cdot 10^3$	$2.5 \cdot 10^3$	nw	nw	nw
	4	$4.5 \cdot 10^2$	$4.5 \cdot 10^2$	nw	nw	nw
	8	$7.5 \cdot 10^1$	$4.0 \cdot 10^0$	nw	nw	nw
	12	$7.0 \cdot 10^0$	nw	nw	nw	nw
	16	nw	nw	nw	nw	nw
S_2	1	$4.5 \cdot 10^4$	$4.5 \cdot 10^2$	$7.0 \cdot 10^1$	nw	nw
	4	$7.5 \cdot 10^2$	$9.0 \cdot 10^2$	$1.1 \cdot 10^2$	nw	nw
	8	$1.1 \cdot 10^2$	$1.1 \cdot 10^2$	$3.0 \cdot 10^1$	nw	nw
	12	$4.0 \cdot 10^1$	$7.0 \cdot 10^0$	$4.0 \cdot 10^0$	nw	nw
	16	$2.5 \cdot 10^1$	nw	$2.0 \cdot 10^1$	nw	nw

The major part of population for the investigated bacteria in D plots were observed in the upper layer of soil (12 cm). 7 days after the application of slurry, the number of *E. coli* varied from $9.5 \cdot 10^4$ MPN/100g of soil in dry summer to $4.5 \cdot 10^5$ MPN/100g of soil in winter (Table 3). The count of streptococci-D varied from $4.5 \cdot 10^4$ MPN/100g of soil in dry summer to $6.5 \cdot 10^5$ MPN/100g of soil in wet summer (Table 4).

At the beginning of the study the most favourable conditions for movement of microorganisms were observed during the wet summer and winter. One week after spreading $9.5 \cdot 10^1$ to $4.0 \cdot 10^2$ colonies of streptococci-D and from $7.5 \cdot 10^1$ to $2.0 \cdot 10^2$ colonies of *E. coli* /100g of soil were noticed at the depth of 43 cm in plot D. At the dry weather bacteria movements were distinctly limited and a small number of microorganisms, especially *E. coli*, was transmitted deeper than 12 cm.

Fecal bacteria were also detected in soil at the depth of 25 cm. The population of streptococci varied from $1.1 \cdot 10^4$ at the beginning of the study, to $7.0 \cdot 10^0$ MPN/100g at the end of 16^{th} week of investigation. *E. coli* were isolated in quantity from $9.5 \cdot 10^4$ to $9.0 \cdot 10^0$ MPN/100g of soil, respectively (Table 3 and 4). The concentration of *Salmonella* isolated from all samples at the depth of 25 cm ranged from $4.0 \cdot 10^0$ to $7.5 \cdot 10^3$ MPN/100g of soil till 8^{th} and even 12^{th} week of the experiment (Table 5). The number of bacteria isolated from soil samples taken from the depth of 43 cm declined rapidly (Tab. 3-5). *Salmonella* was identified there only during the wet summer (from $4.0 \cdot 10^0$ to $1.1 \cdot 10^2$ MPN/100g of soil). Fecal streptococci and bacteria *E. coli* were also found in soil samples taken from 43 cm in that period, while during the other two studied periods they appeared occasionally (Tab. 3 and 4). In lower layers of soil *Salmonella* was not isolated in any sample, and a small number of other fecal bacteria happened to be found accidentally (Tab. 3-5).

It seems that bacteria did not manage to move deeper mainly because of physicochemical soil properties that in spite of favourable moisture conditions prevailing over the certain periods, affected bacteria permeability severely enough. A filtration coefficient of deeper layers is ten times lower in comparison to the top soil zone. It was an important factor inhibiting bacteria movement in soil.

The kinetics fecal microorganisms movement into the soil is illustrated by regression lines, which show a decrease in the count of bacteria with the depth in particular periods of the study (tab. 6). The concentration of the investigated bacteria decreased most intensively in dry weather. The most significant differences appeared during the 4^{th} week of each period of the study. On plot D concentration of *E. coli* decreased with each centimetre of soil: 0.26 ln in dry summer, 0.14 ln in wet summer and 0.11 ln in winter. Similarly, the count of streptococci-D decreased gradually with the depth. It was the quickest in dry summer, slower in winter and in wet summer, with corresponding values of 0.23 ln, 0.17 ln, and 0.13 ln. Differences between distribution of *Salmonella* over the soil profile in dry summer (0.30 ln), wet summer (0.13 ln) and winter (0.14 ln) in 1^{st} week of the study were revealed. After a month the results were 0.20 ln, 0.10 ln and 0.06 ln, respectively.

Table 6. Regression lines for infiltration of the investigated bacteria in the forest meadow chernozem after 1, 4 and 8 weeks during dry summer (S_1), wet summer (S_2) and winter (W) on control (C) and experimental fields (E)

Time in weeks	Season of the year	Salmonella	E. coli		Streptococci - D	
		E	C	E	C	E
1st week	S_1	-0.3x + 13.8	-0.37x + 7.44	-0.18x + 12.6	-0.33x + 7.40	-0.16x + 10.9
	S_2	-0.13x + 10.57	-0.11x + 8.97	-0.15x + 11.83	-0.11x + 9.23	-0.18x + 14.81
	W	-0.14x + 10.76	-0.14x + 9.50	-0.16x + 14.4	-0.13x + 9.40	-0.12x + 12.0
4th week	S_1	-0.2x + 8.7	-0.35x + 5.65	-0.26x +12.3	-0.39x + 6.60	-0.23x + 10.4
	S_2	-0.1x + 8.63	-0.08x + 6.85	-0.14x + 11.6	-0.08x + 6.89	-0.13x + 11.68
	W	-0.06x + 5.24	-	-0.11x + 11.7	-	-0.17x + 10.01
8th week	S_1	-0.14x + 5.7	-	-0.18x + 8.6	-0.28x + 2.40	-0.21x + 9.2
	S_2	-0.14x + 11.58	-0.06x + 4.59	-0.09x + 8.34	-0.05x + 4.74	-0.14x + 11.16
	W	-0.13x + 10.69	-0.13x + 7.20	-0.16x + 11.8	-0.13x + 7.10	-0.15x + 10.7

