WASTEWATER TREATMENT AND REUSE IN AGRICULTURE OF VOJVODINA PROVINCE

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1 INTRODUCTION

The environment protection and development are now directed towards creation of the new ecological systems capable for neutralization of the secondary products of the anthropological activities, and then again their controlled taking into the nature. Many countries have included wastewater reuse as an important dimension of water resources planning. Environment can be regularly regenerated and reproduced only under the conditions of the ecological production and coordination of nature and society with complete use of material in circulating technological processes. In this processes the most important are: microorganisms, biochemical processes and molecular biology genetic possessions. In order to provide suitable end qualitative food for people, wanted income for producers and acceptable and healthy environment it is necessary to make compromises and to reconcile the interests.

This paper deals with analyses of necessity and possibility use of treated municipal wastewater in the first part, and agricultural wastewater application in the second part. Water scarcity during growing season was taken into consideration in the first part. The soil and groundwater exchange caused by application wastewater from cattle farm during field experiment is shown on the second part.

Reuse of the municipal wastewater is wide spread all over the world as a result of a rapid progress in all aspects of life. The usage of municipal wastewater after its treatment is a reasonable alternative for an additional water supply, especially at the regions where there is a lack of water and where it is a limitation factor of development. Such kind of water is used, among others, for irrigation of agricultural lots and also lots for recreation. Irrigation of agricultural lots, which is applied not only for the moisture shortage compensation, but also as ecological and economical satisfaction solution, is most frequently solution for wastewater reuse.

Intensified development of cattle breeding on big industrial farms demands the development of new technologies for agricultural wastewater. The new zootehnical conditions with much greater quantity of water demand new approach to the solution of this kind of problems. Using of the refined, diluted or not diluted wastewater mostly in agriculture is one possible solution way. On the other hand, soil and groundwater contamination is one of the major environmental problems especially in the case of land disposal of agricultural wastewater. The possibilities of agricultural wastewater use, and their influence to the environment, represent an important problem that is nowadays being treated by many researchers all over the world. Among them are: Chang et al (1995), de Haan (1987), Loehr (1974), Maresca (1979), Vermesh and Kutera (1984), Westcot (1997), and others.

PART I

Subotica is a town in the northern boundary area of Yugoslavia, located on the part of a large plain stretching from Hungary to Yugoslavia and thus it is of great agricultural importance. In this area, water shortage is frequently observed during the growing season. It should be mentioned that the city of Subotica is supplied with water from ground resources and that all wastewaters, together with atmospheric waters, are discharged to Lake Palic. The Lake stretches in the southeast and east direction of Subotica and it mainly serves for swimming and recreation. To the year 1975 all municipal wastewaters were discharged to the lake without any pretreatment. This resulted in a total degradation of the Lake, caused by marked eutrophication and excessive muddiness (thickness of silt deposits was from 10 cm to 1.5 m at the wastewater inflow), as well as by overloading of other kinds. The Lake was dried out and silt deposits removed. In 1975, a wastewater treatment plant (WTP) was constructed. In 1976 the Lake was refilled with water, the dominant amounts of it being taken from the WTP.

Having in mind the water shortage in the growing season, the idea is to use this treated water, or in a mixture with other waters, for irrigation, to make up for the deficiency of good quality waters. On the other hand, Lake Palic would thus become less loaded, both in respect of the amounts of water that are constantly coming to it and nutrient matter remaining in the treated water, loading the Lake. The nutritive matter and organic pollutants represent the main danger, yielding gradual or accelerated degradation of the aquatic ecosystem. However, the use of this matter through irrigation of crops with wastewater brings about economical benefits because such irrigation brings about soil fertilization.

2 RESULTS OF INVESTIGATIONS

With the aim of estimating the needs and possibilities of using the municipal wastewaters of the city of Subotica for irrigation we have analyzed a number of factors such as climatic characteristics, quality of the wastewaters after their secondary treatment and lagoon system, distribution of particular soil types, and crop structure on the areas making potential location for using wastewater for irrigation.

