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Sanitary-Bacteriological and Parasitological Estimation of Sewage Sludges from Chosen Sewage Treatment Plants on the Mazurian Lake District and their Utilization in Agriculture

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Abstract

This work comprises the results of investigations on the amount of heterotrophic bacteria (mesophilic), bacteria showing the sanitary state (TC,FC,FS), anaerobic spore - forming bacteria *(Clostridium perfringens),* pathogenic / potentially pathogenic bacteria (*Staphylococcus aureus, Pseudomonas aeruginosa, Salmonella* spp.), filamentous fungi and yeasts and parasitic worms in sewage sludge at sewage treatment plants in Olsztyn, Olsztynek and Kętrzyn in the Mazurian Lake District. The number of FC, *Clostridium perfringens* and *Salmonella* as well as parasitic worms in the soils fertilized by 6.7 and 13.4 t/ha dry wt. of sewage sludge from deposit fields at sewage treatment plant in Olsztyn was also determined. The lowest degree of bacteriological contamination was found in sewage sludge from the sediment fields at the sewage treatment plant in Olsztyn, whereas the highest degree was found in sewage sludge from lagoons at the sewage treatment plant in Kętrzyn. The soils fertilized by sewage sludges from sediment fields at the sewage -treatment plant in Olsztyn contained 100 - 100,000 times fewer FC and *Clostridium perfringens* and parasite worms than sewage sludge. There was a lack of pathogenic bacteria from group of *Salmonella*. The numbers of FC and *Clostridium perfringens* and parasitic worms in soils depended on the amount of sewage used in fertilization.This suggests preliminary hygienization of sewage sludges before they are used in agriculture.

Keywords: Sewage sludge, soil, fertilization, microorganisms, pathogens, parasites

Introduction

Sewage sludge applied as organic fertilizers positively influence physical and chemical properties of soils. In light soils they improve air-water properties, make clod structure, increase the amount of organic and organic-mineral coloids, increase sorptive capacity of soils. The introduction with sludges significant amounts of nutritive components causes the increase of the amount of available forms of elements in soils [9].

Agricultural use of sewage sludge is cheapest method of utilization [11, 17]. Only 20% (about 6 mln t) of sewage sludge is applied in agroculture. The factors limiting their utilization in agriculture are: high content of heavy metals [4, 10, 24, 25], toxic organic compounds and mutagenic factors [16], pathogenic bacteria and viruses [2, 8, 12, 28, 29], and protozoa and parasite worms [15, 18, 21]. The possibility of contaminating pastures, meadows, crops [13,19, 20, 22] surface and underground waters [3,13,18] limits the use of non-hygienic sewage sludge to fertilization of crops which are not consumed raw and, recultivation of degraded areas and woodlands [2]. Sewage sludge in the Mazurian Lake District has not been fully investigated as being applied in agriculture. We even know less of its hygienic-sanitary aspects. The aim of this research was to estimate the usability of sewage sludge from three big sewage treatment plants in Olsztyn, Olsztynek and Kętrzyn for agricultural purposes from a sanitary point of view. The evaluation was carried out on the basis of microbiological and parasitological examinations, as well as data concerning the conditions which should exist for sewage led to the ground or waters [26].

Materials and Methods

Sewage Sludge

Sewage sludges from field sediments of waste-treatment plants in Olsztyn and Olsztynek and from lagoons and putrid settling tanks in Kętrzyn were examined. The samples of sewage sludge from the waste-treatment plant in Olsztyn were taken from 1 field, in Olsztynek from 3 fields; the samples of sludge from the sediment lagoon in Kętrzyn were collected from 7 bore - holes during their exploitation; and from the putrid settling tank at the access platform because of its fluid consistence. According to Wojtas and co-workes [30], the sludges differed significantly as far as dry mass, carbon and macro and micro components are concerned. The least amount of trace elements was found in the sewage sludges from Olsztyn and higher amounts in Olsztynek and the highest in Kętrzyn. All of them contained more then the standard (from the point of view of the usability of sewage sludges in agriculture) amounts of cadmium, zinc (in Olsztynek and Kętrzyn), nickel (in Kętrzyn) and chromium (in Olsztyn).

