Environment Protection Engineering

Vol. 7 1981 No. 2-4

JÓZEF CEBULA*

EXPERIENCE WITH LONG-TERM DISPOSAL OF SEWAGE

The temporary opinions on hygienic and sanitary aspects of agricultural utilization of sewage have been presented. The chief problem of the author's concern was to analyse the influence of sewage irrigations on the quality of ground waters within the area affected by irrigation systems and on the sanitary conditions for health of animals bred on sewage-irrigated grassland. Information given in the paper was based on papers (published in Poland and some other socialistic countries) which present the results of extensive sanitary, veterinary and parasitological studies.

1. INTRODUCTION

The most direct measure of the usefulness of sewage is provided by the content of fertilizers. Sewage discharged from cities or whole regions contains thousands tons of nitrogen, phosphorus and potassium, measured as pure components. Utilization of this amount of sewage would significantly decresase the consumption of mineral fertilizers in agriculture. For example, in Poland the full realization of the program concerning agricultural utilization of 1.5 billion cubic meters of sewage would save over 127 thousands tons of NPK (pure components). This amount is sufficient to fertilize about 300 000 hectares of cultivated land, as far as the requirements for NPK and probably calcium (KUTERA [5]) are concerned.

Fertilizing value of sewage is not limited to the mentioned above main nutrient macrocomponents as it also includes other important organic compounds. Their importance will certainly be more evident in the future because of the inevitable deficiency of manure, particularly essential for light soils.

Municipal and even industrial sewage, properly applied by irrigation, is a most universal fertilizer. Its value is determined by organic substance, nutrient macrocompounds and, moreover by the full array of microelements and rich variety of microorganisms. The complex effects of sewage upon the medium in which the plants grow are manifested in increasing the yields by about 30% referred to irrigation with water and to mineral fertilizers in amounts equivalent to the nutrient value of sewage. Increased crop yields, often those

* Institute of Meteorology and Water Management, 50–375 Wrocław, ul. Norwida 34, Poland.

of grasses and fodder plants, are essential in raising cattle and pigs. According to prevailing opinion, confirmed by experimental results obtained so far, agricultural sewage utilization will enable a significant intensification of large-scale animal production.

Although communal and farm sewage has been used in agriculture for several hundred years, there is still no equivocal opinion concerning the dangers resulting from irrigation and use of irrigated plants. Diverse opinions can be found in the extensive literature concerning this problem and are reflected also by restrictive rules imposed by sanitary authorities in several countries. The rules are to prevent potential dangers, particularly due to pathogenic microorganisms present in sewage. Some sewage types contain large numbers of microorganisms, including pathogenic forms, which may be a source of infections for animals and, indirectly, for people.

The soil is not only the medium where fertilizers present in sewage can be effectively utilized. It is, moreover, an unique treatment plant of high ability to neutralize sewage. This provides a reliable and economically acceptable method of environment protection against pollution. However, incorrect sewage disposal and unsuitable technologies of its agricultural utilization may create some negative aspects. These aspects are discussed in this paper, particularly those concerning the ground waters and public health.

The paper has been based on the ground of the literature study (report), that was prepared in 1977-79 with the USEPA cooperation. The literature material contained in this report describes the present state of knowledge and opinions concerning sewage treatment and land disposal. Literature review was based mainly on Polish original sources, and in part only on publications from Bulgaria, Czechoslovakia, GDR, Hungary, Roumania, and Soviet Union.

During realization of this project there were collected about 1 000 bibliographic positions concerned with many problems of agricultural sewage utilization.

2. THE EFFECT OF IRRIGATION ON GROUND WATER QUALITY

The increasing popularity of agricultural sewage utilization disturbs more and more often the natural balance of mineral component of supply and removal and may be the cause of an excessive salinity of ground waters.

Under Polish climatic conditions there is observed no salinity of soils so that there exists no danger of excessive salinity of ground waters.