3 WATER DEMANDS

Because of the variations in precipitation both in respect of the amounts and time distribution, which is a characteristic of the local climate, water balance was calculated with the aim of establishing shortage/excess of rainfall in the growing season and thus the needs for irrigation in this area. The water balance was calculated by the Thorntwaite method, using mean values of precipitation and ETP for a thirty-year long period, which is presented in the form of graph (Figure 1). It is evident that the amounts of rainfall in the growing season do not satisfy the water demands of agricultural plants in that period, which suggests the need for irrigation, to make up for the water deficit.

4 CHARACTERISTICS OF THE WATER TREATMENT PLANT

The system for treatment of the Subotica municipal wastewaters consists of:

- ***Plant for mechanical-biological treatment*** with **a)** *water line* and **b)** *sludge line*
- ***System of lagoons*** and
- ***Auxiliary elements***.

All wastewaters, both the municipal and industrial, as well as the atmospheric water collected in a system of general type are conducted to the site for the wastewater treatment. Preliminary treatment of the industrial wastewaters is carried out only in the part connected to the municipal sewerage, which results in poor quality of this water, even after its treatment. This is evident from the high concentrations of dissolved salts in the wastewater (Table 1).

The effluent from the WTP is conducted to a system of lagoons, consisting of three lagoons connected in series. The characteristics of a lagoon are area of about 80 000 m^2, depth about 2.0 m, and volume about 160 000 m^3. These values are only orientation because the actual dimensions are significantly smaller because of the long-term silt deposition, so that there are no reliable data about the present size of the lagoons. The existing equipment for aeration of the lagoons is out of function. A natural barrier to impound high waters in the rainy season is located in front of the treatment plant, but it is also out of function.

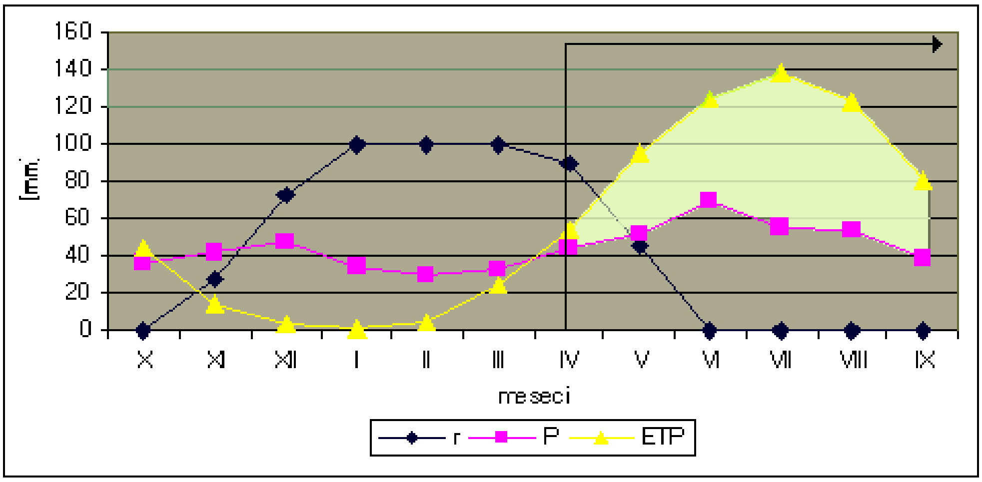

Figure 1. Water balance for 1964/65 -1993/94 hydrologic year periods
P-precipitation, **ETP**-potential evapotranspiration, **r**-water reserve available in soil

5 QUANTITY OF WASTEWATER

The capacity of the secondary plant is about 27 000 m^3/day of wastewater, i.e. 40 000 m^3/day during the rains. According to the mean annual value of Q bypass, which varies from about 5 000 to about 17 000 m^3/day in the analysed period it can be concluded that certain hydraulic overload can be observed during the year. The excess waters are conducted directly to the lagoon system, to sector 2 of Lake Palic (which itself is divided into four sectors). Sectors 2 and 3, being the final stage of water treatment, serve for fish farming. Depending on the hydrological situation, these excess waters are conducted by an outlet canal, bypassing the Lake or to the Lake itself (to sectors 2 and 3), but since the outlet canal is out of function, all the water is now conducted directly to the Lake.