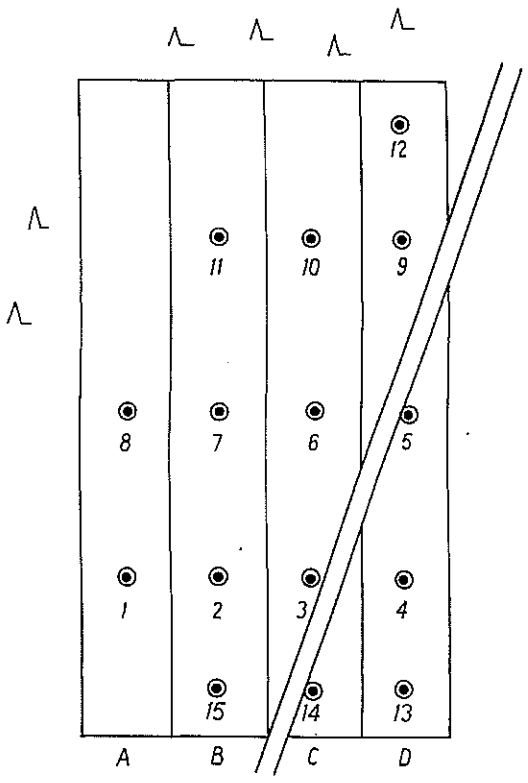


Fig.1. Situational draft of fields being fertilized with sewage sludges
A – non-fertilized field (control);
B – fertilized field with a dose 6.7 t/ha dry wt of sewage sludges and additionally with mineral salts in the amount of 75 kg/ha N and 100 kg/ha K;
C – fertilized field with a dose 13.4 t/ha dry wt of sewage sludges
D – fertilized field with a dose 13.4 t/ha dry wt of sewage sludges and additionally with mineral salts in amount of 37.5 kg/ha N and 50 kg/ha K;
1, 2, 3, ..., 15 – sampling sites

Field Experiments

Field experiments were carried out in one plant (Szynowo Plant) of the State Enterprise of Agricultural Economy in The Mazurian Lake District in 1991. The experimental area was divided into 4 fields (Fig.1) which differed because of the amount of sewage sludges and mineral fertilizers being applied (Table 1). The results of chemical analysis being carried out earlier were the base for the calculation of sewage sludge dose (Wojtas, private information). Potatoes CIS variety planted on 23rd April and collected on 30th September 1991 were cultivated. All the agrotechnical procedures were carried out according to the obligatory rules. The sewage sludges were scattered on the fields and they were covered by ploughing. The mineral fertilizers were put before planting potatoes and mixed with a harrow.

Sampling

Soil samples for microbiological and parasitological examinations were taken from 15 sites (Fig.1) from a ploughed layer - at each site from 16 points in the radius of 10 m into sterile developing dishes. After mixing they were carried into sterile glass wessels and taken to a laboratory.

Microbiological Examination

Sterilized weight 10 g samples (sewage sludges, soils) were ground in a mortar (sewage sludges with sterile sea sand), suspended in physiological solution NaCl (10 cm^3 of physiological solution NaCl/1 g given sample) and homogenized at 1000 rpm for 10 minutes. Universal Laboratory Aid Type MPW - 309 (Poland) was used for homogenization. The sample was diluted in proportion 1:10 -1: 1000,000 and planted on given fluid medium and constant agar medium. Physiological solution NaCl was dilluent. Estimates were made for:

1. the number of aerobic heterotrophic bacteria (TVC);
2. the number of anaerobic spore - forming bacteria (*Clostridium perfringens*);
3. the number of *Staphylococcus aureus*;
4. the number of *Pseudomonas aeruginosa*;
5. the number of filamentous fungi and yeasts;
6. the number of coliforms (TC);
7. the number of fecal coliforms (FC)
8. the number of fecal streptococci (FS) and
9. the number of bacteria of *Salmonella*.