More detailed information on the effects of irrigation with sewage upon the quality of ground waters were obtained during long-term studies (1972-1975) of deeper ground water levels in Wrocław sewage farm [3]. The studies were carried out using a network of piezometers and drilled wells in static as well as dynamic arrangements. The obtained results have confirmed the assumption that the irrigation with municipal sewage does not affect significantly the ground water quality. Table presents some examples of observed concentration ranges of essential components of examined ground waters. Considering the character of the studied object, the information obtained from these experiments can

Table

Ranges of average concnetrations of ground and drainage water pollutants and ranges of pollution indices on Wrocław sewage farm
Zakresy średnich stężeń zanieczyszczeń wód gruntowych i drenażowych oraz zakresy wskaźników zanieczyszczenia na wrocławskich polach irygacyjnych

Point of water sampling	Drying residue mg/dm³	Calcination residue mg/dm³	Alkalinity mv/dm³	Oxygen demand mg O_2/dm³	Total nitrogen mg N/dm³	Nitrates mg NO_3/dm³	Chlorides mg Cl/dm³	Sulphates mg SO_4/dm³	Potassium mg K_2O/dm³	Phosphorus mg P_2O_5/dm³	Iron mg Fe/dm³	Manganese mg Mn/dm³
Piezometers on irrigated area	838-1228	527-818	4.1-7.9	3.7-39.4	4.8-24.3	0.61-18.8	121-156	108-270	13-28	0.02-0.28	0.25-13.30	0.12-1.31
Piezometers on non-irrigated area	391-6383	361-5534	1.3-13.1	2.5-29.1	1.6-19.8	0.09-18.66	26-154	105-219	3-191	0.03-0.43	0.10-15.23	0.08-2.56
Deep wells on irrigated area	601-706	370-511	3.9-6.1	3.0-5.0	3.8-18.1	0.14-0.99	83-144	144-256	4-38	0.09-0.90	0.43-13.60	0.09-0.96
Farm wells beyond irrigated area	601-1407	370-915	2.0-6.1	3.0-25.5	2.3-18.1	0.14-72.0	51-144	130-339	4-210	0.06-0.64	0.004-7.8	0-0.5
Discharge points of drainage	669-785	320-489	5.9-7.2	4.1-14.7	4.5-16.1	0.23-0.44	79-118	11-165	3-5	0.05-0.11	0.09-2.02	0.1-0.47

be regarded as fully representative of this type of sewage treatment under similar soil and climate conditions. Biological studies of ground waters from Wrocław sewage farm [2] demonstrated the presence of psychrophylic bacteria (incubated at 20°C). These bacteria are not directly dangerous to humans, their presence, however, indicates the fertility of medium, and thus the possibility of development of other bacterial species. The presence of psychrophylic bacteria on an area loaded with large amounts of organic pollutants is quite understandable.

The number of mesophylic bacteria (incubated at 37°C) found in ground waters ranged from 20 to 50 colonies per ml. The standard for municipal drinking water is 5 colonies per ml.

Similar results were obtained for Coli number. The measured values oscilated between 10 and above 50. According to Polish standards, water of this quality is suitable for individual use and, in some cases even, as municipal water for cities below 50 000 inhabitants.

General conclusion drawn from these studies [2, 3] are as follows:

1. Ground waters from the areas irrigated with municipal sewage can be a new source of water for farming and industry.

2. Due to constant renewal of resources by irrigation with sewage ground waters from irrigated areas are a more reliable water source than surface water reserves.

3. Under favourable geological conditions (large thickness of aquiferous layer) the ground waters on irrigated areas represent an underground water reservoir providing a uniform water supply in periods of varying demands. Such favourable conditions prevail at Wrocław sewage farm which has been operated for about 90 years.

4. Chemical and bacteriological analyses of ground waters from the areas irrigated with municipal sewage show quite good sanitary indices, often better than those found in farm wells situated beyond the irrigated zone.