6 EFLUENT CHARACTERISTICS AFTER TREATMENT

Because of their origin, the Subotica municipal wastewaters contain ample amounts of diverse polluting matter. The quality parameters of treated wastewater are subjected to statistical analysis to obtain minimal, maximal, and mean values for the mentioned three-year period. The given values are related to the water samples taken from the site of the system outlet (passage from Lagoon 2 to Fishpond 1). The analysis encompassed the following parameters: pH, COD, BOD_5, EC, TDS, suspended matter, CO_3^{2-}, HCO_3^-, SO_4^{2-}, Cl^-, water hardness, Ca^{2+}, Mg^{2+}, Na^+, K^+, total N, organic N, NH_4^+, NO_2^-, NO_3^-, total P, dissolved P and phosphatase activity (Table 2). Also, the analysis included the following microelements: As, Cr, Cu, F, Fe, Hg, Ni, Pb and Zn. The values are given in the sequence corresponding to the maximal allowable concentrations (MAC) of heavy metals in the irrigation water, given by the Yugoslav law and the values recommended by FAO (Pescod, 1992) (Table 3).

The treated wastewater is mainly of weak alkaline character. Mean concentrations of dissolved matter are high if compared with the corresponding values for typical household wastewater, given by Pescod (1992). After the mechanical-biological treatment on the WTP the organic matter content is significantly lower; the purification degree in the WTP being between 72 and 91 %, and after the lagoons it is increased by 1-10 % (Benak et al., 1998). Contents of nutrients, of which most important are nitrogen and phosphorus, remain almost unchanged during treatment because the treatment procedure does not involve nitrification, denitrification and dephosphorysation of the wastewater. The largest portion of total nitrogen makes the ammonia nitrogen (from 68 to 76 %), then comes organic nitrogen (ranging from 22 to 31 %), whereas the smallest portion make the nitrate (NO_3^- N) and nitrite (NO_2^- N) nitrogen. The analysis of microelements (Table 3) shows significantly higher concentrations of fluoride in the treated water.

Table 1. Characteristics of wastewater after treatment

Parameter	Units	Characteristic values								
		1997. year			1998. year			1999. year		
		min	max	mean	min	max	mean	min	max	mean
pH	-	7,47	8,33	-	7,25	8,40	-	6,89	7.95	-
COD	mg/l	18,2	46,4	27,2	19,0	42,9	27,0	16,7	37,8	25,6
BOD_5	mg/l	6,4	51,0	20,4	10,5	37,5	19,6	5,2	28,5	17,2
EC	$\mu S/cm^2$	965	1586	1260	835	1442	1156	853	2305	1220
TDS	mg/l	658	1408	987	669	1029	853	671	1125	919
Suspended matter	mg/l	1,5	28,0	12,1	2,0	64,0	15,4	3,0	23	9,2
CO_3^{2-}	mg/l	0	51	6,88	0	44,4	1,75	0	0	0
HCO_3^-	mg/l	409	647	541	427	626	545	392	642	557
SO_4^{2-}	mg/l	101	193	139,3	102	210	137,8	104	178	138,5
Cl^-	mg/l	85,1	117	96,6	67,4	99,3	82,5	81,5	103	91,4
Hardness	°dH	21,4	28,3	24,6	19,7	31,8	24,4	22,1	26,9	25,1
Ca^{2+}	mg/l	80,1	104	91,5	80,1	94,2	86,4	84,3	102	93,6
Mg^{2+},	mg/l	42,6	65,4	50,8	37,0	55,0	45,8	44,3	57,2	51,5
Na^+	mg/l	97,5	105	99,4	77,5	108	90,8	105	118,0	109,8
K^+,	mg/l	18,0	29,5	24,1	17,0	25,5	21,3	19,5	25	22,6
Total N	mg/l	28,8	72,7	42,4	21,1	39,2	31,2	20,5	36,5	27,8
Organic N	mg/l	2,1	18,2	9,4	1,4	19,6	9,6	2,8	18,9	8,6
NH_4^+ N	mg/l	18,9	53,3	32,2	9,4	30,4	21,4	6,2	30,1	18,8
NO_2^- N	mg/l	0	0,99	0,17	0	0,21	0,03	0	1,69	0,15
NO_2^- N	mg/l	0	6,78	0,66	0	0,44	0,04	0	2,59	0,20
Total P	mg/l	2,68	16,40	7,82	4,48	22,30	7,46	3,56	12,8	6,42
Dissolved P	mg/l	2,13	15,90	5,76	2,15	12,60	5,74	2,26	12,8	5,72
Phosphate activity	$\mu mol/sdm^3$	1,10	12,54	4,15	1,36	19,27	3,85	2,43	12,95	5,27

