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IRRIGATED FIELDS FOR URBAN SEWAGE (POLA NAWADNIANE DLA SCIEKOW --ETC(U)
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IRRIGATED FIELDS FOR URBAN SEWAGE

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COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
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The problem of gravity sewage flow to a sewage treatment plant is of great importance to the community economy, and this method of removing waste water from the city should be the primary one. One of the cities of Lower Silesia can serve as an example of the reasonable solution of difficulties in conducting urban sewage to a sewage treatment plant. This report discusses the attempts made to use wastewater for irrigating fields.

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IRRIGATED FIELDS FOR URBAN SEWAGE

By Dr. Jan Wierzbicki

The problem of gravity sewage flow to a sewage treatment plant is of great importance to the community economy, and this method of removing waste water from the city should be the primary one.

One of the cities of Lower Silesia can serve as an example of the reasonable solution of difficulties in conducting urban sewage to a sewage treatment plant.

This city, as can be seen on the contour map (Figure 1), is located in slightly rolling terrain and no river, nor even a valley, crosses the developed area. To an inhabitant of this city who is well acquainted with the configuration of the surface occupied by structures, the possibility of gravitational removal of sewage water seems to be unrealistic. Only thorough study of the contour map, which also embraces a good deal of the vicinity of the city, and in particular the land along a stream, can lead to some definite conclusions. Although the valley of this stream is situated on coordinate 205 near the village of Gasiorowice, i.e., 20 m lower than the lowest point in the city, the rather long distance of 6.5 km and the deep excavation through the hills running north and northwest of the city are an obstacle to the direct removal of sewage to the Chrzastawa valley.

Both of the above-mentioned difficulties were overcome by the design worked out in 1906. A sewage treatment plant would be built about half that far away and the hill would be bypassed by laying the line further to the east. The flow of the effluent from the purification plant drains (irrigation fields) would be conducted to a ditch, and after travelling 2.3 km, the flow would discharge into the Chrzastawa stream.

In Poland only a few cities use gravity flow to convey their sewage to the irrigation fields. In addition to the city mentioned and Kozuchow, only Rawicz is able to conduct this water to the irrigation fields via a natural gradient. The sewage from Leszno, in the Summer, and from Lodz and Pabjanice flow by gravity to irrigated meadows and the latter eventually runs into the Ner River. Outside Poland many cities irrigate their with sewage water without pumping. In Germany the cities of Celle, Darmstadt and Freiberg in the Rhineland, and Quedlinburg and Stadtlim have sewage irrigated fields with gravity flow supply.

The profitability of treating sewage in relation to agricultural usage, when it is necessary to pump this water to a considerable height, is completely different. Bydgoszcz can serve as an example of an unfortunate irrigation field design. The sewage water from this city is pumped to fields in two areas that are 3.5 and 5 km from the cities and are at a considerably higher elevation, due to which the manometric pumping height is 70 m. The considerable costs of such high pumping can consume any profit from the agricultural use of sewage.

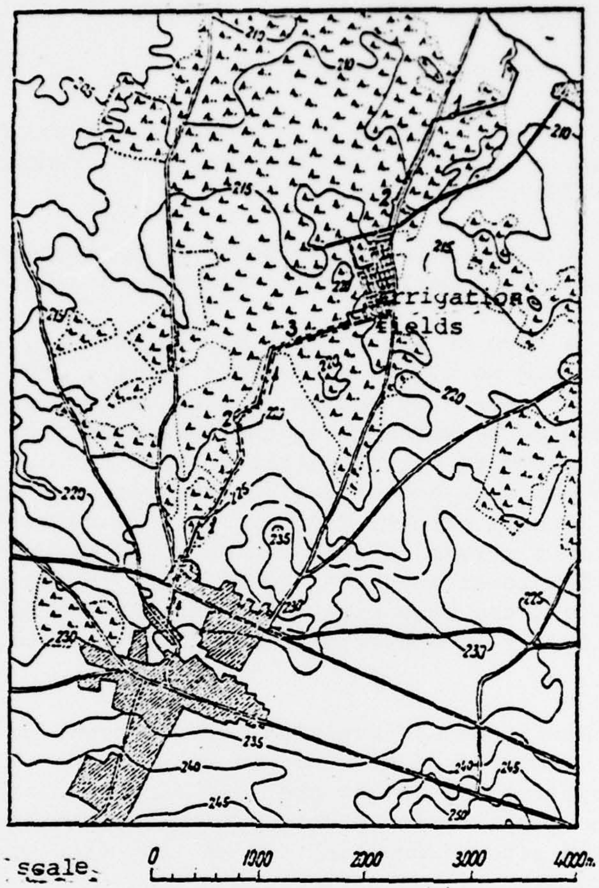

Figure 1.