The results indicate that migration of microorganisms into soil profile was the most difficult in dry weather; while during winter and wet summer and it was easier. The movement of *Salmonella* in forest-meadow chernozem was the slowest at the beginning of the study. In 1st week of the study a decrease in the count of *Salmonella* per each centimetre of depth amounted to 0.30 ln, and the count of *E. coli* and streptococci-D decreased only by 0.18 and 0.16 ln. During wet summer and in winter the distribution of bacteria, examined after a week, was similar. In the 8th week of the study in dry weather (L1) *E. coli* were found to move easier in comparison to the other species of bacteria; a respective decrease by 0.09 ln/cm^3 and 0.14 ln/cm^3 were recorded.

Similar tendencies were noticed in the control plots in the 1st, 4th, and 8th week of the experiment, for which statistical analyses were performed. Correlation coefficients characterizing the rate of the decrease in number of fecal bacteria with depth were distinctly lower in dry summer (L_1) in comparison to wet summer (L_2) or winter (Z). In dry weather the decrease in the number of bacteria analysed with depth for the control plots was faster in comparison to the experimental ones. In wet summer and in winter opposite tendencies were observed.

DISCUSSION

Fecal bacteria penetration into the soil profile was related to both climatic conditions, especially precipitation, and physicochemical properties of the soil. Bacteria movement was very quick at the beginning of the experiment. In dry weather fecal bacteria were usually isolated in soil samples taken from the depth of 25 cm, and occasionally also in deeper layers. More intensive migration of bacteria took place in wet summer. They were found in chernozem as deeply as 43 or even 75 cm. The infiltration rate for bacteria was so fast due to mega and macropores, observed in great number in chernozem, which facilitated their transport into the deeper soil layers. The megapores included passages made by earth-worms and plant roots and reached even 1 m of depth. Other reports proved that bacteria movement through megapores into the plants root zone area may occur after a few hours, and in some cases (heavy rainfalls) even after several minutes [7,27]. According to Koop [13] such microorganisms movement may occur also in soil profiles with not fully saturated water capacity. In our investigations little amount of fecal microorganisms was isolated during drought.

Apart from fast migration of microorganisms through mega and macropores, slow bacteria movement into moistened soil profile must be taken into account [12]. Movement of water, the basic carrier in transport of fecal bacteria through soil, depends to a great degree on the physical properties of soil [10.11,25].

Adsorption of bacteria on soil particles, especially on clays, seems to contribute most significantly [17]. It becomes stronger when infiltration of microorganisms into the soil profile is slow due to low soil moisture content [8]. Therefore, it seems that an increased absorption of bacteria was one of the main factors that inhibited migration of fecal bacteria into the soil profile in dry weather. It is confirmed by the regression coefficients illustrating the distribution of fecal bacteria over particular layers of the researched soil. They show that the decrease in the number of *E.coli*, *Salmonella*, and streptococci-D with depth after 1, 4, and 8 weeks was the smallest during that period.

Heavy precipitation can, however, remobilise microorganisms accumulated on soil particles and increase their diffusion rate into the soil profile. It can be noticed especially as a result of rapid precipitation [19].

Unfavourable conditions for bacteria movement in soil were determined by low filtration coefficients especially in deeper soil layers. It was associated with larger content of small soil particles and lower content of macropores. In heavy soils the number of pores that are too small to transport bacteria may vary from 30 to 70% [1]. Filtration capacity is inversely proportional to the size of soil particles, and to the size of bacteria [4]. From the presented data, it is evident that transmission of microorganisms into soil involves many mechanisms.

Parrakova and Mayer [22, 23] isolated bacteria after organic fertilization of soil even from the depth of 3 m. Edmonds [5] concluded that fecal bacteria migrated to several cm into soil, and Krannich [14] occasionally isolated little counts of bacteria from the soil layers of 40 cm depth. Our investigation into the subject revealed fecal microorganisms have been isolated at various depths, and such occurrences were attributed to the type of soil and weather conditions. During wet summer in chernozem small numbers of bacteria appeared at the depth of 75 cm. It seems that fecal microorganisms movement was influenced by the size of bacteria population on the plots spread with slurry. Bacteria generally did not migrate that deep in the control plots.

The investigation proved that although fecal microorganisms introduced to soil with slurry can move at quick or slow rate into considerable depths, this process is usually related to? small number of bacteria. Majority of the fecal bacteria population was stopped in the upper part of the soil profile, i.e. at depths of 12 to 27 cm. Available literature provides many reports showing retention of fecal bacteria by soil Decrease in the concentration of fecal bacteria by 2 to 3 log after transmission through a 15-25 cm thick soil layer was conducted by Faust [6], Reddy et al. [24] as well as Liu and Kwaśniewska [16] suggests that over 90% of fecal bacteria is held up in the upper soil layer of several centimeter length. Filtration capacity of soil is the resultant of many factors and may fluctuate considerably.

The results obtained during the study clearly show complexity of factors that affect behaviour of fecal bacteria in soil. It constitutes the necessity to undertake steps that will minimize the potential environmental contamination with pathogenic microorganisms originating from animal wastes.

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