7 CRITERIA FOR WASTEWATER USE IN IRRIGATION

Because of the lack of classification of wastewater for irrigation in Yugoslavia (Belic et al, 1996) in our assessment of suitability of the Subotica municipal wastewater for this purpose we used the FAO criteria. The analysis encompassed conventional criteria for assessing the possibility of using wastewater for irrigation purpose, which are also valid for wastewaters, taking into account the nutritive matter in the wastewater and soil characteristics. According to the classification of irrigation water given by Ayers and Westcot (1985), which is according to Pescod (1992) equally suitable for the assessment of wastewater for irrigation, on the basis of their chemical characteristics such as content of dissolved salts, relative content of sodium and toxic ions, it was possible to derive conclusion about the possibility of using the investigated water for irrigation.

From the aspect of salinity, the observed minimal, maximal and mean values of electrical conductance and total dissolved matter indicate the need for a moderate restriction of the use of this water which, according to the authors, should mean that it is necessary to pay attention to the selection of crops and alternatives of soil management with the aim of achieving full potential of crop yield.

By analysing the values of the parameters exhibiting adverse effects on soil porosity (including the decrease of filtration rate and crust formation on the soil surface) it can be concluded that there should be no restriction in using this water for irrigation.

Table 2. Characteristic values of microelements with MAC and FAO recommendation

Elements	Units	Microelement values after treatment						**MAC**	**FAO**
		1997. year		1998. year		1999. year			
		max	mean	max	mean	max	mean		
As	mg/l	0,03	0,011	0,03	0,006	0,09	0,034	**0,05**	**0,1**
Cr	mg/l	0	0	0	0	0	0	**0,5**	**0,1**
Cu	mg/l	0	0	0	0	0,037	0,005	**0,1**	**0,2**
F	mg/l	24,6	14,19	39,0	22,7	20,1	14,53	**1,5**	**1,0**
Fe	mg/l	0,46	0,215	0,23	0,175	0,322	0,195	**-**	**5,0**
Hg	mg/l	0	0	0,01	0,005	0,008	0,005	**0.001**	**-**
Ni	mg/l	0,038	0,008	0,016	0,003	0,028	0,006	**0,1**	**0,2**
Pb	mg/l	0	0	0	0	0	0	**0,1**	**5,0**
Zn	mg/l	0,03	0,017	0,027	0,019	0,07	0,038	**1,0**	**2,0**

Concentrations of specific toxic ions of sodium and chlorine indicate that restriction is unnecessary when potential surface irrigation is concerned; sodium concentration in sprinkling irrigation would require selection of crops tolerable to higher sodium concentrations and other accompanying measures. Concentration of toxic boron ion is not encompassed by the WTP analysis, so that its effect could not be analysed. When analysing the concentrations of other toxic ions, belonging to the group of microelements, because of their low levels at which they are present in the wastewater, their concentrations were compared to the MAC values recommended by FAO and the corresponding values for these substances in water prescribed by the Yugoslav laws. Significantly higher differences are observed in fluoride concentration compared to the MAC values and those recommended by FAO. According to the authors of FAO recommendations, fluoride is inactive in the neutral and alkaline soils. Somewhat increased concentration of mercury with respect to the MAC values can be observed for the years 1998 and 1999.

Contents of nutritive elements should be considered from the aspect of the requirements for these components by crops grown in this area. If the contents of nutrients in the wastewater are higher than required by the crops in question, according to Arceivala (1987), it is possible to carry out dilution of the wastewater for irrigation.