5. The quality of water from deep wells was still better. During experimental pumping it has been found that the majority of sanitary indices were within the limits set by standards for drinking water.

3. THE EFFECT OF IRRIGATION ON HYGIENE AND PUBLIC HEALTH

3.1. GENERAL SANITARY ASSESSMENT OF AGRICULTURAL SEWAGE UTILIZATION

All infectious organisms, eventually present in municipal or communal sewage, have one feature in common: they lived previously in the intestines or urinary tracts of humans or animals. These microorganisms may be present in their invasive forms as well as in forms of eggs and spores which would be developed later into infectious froms either directly or through some carriers. Dangers to public health resulting from irrigation with sewage depend upon the following factors:

1. the presence of infectious organisms in sewage,

2. type of infectious organisms carried by sewage,
3. virulence of infectious organisms,
4. resistance of infectious organisms to sewage treatment processes.

One of the early detected diseases which are carried by sewage is schistosomiasis. It is due to parasites developing in snails as direct hosts. Another disease, spread by incorrect use of sewage for irrigation, is helminthiasis. The eggs of helminths become infectious after several days of development under suitable temperature, moisture and aeration conditions. These eggs die rapidly at freezing temperatures, excessive dryness or direct insolation, but under favourable conditions, usually in autumn and winter, they are able to survive for several months on soil surface. Because of their comparatively high density they settle in settling tanks and for this reason helminthiasis is spread more readily by raw sewage than by mechanically treated sewage. Communal sewage containing pig manure may be infected with the worm *Ascaris lumbricoides*. Infectious forms of this worm may infect people eating raw vegetables or drinking not boiled water. The eggs of this worm are very resistant to dry environment. They settle down in settling tanks.

Taenia saginata (tape worm) may infect humans eating raw or not adequately cooked beef. This parasite presents a potential danger to cattle grazing on pastures irrigated with sewage and fertilized with sludges but it is less dangerous to people observing hygienical rules and eating veterinary-tested meat prepared properly at slaughterhouses and at home.

Entamoeba histolytica is a protozoan causing amoebic dysentery. It is transferred to humans without an intermediate carrier. It is seldom encountered in sewage. It can be a cause of infection if crude sewage is used for irrigation of vegetables which are eaten raw.

Most dangerous bacteria present in sewage include those causing leptospirosis (Weil's disease), tuberculosis, typhoid fever, infectious dysentery and cholera. Bacteria from sewage may be a direct source of infection or indirect one being spread by carriers, such as rodents including mice and rats. Systematic extermination of rats, as it is commonly performed now, resulted in a significant limitation of this hazard.

Mycobacterium tuberculosis is commonly found in several types of sewage, but any serious danger of infection is possible only in the case of sewage from hospitals, reconvalescence homes, health resorts, and sometimes from slughterhouses and zoological gardens.

In the literature the possibility of sewage acting as a carrier of typhoid fever is most often discussed. The survival of typhoid bacteria in sewage is comparatively brief, 3-4 days, but spores may survive for several weeks under favourable conditions.

The mechanisms of transferring virus diseases are not yet properly recognized. There is no evidence so far that sewage is responsible for infectious jaundice or meningitis. Nevertheless, these diseases are very dangerous and their viruses were detected in human fecies. Consequently, sewage is also suspected to contain viruses.

The studies on the effect of various stages of sewage treatment on the virulence or removal of helminth eggs were conducted in USSR. WASILKOWA [4] has found that mechanical

treatment is most effective in removal of helminth eggs. The remaining eggs, being larger than soil pores, are retained on soil surface and their number penetrating below few centimeters is very low. No eggs were found in drainage waters, even in effluents from highly loaded ground filters.

Biological treatment of sewage fails to destroy completely the eggs of helminths, even if followed by chlorination.

Thus, agricultural utilization of mechanically treated sewage offers better protection against helminthiasis than artificial biological treatment.