The number of aerobic heterotrophic bacteria were determined on broth agar after 24 h of incubation at 37°C according to the bacteriological technique of examination water and sewages. The number of *Clostridium perfringens* was determined on Wilson-Blair

medium after 18 h of incubation at 37°C (after being pasteurized for 10 minutes at 80°C). The number of *Staphylococcus aureus* was determined on Chapman's medium (*Staphylococcus* 110 Medium, Difco) after 48 h incubation at 37°C. Typical colonies were grafted on Coagulase Plasma (Difco). Bacteria coagulase positive were tested for oxidase, catalase, in preparates stained by Gram' s method and in disseminations on mannitol and glucose medium. The number of *Pseudomonas aeruginosa* was determined on the medium with cetrimide and nalidixic acid after 24-48 h of incubation at 37°C. The number of filamentous fungi and yeasts was determined on Sabourano and Trichophyton's Agar (Difco) after 3 and 2 days of incubation at 25°C and 37°C, respectively. The results of these indices were given per 1 g wet matter of sewage sludges (CFU/ 1 g wet wt.) The total number of coliforms and the number of fecal coliforms was determined by fermentation-tube method on Eijkman's medium with Durham's tubes after 48 h of incubation at 37°C and 24 h at 44.5°C. Positive results of the presence of bacteria from *Escherichia coli* group were checcked on Endo's medium, in fermentation-tube test on Lauryl Tryptose Broth and in preparates dyed by Gram's methods. The number of fecal streptococci was determined on Slanetz and Bartley's media after 72 h of incubation at 37°C. Positive results showing the presence of fecal streptococci were checked on m-Enterococcus Agar. Typical colonies grown on this medium were inoculated on broth medium determining the ability of growth at 44.5°C; pH 9.6, in the presence of 6.5% NaCl and in milk with 0.01% methylene blue. The number of bacteria from *Salmonella* was determined on the broth with sodium selenite and on broth with sodium tetrathionate at 37 and 41.5°C. After the period of incubation they were inoculated on different agar media with xylose, sodium desoxycholate (XLD - Agar) and brillant green (BG-Agar) and incubated at the same time at 37°C and 41.5°C for 24 h [5]. Typical colonies were found on Kligler's medium, urea medium (Urea-Agar) and in the test of glass aglutination with polyvalent specific serum for the flagellar antigen HM carried out according to the technique accepted in Poland [6]. The total numer of coliforms, the number of fecal coliforms, the number of fecal streptococci and the numer of *Salmonella* (MPN/1 g wet wt.) were read from MacCrady's tables [1]. All the microbiological evaluations were carried out in 3 parallel inoculations of the same sample.

Microbiological examinations of the soils fertilized by sewage sludges comprised the determination of fecal coliforms, anaerobic sporeforming bacteria (*Clostridium perfringens*) and bacteria of *Salmonella* type. The evaluations were carried out according to the technique given for sewage sludges.

Table 1. Scheme of fertilization of arable fields with the use of sewage sludges from sediment fields of the communal sewage-treatment plant in Olsztyn

Field	Sewage sludges (t/ha dry wt.)	Mineral fertilization (kg/ha)	
		N	K
A	0	0	0
B	6.7	75	100
C	13.4	0	0
D	13.4	37.5	50

Parasitological Examinations

Parasitological examinations of sewage sludges and soils fertilized by them included counting the parasites and their invasive forms by sedimentation, flotation and larvoscopy, in 5 g samples.

Results

Sewage Sludges

The number of heterotrophic bacteria in sewage sludges was 6.0×10^6 CFU/GWW from sludge fields in Olsztyn, 3.0×10^5–7.6×10^6 CFU/GWW from sludge fields in Olsztynek and 3.0×10^6–28.0×10^6 CFU/1 GWW from lagoons and 57.3×10^6 CFU/1 GWW from a decay settling pond in Kętrzyn. The number of bacteria of sanitary significance (TC, FC, FS) was: 1.1×10^6; 4.6×10^5 and 9.0×10^3 MPN/1 GWT in sewage sludges from deposit fields in Olsztyn, 43.0×10^3–210.0×10^3; 23.0×10^3–1.1×10^6 and 46.0×10^3–46.0×10^4 MPN/1 GWW in sewage sludges from sludge fields in Olsztynek, and 64.0×10^3–2.4×10^6; 210.0×10^3–2.4×10^9; 7.0×10^3–440.0×10^3 MPN/1 GWW from lagoons and 1.1×10^6; 210.0×10^3; 15.0×10^3 MPN/1 GWW from a decay settling pond in Kętrzyn. AS far as pathogenic bacteria are concerned the lowest amount of *Salmonella* spp. was noted (0 - 140 MPN/1 GWW), but the highest was *Staphylococcus aureus* (1.0×10^2–410.0×10^3 CFU/1 GWW). The number of *Pseudomonas aeruginosa* ranged from 30 to 700 CFU/1 GWW. The number of filamentous fungi and yeasts determined on Sabourands's medium was 56.0×10^3 and 152.0×10^3 CFU/1 GWW in sewage sludges from sediment fields in Olsztyn, 3.5×10^3–6.8×10^3 and 5.0×10^3–17.6×10^3 CFU/1 GWW in sewage sludges in Olsztynek, 3.5×10^3–72.0×10^3 and 1.3×10^3–72.5×10^3 CFU/1 GWW in sewage sludges from lagoon and 1.5×10^3 and 35.0×10^3 CFU/1 GWW in sewage sludges from the decay settling tank in Kętrzyn. The number of filamentous fungi and yeasts determined in Trichophyton Agar was 1.25×10^3–11.0×10^3 and 6.2×10^3–10.4×10^3 CFU/1 GWW in sewage sludges from sediment fields in Olsztynek, 1.65×10^3–47.0×10^3 and 7.5×10^3–83.0×10^3 CFU/1 GWW in