In the surrounding of the system for treatment of the Subotica municipal wastewaters the most widespread type of soil is Chernozem calcareous. This soil is characterized by good water, air, heat and biology regime with ideal filtration capacity and minimal leaching process. Intensive utilization of this soil, rich in easy-available assimilative elements, can result in their depletion, which can be made up for by using mineral fertilizers. Chernozem carbonaceous on loess plateau is a soil of excellent production value and it is characterized by sufficient moisture level during the growing season, resulting in steadiness of the agricultural yields.

Selection of crops under the conditions of irrigation with the treated wastewater was carried out according to the FAO criteria, bearing also in mind the types of crops that have already been grown on the same soil. On the basis of literature data on tolerance of particular crops to salinity it is possible to grow barley and sugar beet as tolerant, as well as oat, rye, wheat and soybean as moderately tolerant plants.

The analysis of the criteria important to human health, the presence and distribution of pathogenic microorganisms as most important among them was not carried out. The reason is the absence of the necessary microbiological analyses that could serve as the basis for the assessment of the wastewater from this aspect.

PART II

Large amount of wastewater is caused by intensified development of cattle breading in Vojvodina Province. Having in mind posibility of its reuse for irrigation, the field experiment was established. Wastewater from cattle breading farm was applied for irrigation of growing crops. To monitor the changes in composition of groundwater, four wells were drilled on the field. Groundwater samples were taken and analyzed four time a year. Soil samples were analyzed at the beginning and at the end of experiment.

8 EXPERIMENT AND RESULTS

8.1 General characteristics of experimental field end farm

The experimental field lies between farm and canal, on the right side of a traffic road. It occupies the area of 182 ha, end it is divided into four parts of production. There is a system for irrigation supplied by water from the canal.

Farm, from which wastewater was used during investigation, is located just beside experimental field. Wet system of discharge is applied in the farm, with separation of solid and liquid phase. Liquid phase is about 82-96% and it goes into thermal protected reactors (there are three ALFA-LAVAL type) where aerobic biochemical process begins by inflow of oxygen from air. The temperature in reactors makes microbiological activity and decomposition of organic matter possible. Retention time in reactors is related to concentration and it lasts from 5 to 7 days. The treated wastewater goes into basin and there from it is used by pumping and thrown into system for irrigation. This wastewater is rich in organic matter, total and ammonia nitrogen, and the high amount of microorganisms and can be used as organic fertilizer.

The effect of hot treatment is related to degree of concentration, and before the hot treatment BOD_5 was 15 000 - 18 000 mg/l and afterwards it was 447 mg/l. Bacteriological examination done after biological treatment shows that there is neither salmonella nor some other pathogenic microorganisms present. After the hot treatment the amount of total nitrogen in liquid phase was from O.77% (in the collecting basin before treatment) to 0.36% (in the third reactor). At the same time amount of ammonia nitrogen was from 0.74% to 0.31% and nitrates from 0.31% to 0.10%. Phosphorous in liquid phase was from 0.17% to 0.20%, and potassium from 0.74% to 0.68%. The amount of some nutrients in the solid phase was similar.

8.2 Soil characteristics

The experimental field is on chernozemlike calcareous meadow soil type on the terrace, the hydromorphism of which is expressed. The first soil profile (M1) was opened for define initial conditions. Physical, water-physical and chemical properties of soil samples from the profile Ml are shown on Table 3. Six samples, however, were investigated at the following depths: 0-20 cm, 20-38 cm, 38-55 cm, 55-73 cm, 73-86 cm, 86-128 cm. Soil profiles M2 and M3 were opened in order to define changes in the soil caused by land disposal of treated and diluted wastewater from farm. The place of M2 profile seems to be of greater hydromorphism while the place of M3 profile is more similar to M1. The four samples investigated from profile M2 were at the depths of 0-38 cm, 38-55 cm, 55-86 cm, and 86-120 cm. Samples from profile M3 were investigated from 0-30 cm, 30-60 cm, 60-go cm, and 90-120 cm deep. The results of these investigations are given in Table 4.