During the war, in 1945, this city lost 30% of its buildings, but the number of inhabitants, amounting to 11,500 people in 1940 declined only very slightly. The amount of urban sewage conveyed to the irrigation fields is about 550 m^3 per day, equalling 50 l/day per inhabitant. In the vicinity of the city this water is further diluted by pure water from four artesian wells whose surplus water runs off into the city gutters. The dilution doubles the amount of water and the irrigation fields receive an average of 1100 m^3/day. The addition of industrial waste water is insignificant and plays no role in the agricultural consumption of the urban sewage.

A circular concrete conduit 600 mm in diameter with an average drop of 2.5%, conducts the sewage 3.2 km to the field. This conduit predominantly runs just below the surface or on the surface, and is then covered with an earthen embankment. Inspection catch basins are found every 100 m.

The irrigation fields are 3.5 km from the city and located in the old city pine forest. In 1907 - 1908, irrigation fields were established in the clearing left after the trees had been removed, in this way artifically altering the configuration of the land. The total field area is 18 ha, of which

16 ha are irrigated. The rest are roads, boundaries, dams and ditches.

Thanks to the gravitational flow of the sewage water to the irrigation fields, the costs of constructing this apparatus for sewage treatment were low:

conduit cost	55,000 mk
accomodation of an area of 18 ha for irrigation and drains..	50,000 mk
clarification tanks, concrete beds......................	5,000 mk
Total	110,000 mk.

In comparison with the cost of the urban sewage treatment system, which is 357,000 marks, the cost of conducting the sewage outside the city and constructing the sewage treatment plant came to 30%.

The average flow of sewage water to the fields during the day amounts to 20 l/second. During the night this flow is reduced to a few liters per second. Taking into consideration the mean flow for 24 hours (550 m^3), the average annual burden of undiluted sewage on the fields amounts to:

$$\frac{550 \cdot 360}{16 \cdot 10} = 1200 \text{ mm.}$$

This burden increases twofold as the result of dilution with water from the artesian wells and amounts to about 2400 mm.

The diluted sewage water conducted to the irrigation fields contains 619 mg/l of dry residue and 208 mg/l of residue after calculation, thus about 50% of the relative value of the Wroclaw sewage[1].

The soil appropriated for the irrigation fields is poor, sandy and contains an average of only 7% buoyant particles and 3.2% dusty particles in its upper layers. The rest is sand. In the lower layers the fine fraction content is considerably lower, as shown in Table 1.

Table 1
Chemical Composition of the Original Soil

Level in cm	Percentage in particle content		
	Buoyant	Dusty	Sand
	Ø grain < 0,02	0,02 — 0,1	0,1 — 2 mm
0 — 10	7,0	4,0	89,0
10 — 20	7,0	2,5	90,5
35 — 45	5,0	3	92,0
65 — 75	2,0	1,1	96,9

[1]Analysis of specimen collected 19 May 1951.

Thanks to many years of uninterrupted irrigation beginning in 1909, the soil's fine particle content has increased, as is confirmed by the results of research in 1951, shown in Table 2.

Table 2
Mechanical Composition of the Irrigated Soil

Level in cm	Percentage of Particle Content		
	Ø buoyant	dusty	sand
	grain <0.02	0.02 - 0.1	0.1-2 mm
0 - 10	16	14	70
10 - 20	7	3.3	89.7
35 - 45	2	1.0	97
65 - 75	2	1.7	96.3

Likewise the content of raw humus, phosphorous compounds and potassium has favorably changed under the effect of sewage irrigation, while acidity has increased, as shown in Table 3.

Table 3
Percentage of Humus Content, P_2O_5, K_2O and Soil Acidity

Soil	Level cm	humus	P_2O_5	K_2O	pH
not irrigated	10	4,50	0,020	0,003	6,0
	30	1,35	0,0135	0,003	5,7
	100	—	0,0018	0,002	6,1
irrigated	10	7,23	0,020	0,008	5,7
	30	2,16	0,020	0,003	5,7
	100	—	0,0067	0,001	5,8

Even though the soil is sandy, the irrigation fields have been drained. The average drainage depth is 1.30 m, and the spacing of the tiles is 8 cm. The tiles conduct the effluent to storage tanks, from which the effluent flows through 4 outlets and then through ditches to the Chrzastawa River.

In view of the high permeability of the soil, particularly in the lower levels, the amount of effluent from the drain outlets is very small and there is no effluent despite the irrigation in good weather. Actually it was not even necessary to drain irrigation fields located on such light soil. Certainly the reason for draining the irrigation fields in this locality was the assumption that in the future the population of this city would increase many times over, and the burden on these fields would increase up to 4000 - 6000 mm annually.