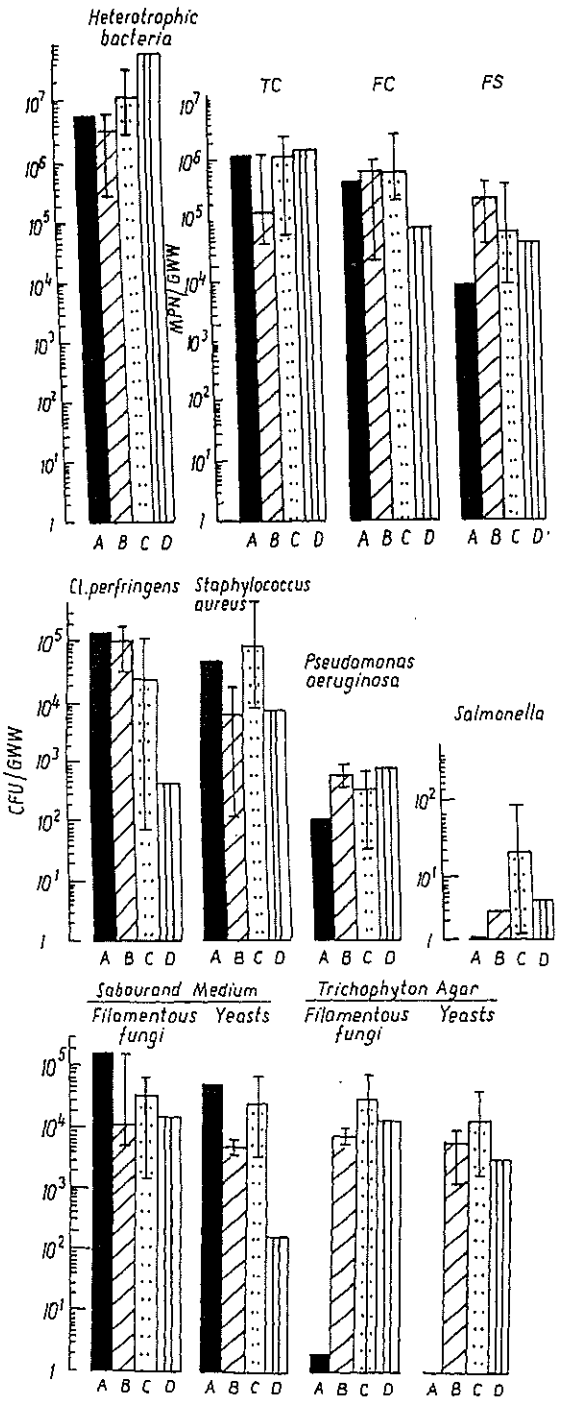


Fig. 2. Number (average and range) of indicatory bacteria of sanitary state and pathogenic ones and filamentous fungi and yeasts in sewage sludges from the fields of the municipal sewage-treatment plants in Olsztyn (A) and Olsztynek (B) and lagoon (C) and the decay settling tank (D) in Kętrzyn. Explanations as in Fig. 1

sewage sludges from lagoons and 3.2×10^3 and 13.4×10^3 CFU/1 GWW in sewage sludges from the decay settling tank in Kętrzyn. There are no data concerning the last group of microorganisms from sewage sludges taken from sediment fields in Olsztyn. Detailed data concerning the ranges and mean values of these microorganisms are given in Fig. 2. Any forms of para-