The eggs of intestinal parasites survive for several months under favourable conditions, particularly in autumn and winter. This fact should be taken into condsideration in the technology of utilization of land irrigated with municipal sewage.

Parasitological studies by PATYK [8] on Wrocław sewage farm have demonstrated that infection of animals with parasites is due mainly to effluents from slaughterhouse. Parasitological assessment of Wrocław sewage farm was positive: infestation of animals with worms was not higher than in the case of animals from other areas.

Poor survival of bacteria in soil was the factor limiting the occurrence of sewage bacteria virtually to the irrigated area. Thus, from the epidemiological point of view, land treatment of sewage is better than artificial treatment. A more exact sanitary evaluation of sewage treatment is provided by decrease of *E. coli* titer as coli bacteria serve as an index of human and animal fecies present in sewage.

BOĆKO [2] in his broad study points out the particularly effective treatment of sewage on land manifested in the decreased total count of bacteria or *E. coli* bacteria. Sewage filtered through soil is practically free from *E. coli.*

Much information on the virulence of sewage bacteria on plants and in soil is provided by studies conducted by MARCILONEK [7]. It is known that immediately after irrigation plants and soil are highly contaminated with sewage bacteria, including pathogenic ones. However, elimination of bacteria from plants and soil is quite rapid due to the combined action of climatic factors, antagonistic bacteria native to soil, epiphytical plant microflora and oxydative destruction of organic matter. Processes effecting the removal of bacteria are particularly intensive in summer. Some authors indicate that bacteria removal requires 3 to 5 days during the vegetation period while others estimate this period to last for 10-14 days. Elimination of bacteria is much slower in winter, but during winter season there is little chance that people or animal come in contact with soil and plants.

So far there is no evidence in favour of the assumption that pathogenic microorganisms are able to invade the inner parts of plants with cellular juices. Thus, the principal problem is to observe hygienical rules while utilizing crops are suspected of being contaminated with sewage bacteria.

Long term statistical studies concerning sewage farms of Wrocław, Berlin and other cities indicate that there is no danger of disease expansion resulting from land treatment of sewage. In population using irrigated crops or having other contact with irrigated land incidence of disease was not higher, and in many cases even lower than among population from other localities.

3.2. CONDITIONS OF SANITARY PROTECTION IN AGRICULTURAL UTILIZATION OF SEWAGE

Sanitary dangers can be totally eliminated if the irrigation is organized properly and principal hygienic rules are observed. Principal sanitary conditions of agricultural sewage utilization are as follows:

Sewage should contain the least possible number of helminth eggs. The best is mechanically treated sewage in effective settling tanks with 1.5-2 hr flow times [5, 7].

Sewage must not be used for irrigation of vegetables and berries which are eaten raw [5].

Sewage used to fertilize fish ponds should be well settled and diluted with pure water [5].

It is also necessary to keep proper distance between irrigated land and buildings or roads. In addition, there are regions where no irrigated fields should be installed [7]. These region include:

1st and 2nd sanitary protection zones of water sources and mineral wells.

Sites of upwelling of underground aquifers and geological fissures.

Sites where artesian well might be contaminated.

National parks, reserves and recreation areas.

Sanitary protection zones of proper sizes should protect the neighbourhood of irrigated fields against bad smells and eliminate the possible contact with sprinkled sewage or sewage fog carried away by winds during sprinkling.

There is no uniform opinion as to the size of protection zones. German rules state generally that sprinkling with sewage must not affect areas neighbouring buildings and public roads. Soviet sanitary rules recommended a distance from inhabited buildings not shorter than 250-300 m. Czechoslovakian regulations recommend protection zones of different sizes, depending on the used system of irrigation. A zone of 200 m is recommended for overhead irrigation and 100 m for gravitational irrigation. The distance of irrigated fields from roads should be not less than 50 m. Polish instruction specify the following sanitary protection zones:

100 m for gravitational and 200 m for overhead irrigation of fields where sewage load does not exceed 1500 mm annually.