From profile M1 we can say that the soil is of good physical properties (dates about specific and volume weight and about moisture retention). Specific weight is less in humus horizon, while it is increasing in deeper layers. The values range from 2.61 to 2.81, and it depends up on the depth of a layer. Volume weight is also increasing in deeper layers end has value between 1.42 end 1.25. For the layer from 0 cm to 128 cm the average value of field water capacity is 38.29 vol.%, the average value of moisture retention capacity is 25.13 vol.% while the average value of wilting point is 17.90 vol.%. For the layer from 0 cm to 86 cm the K-Darcy value ranges from 1.33×10^{-5} to 4.46×10^{-3} cm/s.

Table 3. Soil characteristics on profile M1

Soil characteristics on M1 profile (beginning of the experiment)	0-20 cm	20-38 cm	38-55 cm	55-73 cm	73-86 cm	86-128 cm
pH in 1N KCl	7.44	7.66	7.75	7.85	7.95	8.02
pH in H_2O	8.00	8.27	8.42	8.78	9.01	9.09
Ca CO_3 %	3.18	11.6	16.3	18.7	19.8	21.5
Humus %	3.42	2.21	1.84	1.27	-	-
P_2O_5 mg/100 g	9.5	2.7	1.4	1.2	0.9	0.7
K_2O mg/100 g	22.0	14.0	11.4	10.0	9.6	9.2
Total nitrogen	0.227	0.155	0.123	0.107	0.099	0.079
Particles > 0.2 mm	0.81	1.30	0.70	0.40	0.30	0.50
Particles 0.2-0.02 mm	42.8	51.3	43.1	42.1	33.4	42.7
Particles 0.02-0.002 mm	39.9	31.1	39.5	40.4	39.6	30.0
Particles < 0.002 mm	16.5	16.3	16.7	17.1	26.7	26.8
% of sand	43.6	52.6	43.8	42.5	33.7	43.2
% of clay	56.4	47.4	56.2	57.5	66.3	56.8
Spec. weight	2.61	2.66	2.65	2.76	2.75	2.81

According to the investigation on locality M1, clay loam to loamy clay can be found. Classification of soil particles, according to grain size, is as follows: coarse sand from 0.30% to 1.30% which depends on layer depth, fine send from 33.40% to 43.10%, silt from 30.00% to 40.40% and clay from 16.30% to 26.80%. According to investigation from localities M2 and M3, classification of soil particles is as follows: coarse sand from 0.50% to 1.50% (M2), and from 0.90% to 1.30% (M3), fine send from 23.90% to 24.22% (M2), and from 28.50% to 29.60% (M3), silt from 27.44% to 28.84% (M2), and from 76.76% to 29.40% (M3), clay from 41.00% to 46.92% (M2), and from 40.80% to 41.46% (M3). It is evident that results from localities M2 and M3 show the average values of coarse sand (%) decrease from 44% (M3) to 73% (M2), and average values of clay (%) increase from 23% (M3) to 32% (M2), comparing with the results obtained on locality M1. The difference of results, however, is not influenced by application of the wastewater from the farm but by the results of general heterogeneous natural conditions in this locality.

According to the results of soil samples investigation from localities M1, M2 and M3, values of $CaCO_3$ are between 3.18% and 21.5%, which depends on layer depth. The same happening to M2 (2.55% - 28.09%) and M3 (11.92% - 39.16%). This soil is alkaline, with higher degree of alkalinity in deeper layers. During the investigation pH values were between 6.43 and 8.02 in KCl 1 N, and between 7.44 and 9.09 in H_20. The obtained results concerning humus quantity from beginning of investigation compared to the results from the end show that there is a weak increase of average value, by 0.8%, in all layers in soil profile.

The amount of nutrients in the soil was closely related to the initial conditions. Changeability is more evident in phosphorus and potassium then in nitrogen. The amount of easy accessible phosphorus (P_2O_5) in the surface layer increased and ranged from 9.5 mg/100 g soils to 25.0 mg/100 g soil, while in other layers the increase was considerably less. The amount of easy accessible potassium (K_20) increased from 22.0 mg/l00 g soil to 50.0 mg/1O0 g soil. The amount of total nitrogen was from 0.227 % in surface layer to 0.079% in deeper layers. The amount of total nitrogen in samples investigated at the end of observation ranged from 0.266% to 0.229% in surface layer end from 0.106% to 0.119% in deeper layers. As the result show the conditions remained unchanged in surface layer while the amount of total nitrogen increased in deeper layers due to its higher mobility in irrigation conditions. The amount of nutrients in soil is affected not only by applying mineral manure but by wastewater from the farm, too. In order to meet the demands of particular kinds of plants, in experimental field, 234 000 kg NPP, 51 800 kg "KAN" and 59 870 kg "URE" was added, as well as 2.56 kg phosphate, 21.68 kg potassium and 47.10 kg total nitrogen from disposed treated wastewater. At the same time 0.25 kg phosphate, 4.40 kg potassium and 1.55 kg total nitrogen from canal water was brought to the field.