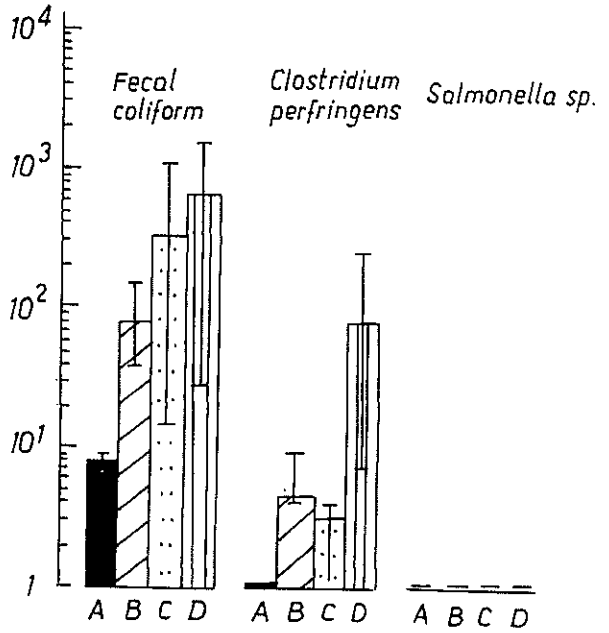


Fig. 3. Number (average and range) of indicatory bacteria of sanitary state and pathogenic ones in the soils of the fields being fertilized with sewage sludges. Explanations as in Fig. 1.

sites were noticed in the samples of sewage sludges from sediment fields in Olsztyn and the decay settling tank in Kętrzyn. Only single eggs of *Fasciola hepatica* and *Ascaris* sp. and larva and imago forms of nematodes were found in the samples of sewage sludges from sediment fields in Olsztynek. Fragments of strobili *Taenia solium* and single eggs of *Toxocara* spp., *Trichocephalus* spp. *Chabertia* spp., *Fasciola hepatica* and the cysts of *Balantidium* spp. (Table 2) were found in the samples taken from lagoons in Kętrzyn.

Soil

The number of FC ranged from 99 to 120 MPN/1 GWW (titre 0.1–0.01) in the soils which not fertilized with sewage sludges (controlled). *Clostridium perfringens* were not found in 1 GWW of soil. There was also a lack of pathogenic *Salmonella* bacteria and the eggs of parasitic worms of *Ascaris lumbricoides* and *Trichocephalus trichuria*. In the soils being fertilized with a dose 6.7 t/ha DWT of sewage sludges from the fields in Olsztyn the number of FC ranged from 45 to 160 MPN/1 GWW (titre 0.2–0.01), *Clostridium perfringens* from 4 to 9 CFU/1 GWW (titre 0.7–0.1); there were pathogenic bacteria of *Salmonella* type. Eggs of *Ascaris lumbricoides* were only found in 1 sample out of 5. The soils being fertilized with 13.4 t/ha DWT of sewage sludges from the fields in Olsztyn contained FC, which ranged from 115 to 1470 MPN/1 GWW (titre 0.06–0.0004); and *Clostridium perfringens*, from 0 to 200 CFU/1 GWW (titre >1-0.04). There were no pathogenic bacteria of *Salmonella* type. *Ascaris lumbricoides* were found only in 2 out of 5 examined soil samples (Fig. 3, Table 3).

Table 2. Parasites and their invasive forms in the sewage sludges from the sediment fields and lagoons and a decay settling tank of some municipal sewage treatment plants on the Mazurian Lake District

Sewage treatment plant	Methods of investigations		
	Sedimentative	Floating	Larvo-scopy
Olsztyn (sediment fields)	ND[a]	ND	ND
Olsztynek	Fasciola hepatica (ova)[d] – 2 ind Ascaris sp. (ova)[g] – 4 ind.	Roundworm free-living (larvae) – 5 (Imagines)[c] – 1	ND
Kętrzyn (lagoons)	Taenia solium (fragments)[b] Toxocara sp. (ova)[d] – 3 ind. Trichocephalus sp. (ova)[d] – 1 ind. Chabertia sp. (ova)[d] – 1 ind. Fasciola hepatica (ova)[e] – 1 ind.	Balantidium sp. (cysts)[f] – 2	ND
Decay settling tank	ND	ND	ND

a – not detected; b – lack of direct endanger for people; c – lack of direct endanger for people and animals; d – possible endanger for the health of people and animals; e – possible endanger for breeding animals; f – possible endanger for pigs; g – endanger for health of people.