Fields where sewage load is higher than 1500 mm are included into III class for which protection zones of 300 m are required.

The specified protection zones can be increased or diminished as need arises with the approval of sanitary authority. When smaller protection zones are applied the possibility for sprinkling roads and places visited by people [5] must be eliminated.

The hygiene of irrigated fields should be improved by means of tree belts 5 to 10 meters wide, situated opposite to inhabited or otherwise used buildings. Similar protective tree belts should be planted also along more important roads and canals bringing sewage to the fields. Such tree belts improve hygienic conditions and the aesthetics of landscape.

Protective belts should consist of trees and bushes. The separate rows should consist of high trees, such as poplar, willow, linden and white acacia which are cheap and grow fast.

3.3. PROHIBITION OF IRRIGATION AND WAITING PERIODS IN SEWAGE UTILIZATION

Sanitary rules in Poland and in other neighbouring countries distinctly prohibit irrigation with sewage if there are particular hygienical and sanitary objections. Particular prohibition includes sewage from hospitals where infectious diseases are treated, tuberculosis hospitals, preventories, prosectoriums, sloughterhouses, plants processing waste animal products from sloughterhouses, tanneries, wool washing plants, and from production of vaccines and sera. Radioactive sewage is also prohibited.

Prohibited sewage should be carried away by separate sewage systems and treated mechanically, biologically and chemically and sterilized in treatment plants on site of sewage origin. After treatment, sewage of this type can be discharged into general sewage system and used for irrigation. However, its agricultural utilization should be done in accord with rules for using sewage which is questionable from the sanitary point of view. Irrigation with such sewage must not be done during vegetation period. Rules concerning radioactive sewage are included in a special instruction.

Sewage qualified as objectionable from sanitary view-point includes communal sewage and wastewaters from dairies, bone glue production and meat industry. Crude sewage from this group can be used for irrigation of poplar plantations and cultivated land during non-vegetation season. Only poplars can be irrigated during vegetation, provided that the areas taken by the plantations are not used for grazing, growing grasses or other crop plants. Crude sewage may be used without limitation if the subsoil system or irrigation is employed. Overhead irrigation with objectionable sewage is strictly prohibited unless it is mechanically treated.

Irrigation with objectionable sewage during vegetation is permitted only if sewage is treated mechanically. It is required that the retention time in settling tanks is at least 1.5 hr and horizontal velocity of flow should be not higher than 1 mm/s.

Preliminary treated sewage can be used for irrigation of all plants during non-vegetation season. During the vegetation season such sewage can be used only for irrigation of the following crops:

poplar plantations — until two months before cutting,

sugar beets, fodder oleiferous plants, fiber plants, fodder potatoes, industrial potatoes — until four weeks before harvest,

edible potatoes and grain crops — before flowering,

annual and perennial fodder plants, meadows and pastures — until 14 days before harvesting or grazing,

meadows harvested for hay to be dried in thermal drying units and processed to hay meal — until 5 days before harvest,

vegetables eaten after cooking — until 3 weeks before harvest with furrow or subsoil irrigation and until 6 weeks before harvest with other systems,

fruit trees and bushes and ornamental plants — until 6 weeks before harvest.

All system of irrigation may be used except for sprinkling.

Sewage subjected to a proper secondary treatment can be used to irrigate all crops by all systems of irrigation and around the year, with the exception of vegetables which are eaten raw. Irrigation of plants grown under glass during vegetation is not permitted either. Water used for irrigation of vegetables eaten raw and grown under glass must belong to at least III class of purity [5].