The sewage water conveyed to the irrigation fields undergoes a primary treatment. For this purpose two identical clarification tanks, operating alternately, were built into the upper part of the fields. The tanks are 35 m long, 5 m wide at the top, and narrow to 3 m at the bottom; the average depth is 1.50 m. The sides of the tanks are made of fired bricks and cement mortar, and this material has not shown any wear after 43 years. Each tank is separated crosswise with a 2 cm grating at a distance of 7 m from the sewage intakes and there is an underwater partition that retains the light matter rising to the surface 20 m off. Finally, at a distance of 8 m, i.e., at the end of the tank, the sewage that is quite thoroughly purified at this initial stage floats across a horizontal overflow partition and proceeds to the irrigation fields through concrete conduits.

The average rate of sewage flow in the tanks free of sediment is 3 mm/sec. As the tanks half fill with sludge this rate increases to 6 mm/sec, and when the depth of the sludge layer reaches 3/4 the height of the tank, the rate is 10 mm/sec and the sewage is only superficially purified in this initial stage.

Due to the dilution of the sewage by water from the artesian wells and to the customary use of cursory initial treatment of the sewage, the amount of sludge is relatively small and is about 2 m^3 of diluted sludge per 1000 m^3 of diluted sewage conveyed to the tank (an average of 1100 m^3 per day).

The capacity of the tank chamber filled 3/4-fold (i.e., 180 m^3) is sufficient for about 3 months. During this time the sludge in the reserve tank concentrates to such an extent that it can be removed by shovels to the edge, where it is composted and then used for fertilizer. Until 1945 the fermented sewage sludge, in an amount of about 200 m^3 annually, was eagerly purchased by neighborhood truck farmers. The price for 1 m^3 of this sludge, containing about 65% water, came to 3.20 marks in 1912. In comparison with the price obtained by other cities in the Germany of that time (0.30 - 2.0 marks for 1 m^3 of sludge)[2], the price for sludge sold in this city was quite high. At present there is no difficulty in selling the sludge, and this sludge is purchased to fertilize vegetable crops.

A concrete channel made of 1 m long sections was used for the purpose of conducting the initially purified sewage water to the irrigation plots. These channels had the dimensions shown in Figure 2, and this material has not exhibited any drawbacks in the course of its 43 years of use.

The use of gutters with sod slopes have been associated with many shortcomings, such as the following:

1. Lush growth of vegetation, mainly worthless weeds, on the slopes and a concomitant drop in the free passage of flowing material,

2. mud deposit in the earthen ditch,

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[2] Koenig and Lacour. Die Reinigung stadtischer Abwasser in Deutschland nach den naturlichen biologischen Verfahren. [The Purification of City Waste Water in Germany by Natural, Biological Processes], Berlin, 1915.

3. collapse of the sides and edges due to user activity and damage caused by rodents, and

4. the need for constantly repairing the channels, due to the need frequently to clean out the mud. It is difficult to mow the sides.

In view of the permanence of the channels and the many advantages found in comparison with normal channels, the use of concrete channels for conducting sewage water must be considered as completely reasonable.

Concrete gutters were used to carry the water to the irrigation channels and to plots 1 ... 4, (Figure 2), permitting one to avoid a gradient of 0.8 m or more. Many years of using this type of set-up, without the need for repairs and without erosion of the irrigation ditches, confirms the practical aspect of the construction.

The irrigation fields, with a total surface of 16 ha, were divided into 73 rectangular or trapezoidal parcels (plots), 28 of which are irrigated by flooding and 45 by water running downhill. The area of the individual parcels is between 0.10 - 0.56 ha. Only 4 parcels, designated by the numbers 1 - 4 and located in the southern part of the fields, with an area of 1.36 ha, are used as arable land, while the rest of the plots form irrigated meadows.

The access roads, shown on the irrigation field map (Figure 3) are 4 m wide. Such a width was justified because the rows were planted with fruit trees. In 1910 these trees numbered 500. They were plum trees, of the Hungarian variety, which grew well and produced abundantly until 1929, when almost all of them perished during t[illegible]ugh Winter of 1928 - 1929 because of the extreme period of cold weather [illegible]e forest clearing. The remaining, already old trees, which were never com[illegible]d, still produced good fruit until 1941, when they finally died during t[illegible]treme cold.

The good yield of plum trees on the irrigation fields can serve as an example for introducing this type of fruit tree culture on the irrigation fields of other cities. Obviously frost-resistant varieties should be used, suitable for the given climatic conditions, and likewise the individual trees should be replaced as they die.

In 1908 the irrigation meadows were located on landscaped terrain.

Thanks to the many years of continuous irrigation, a layer of humus 18 - 20 cm deep has formed on the originally poor sandy soil, guaranteeing favorable conditions for grass growth. The meadow growth generally consists of valuable grasses: cocksfoot, wild oats, English rye-grass, fescue and meadow-grass.