Discussion

A high number of indicatory bacteria of sanitary state in sewage sludges from sediment fields in Olsztynek and lagoons in Kętrzyn, *Pseudomonas aeruginosa, Staphylococcus aureus* and pathogenic fungi determined on Trichophyton Agar in sewage sludges from fields and lagoons from all 3 sewage- treatment plants limit the possibility of using them for fertilizing arable soils and grasslands. The results of parasitological examinations suggest the possibility of danger for human health or animal health during fertilization or in case of using raw crops and feeding animals. In each case if we want to take up agricultural utilization of sewage sludges from any sewage-treatment plant it is necessary to subject them to preliminary hygienization in order to decrease danger. This can be done by dilution while composting with tree bark, sawdust, feathers and other agricultural wastes. In this way the obtained organic fertilizer can be used for agricultural utilization. During composting a significant part of pathogenic bacteria, fungi and eggs of parasites are destroyed [8, 17]. Therefore, present investigations are preliminary and their further development towards obtaining valuable organic fertilizers from sludges should continued. There is no question as far as low numbers of indicatory bacteria of sanitary state (FC), *Clostridium perfringens* and total lack of pathogenic bacteria of *Salmonella* type, parasitic worms (*Ascaris lumbricoides, Trichocephalis trichuria*) in the fields not being fertilized with sewage sludges are concerned. Their low contamination by indicatory bacteria of sanitary state (FC) may be a result of contamination by wild animals, rodents, migrating birds and so on. On the contrary - high numbers of indicatory bacteria of sanitary state (FC) and *Clostridum perfringens* in the soils fertilized with a larger dose of sewage sludges (13.4 t/ha DWT) can be explained by their higher number in non hygienized sewage sludges. A significant decrease in their number in the samples of the soils fertilized with a smaller dose of sewage sludges (6.7 t/ha DWT) suggest that the degree of bacteriological and parasitological contamination of the soils depends on the amount of sewage sludge dose calculated for a unit of area of the soil being fertilized. The lack of pathogenic bacteria of *Salmonella* in the samples of soils not being fertilized (controlled) and fertilized with sewage sludges can be a result of their lack in the sewage sludges used for fertilization and/or their low survival in soil environment [16]. On the contrary - the presence of parasites in 40% of the examinated soil samples being fertilized with larger doses of sewage sludges and in 20% of the examined soil samples being fertilized with a smaller dose of sewage sludges can be explained by the high survival of these organisms in soil. It is very well known from literature that after introduction of 240 CFU/1 GDW *Salmonella* rods together with sewage sludges into soil most of them die within the first 6 days; after 12-15 days they cannot be found in 1 GDW of soil. However, the eggs of *Ascaris* spp. in the soils fertilized with the sewage sludges in spring before planting potatoes were still found after 5 months i.e. while picking them up. Pathogenic bacteria, viruses, parasites do not penetrate potatoes, carrot and others as long as their natural cover is not damaged [16]. The possibility of bacteriological and parasitological contamination of agricultural crops suggests the utilization

Table 3. The occurence of indicatory bacteria of sanitary state and pathogenic of alimentary tract and the eggs of parasite worms in the soils being fertilized with sewage sludges.

Field	FC (titre)	Clostridium perfringes (titre)	Salmo-nella	Ascaris lumbricoides, Trichocephalus trichuria
A	0.1–0.01	ND_a	ND	ND
B	0.2–0.01	0.07–0.1	ND	Ascaris in 1 out 5 examined soil samples
C	0.06–0.0009	1–1	ND	ND
D	0.04–0.0004	0.2–0.04	ND	Ascaris in 2 out of 5 examined soil samples

a – not detected

of sewage sludges from the sewage-treatment plants in Olsztyn, Olsztynek and Kętrzyn only for recultivation of degradated soil, woodlands and so on. In the case of fertilization of arable soil the sewage sludges from these plants should be composted, limed or hygienized in some other ways before use.