BIBLIOGRAPHY

[1] Boćko J., Paluch J., *Oddziaływanie nawodnień ściekami miejskimi na stan sanitarny wód gruntowych*, Zeszyty Naukowe Wyższej Szkoły Rolniczej, Wrocław, Melioracje XV, 1970, pp. 49–59.
[2] Boćko J., *Gleba jako środowisko oczyszczania ścieków* WSR, Wrocław 1964.
[3] Boćko J., *Zmiany ilościowe i jakościowe wód gruntowych na terenach nawadnianych ściekami* (not published), AR, Wrocław 1975.
[4] Cebula J., *Critical Review and Assessment of Polish Literature on Sewage Irrigation* (not published), Inst. of Met. and Water Management, Wrocław 1978.
[5] Kutera J., *Instrukcja w sprawie rolniczego wykorzystania ścieków*, IMUZ, 1963, p. 1.
[6] Marcilonek S., *Przepisy sanitarne przy rolniczym wykorzystaniu ścieków*, Wiadomości Instytutu Melioracji i Użytków Zielonych, Vol. 3 (1962), No. 1, pp. 57–65.
[7] Marcilonek S., Meks-Burmecha H., *Oczyszczanie ścieków miejskich w glebie z punktu widzenia sanitarnego*, Zeszyty Problemowe Postępów Nauk Rolniczych, 1964, No. 47.
[8] Patyk S., *Z zagadnień parazytologicznych nad wrocławskimi wodami ściekowymi*, Zeszyty Problemowe Postępów Nauk Rolniczych, 1964, No. 47.
[9] Wachnik Z., *Badania nad zdrowotnością zwierząt wypasanych na pastwiskach deszczowanych wodami ściekowymi z uwzględnieniem różnych okresów karencji*, Zeszyty Naukowe WSR, Wrocław, Weterynaria XVI, 1963, No. 54.

EFEKTY DŁUGOTRWAŁEGO WYKORZYSTYWANIA ŚCIEKÓW DLA CELÓW ROLNICZYCH

Przedstawiono aktualne poglądy na higieniczno-sanitarne aspekty rolniczego wykorzystania ścieków. Zajęto się analizą wpływu nawodnień ściekami na jakość wód gruntowych znajdujących się w obszarze oddziaływania systemów nawadniających oraz zdrowotnością zwierząt hodowanych na użytkach zielonych nawadnianych ściekami. Informacje zawarte w artykule oparto na materiałach (publikowanych w Polsce i niektórych krajach RWPG), które prezentują wyniki wielostronnych badań sanitarnych, weterynaryjnych i parazytologicznych.

DIE WIRKUNG LANGJÄHRIGER LANDWIRTSCHAFTLICHEN ABWASSERVERWERTUNG

Dargestellt werden gegenwärtige Anschauungen auf die hygienischen Probleme der landwirtschaftlichen Abwasserverwertung. Analysiert wurde der Einfluß des Abwassers auf die Grundwasserqualität im bewässerten Boden und in nächster Umgebung sowie auf den Gesundheitszustand des Viehbestandes, das auf dem bewässerten Grassland weidet. Zusammengefasst werden Untersuchungen, die sowohl in Polen, wie in einigen Mitgliedsstaaten des Rates für Gegenseitige Wirtschaftshilfe durchgeführt wurden. Sie umfassten weitgehende sanitäre, tierärztliche und parasitologische Untersuchungen.

ЭФФЕКТЫ ПРОДОЛЖИТЕЛЬНОГО ИСПОЛЬЗОВАНИЯ СТОЧНЫХ ВОД ДЛЯ СЕЛЬСКОХОЗЯЙСТВЕННЫХ ЦЕЛЕЙ

Обсуждены актуальные взгляды на санитарно-гигиенические аспекты сельскохозяйственного использования сточных вод. Описан анализ влияния орошения сточными водами на качество грунтовых вод, находящихся в области воздействия ирригационных систем, а также состояния здоровья животных, выращиваемых на лугопастбищных угодьях, орошаемых сточными водами. Информация, содержащаяся в статье, основана на материалах, публикуемых в Польше и в некоторых странах-членах СЭВ, которые представляют результаты многосторонних санитарных, ветеринарных и паразитологических исследований.