Just as in other areas irrigated by sewage water, the soil of the irrigated meadows suffers from exhaustion, revealed by a drop in yield, and the appearance of barren spots and thick stands of weeds.

Plowing meadows with exhausted soil, cultivating and sowing grass seeds completely regenerate the conditions for the growth of these plants and increase the yield several times over.

The amount of individual doses of sewage is quite high, and amounts to 300 - 400 mm of dilute sewage in a ratio of 1:1. The number of doses is 6 - 8. The meadows are mowed 3 - 4 times. The meadows are irrigated for about 10 months. For the rest of the year the sewage water is conducted to plots 1 - 4, which form arable land. During hoarfrost, and even during light frosts, the meadows are irrigated; as many years of practice in this area have shown this does not have any adverse effects. It may be judged that increasing the number of crops to 5 and reducing the amount of individual sewage doses while a simultaneously increasing frequency of these dosages would have a favorable effect on crop increase. It should also be recommended that grass be dried on racks or fences, and not on the ground as is done presently, which has an adverse effect on the quality of the hay.

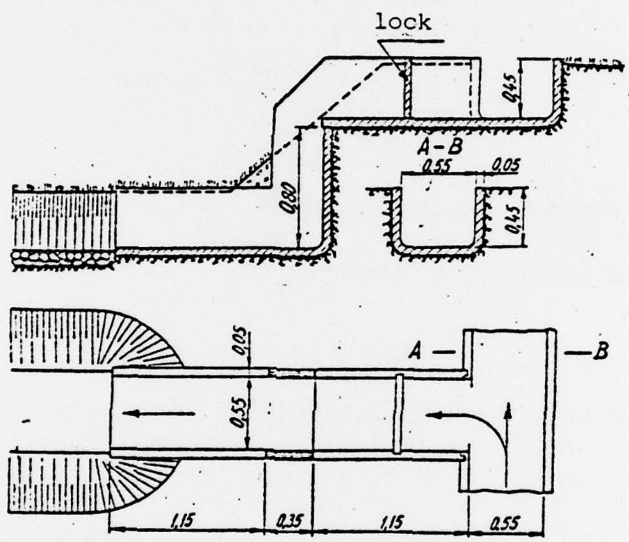

Figure 2.

Vegetables are cultivated on plots 1 - 4. The soil of these plots is particularly unfertile because these plots were excavated up to 1 - 1.5 m deep to obtain material for building dikes and rows on the fields.

Despite the completely barren soil at this depth, rather good vegetable harvests are obtained because of the sewage water irrigation. Good results are obtained with the cultivation of tomatoes, white cabbage, cauliflowers, cucumbers and onions, while parsley must be considered as unsatisfactory. These crops are not irrigated during the growing season.

The sanitary conditions under which the urban sewage water in this locality is used agriculturally must be considered good, without regard to conducting the water to the irrigation field area through a covered conduit 3 km outside the city. In addition the irrigation fields are located on a forest clearing far from human settlements.

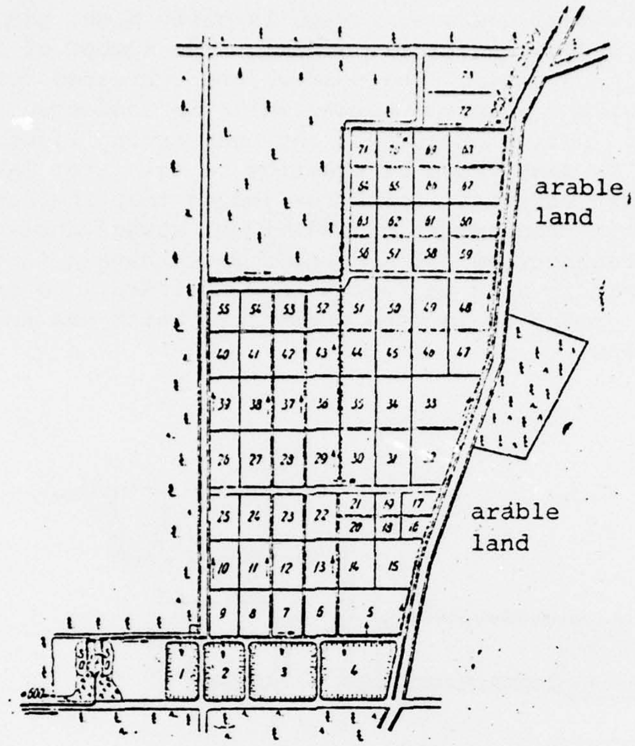

Figure 3.

It should be mentioned that until now the owners of animals that consume the fodder produced on the irrigation fields (used for more than 30 years) have not found any outbreak of illness among the people servicing the fields or using the crops obtained from the irrigation fields, to the extent that an outbreak could be attributed to the agricultural use of sewage from the city mentioned above.