Conclusions

1. Large numbers of indicatory bacteria of sanitary state (TC, FC, FS) and *Clostridium perfringens* in the sewage sludges from the sewage- treatment plants in Olsztyn, Olsztynek and Kętrzyn exceeding several times the maximum accceptable values for sewage for agricultural use limit the possibility of their usage in a raw state for fertilizing degradated soils, coal-mine damages, woodlands and so on.

2. The presence of pathogenic bacteria or potentially pathogenic *Pseudomonas aeruginosa* and *Staphylococcus aureus* in the sewage sludges from the plants in Olsztynek and Kętrzyn as well as pathogenic bacteria of *Salmonella* type and the eggs of parasitic worms suggests the necessity of their preliminary hygienization (composting, liming) before being used in agriculture.

3. The degree of soils contaminated by the indicatory bacteria of sanitary state (FC), *Clostridium perfringens* and the eggs of parasitic worms being fertilized with non-hygienized sewage sludges depends on the amount of dose of sewage sludges per a unit of the surface.

References

1. AMERICAN PUBLIC HEALTH ASSOCIATION (APHA), Standard Methods for the Examination of Water and Wastewater, 15 Ed. APHA, Washington, D.C. , **1980.**
2. ARGENT V.A., BELL J.C., EDGAR D. Animal disease hazards of sewage sludge disposal to land. Effects of sludge treament on Salmonellae. Water Pollution Control, **88**,537-540,**1981.**
3. BARBIER B., PERRINE D., DUCHAMEL CH., DOUBLET R., GEORGES P. Parasitic hazards with sewage sludge applied to land. Appl. Environ. Microbiol. **56**, 1420-1422, **1990.**
4. BECKETT P.H.T, DAVIS R.D., BRINDLEY P., CHEN C. The disposal of sewage sludge onto farmland: the scope od the problem of toxic elements. Water Pollution Control, **78**, 419-440, **1979.**
5. BORDNER R., WINTER J., SCARPINO P. Microbiological Methods for the Monitoring the Environment. Weter and Wastes. EPA (Enivironmental Protection Agenc) /-600/8-78-0770. Cincinnati. Ohio, 1-338, **1978.**
6. BURBIANNKA M., PLISZKA A., BURZYŃSKA H.Mikrobiologia żywności. 5 Ed., PZWL, Warszawa, 1-540, **1983.**
7. BURGE W.D., CRAMER W.N., EPSTEIN E. Destruction of pathogens in sewarg sludge by composting. Transactions of the ASAE, **21**, 510-514, **1978.**
8. CLARK C.S. Health effects associated with wastewater treatment and disposal. Journal WPCFed. **56**, 625-627, **1984.**
9. DECHNIK J., WIATER J. Oddziaływannie obornika i osadu ściekowego na niektóre wskaźniki żyzności gleb (In); Nawozy Organiczne. Zeszyt 2. Materiały z Konferencji naukowej "Nawozy Organiczne" w Szczecinie, w dniach 8.09 -9.09 1992. Komitet Gleboznawstwa i Chemii Rolnej, Akademia Rolnicza w Szczecinie, 117-122, **1992.**
10. DEMIRJIAN Y.A., YOSHT A.M., VAN WEST T.R. Fate of organic compounds in lannd application of contaminated municipal sludge. Journal WPCFed. **59**, 32-78, **1987.**
11. DORN C.R. , REDDY C.S. , LAMPHERE D.N., LANESE R . Municipal sewage sludge application on Ohio farms: Health effects. Eviron mental Research, **38**, 332-359, **1985.**
12. FARRAH S.R., BITTON G. Enteric bacteria in aerobically digested sludge. Appl. Environ.Microbiol. **47**, 831-834, **1984.**
13. HUDSON J.A., FENNELL H. Disposal of sewage sludge to land: Chemical and microbiological aspects of sludge to land policy. Water Pollution Control, **79**, 370-387, **1980.**
14. JAKOB J. , ROOS H.J. SIEKMANN K. Aerobic thermophilic methods for disinfecting and stabilizing sewage sludge. Sewage Sludge Treatment and Use. Eds.: Dirkzwager A.H., L'HEERMITE P., Elsevier Applied Science, London, 378-399, **1989.**
15. KANESHIRO E.S., STERN G. Survival of parasite eggs in stored sludge. Project Summary. EPA (Environmental Agency)/600/S2-85/142 Mar. 1-5, **1986.**
16. KOWAL N.E. Health effects of land application of municipal sludge. EPA (Environmental Protection Agency) 600/1-85/015. Sept. 1985. Health Effects Research Laboratory. Office of Research and Development. U.S.EPA Researrch Triangle Park, N.C. **27711**, 1-78, **1985.**
17. LEKAN S., KACPEREK K. Możliwosci stosowania w rolnictwie osadów ściekowych z oczyszczalni miejskiej w Puławach. Problemy Gospodarki Wodno-Ściekowej w makroregionie południowo-wschodnim. Seminarium Naukowo-Techniczne w Tarnowie, 7 I 8 listopada 1983. Materiały Seminaryjnr, t.1 Nr.410, 89-97, Kielce-Tarnów, **1983.**
18. LEWIS-JONES R., WINKLER M. Sludge parasites and other pathogens. Ellis Howard. New York, London, Toronto, Sydney, Tokyo, Singapore, 1-201, **1991.**
19. MÜLLER H.E. Hygienische Aspekte der landwirtschaftichen Verwertung von Abwasser und Klarschlamm. Naturwissenschaften, **72**, 238-248, **1985.**
20. MÜLLER H.E. Abschatzung des Infektionsrsikos durch Abwasser und Klarschlamm. Formum Stadte Hygiene, **32**, 146-152, **1981.**
21. O'DONNELL C.J., MEYER K.B., JONES J.V., BENNTON T., KANESHIRO E.S., NICHOLS J.S., SCHAEFER III F.W. Survival of parasite eggs upon storage in sludge. Appl. Environ. Microbiol. **48**, 618-623, **1984.**
22. PEDERSON D.C. Density levels of pathogenic organisms in municipal wastewater sludge.A literature review. Technical Report Data. Municipal Environmental Research Laboratory. Office of Research and Development.US EPA (Environmental Protection Agrncy). Cincinnati, Ohio, 1-298, Contract No. 68-03-2805, USA, **1980.**
23. PIKE E.B.The control of salmonellosis in the use of sewage sludges on agrocultural land. Ind. European Symposium Characterisation Treatment and Use of Sewage Sludge, Vienna, 21-23 October 1980. De Reidel Publishing Co., Dordrecht, 315-329, **1980.**
24. REDDY C.S., DORN C.R. Municipal sewage sludge application on Ohio farms: Estimation of cadmium intake. Environmental Research, **38**, 377-388, 1985.
25. REDDY C.S., DORN C.R., LAMPHERE D.N., POWERS J.D.Municipal sewage sludge application on Ohio farms: Tissue

metal residues and Infections. Environmental Research, **38**, 360-376, **1985.**

26. ROZPORZĄDZENIE MINISTRA OCHRONY ŚRODOWISKA, ZASOBÓW NATURALNYCH I LEŚNICTWA z dnia 05.02.1991 w sprawie klasyfikacji wód oraz warunków jakim powinny odpowiadać ścieki wprowadzane do wód lub do ziemi. Dziennik Ustaw Nr. 116, poz 503, Warszawa 16.12.91, **1991.**
27. SKANAVIS C., YANKO W.A. Evaluation of composted sewage sludge based soil amendments for potential risks of Salmonellosis. Journal of Environmental Health, **56**, 19-23, **1994.**
28. STRAUCH D.Ursachen und mogliche Auswirkungen des Vorkommens pathogener Agention in komunalem Klarschlamm. Schweiz. Arch. Tierheilk. **125**, 621-659, **1983.**
29. STRAUCH D. Hygienische Probleme des Klarschlamms. Forschritte der Medizin, **101**, 665-66, **1983.**
30. WOJTAS A., NIEWOLAK S., MAZUR T., SZELĄGIEWICZ M. Charakterystyka argochemiczna i mikrobiologiczna osadów ścieków komunalnych. Urząd Wojewódzki w Łodzi, ENVIRONMENT 94. Międzynarodowa Konferencja Ochrony Środowiska. Streszczenie referatów. Łódź 3-4 listopad 1994. 30-31, **1994.**