Table 5. Soil characteristics on profiles M2 and M3

Soil characteristics on M1 and M2 profiles (end of the experiment)	M2				M3			
	0-38 cm	38-55 cm	55-86 cm	86-120 cm	0-30 cm	30-60 cm	60-90 cm	90-120 cm
pH in 1N KCl	6.43	6.95	7.22	7.44	7.27	7.43	7.48	7.56
pH in H_2O	7.44	7.99	8.25	8.36	8.12	8.19	8.32	8.64
Ca CO_3 %	0	2.55	15.31	28.09	11.92	29.8	35.76	39.16
Humus %	3.78	2.88	2.30	1.65	3.76	2.17	1.72	1.64
P_2O_5 mg/100 g	24.2	5.3	3.1	1.8	25.0	4.5	2.0	2.5
K_2O mg/100 g	41.4	30.4	22.0	18.0	50.0	20.0	15.4	15.4
Total nitrogen	0.266	0.206	0.102	0.106	0.229	0.149	0.121	0.119
Particles > 0.2 mm	0.50	0.80	1.50	0.70	1.30	0.90	1.0	1.0
Part. 0.2-0.02 mm	24.22	23.96	24.14	23.90	28.50	28.90	29.60	28.72
Part. 0.02-0.002 mm	28.60	28.56	27.44	28.84	29.20	29.40	27.76	28.72
Part. < 0.002 mm	46.68	46.68	46.92	46.56	41.00	40.60	41.64	41.56
% of sand	24.72	24.76	25.64	24.60	29.80	29.80	30.60	29.72
% of clay	75.28	75.24	74.36	75.40	70.20	70.20	69.40	70.28

During experiment the irrigation clean water from canal and mixed water (treated wastewater and canal water in volume relation 1:6) was used meeting the particular plant production demands. Amounts and kind of water used for irrigation, during experiment, are given in Table 6.

Table 5. Quantity and kind water used for irrigation

Period of irrigation	Quantity of water used for irrigation - m^3				Total amount of water m^3
	clean water m^3	mixture of clean and wastewater m^3			
		total	clean water	wastewater	
1st growing season	93 000	69 600	59 650	9 950	162 600
2nd growing season	216 000	87 000	74 570	12 430	303 000
3rd growing season	-	94 100	80 650	13 450	94 100
Sum	309 000	250 700	214 870	35 830	559 700

8.3 Hydrogeology characteristics

The territory, where the experimental field is located, lies on loess terrace and alluvial plain. Water table aquifer, formed in these conditions, has not hydraulic connection with deeper sub artesian and artesian aquifer or that connection is indirect.

By previous analysis it is possible to conclude that steady groundwater flow directed from North-West to South-East exists. Inflow from below water bearing layer was estimated by the supposition of artesian pressure H=1 m (it was not registered by drilling) and with $K=6.7x10^{-10}$ m/s. Inflow is $7.3x10^{4}$ 1/s/ha or about 2 mm of water layer per year. Outflow is about 0.2 mm of water layer per year. Both values (inflow and outflow) are of no importance to the amount of water in water table aquifer.

Groundwater balance of water table aquifer in experimental field is among influenced by many natural and artificial factors, which the most important are climate and hydrogeology. Collector is a single layered aquifer from the surface to about 5-10 m down, and it consists of loess, silty clay. At the depth of 0.9 m gley, and deeper, lenses of sand, are traced. According to the curve of grain-size distribution there are 36% of clay, 32% of silt and 32% of sand. Collector is aquifer with hydraulic conductivity K ranges from 10^{-4} to 10^{-7} cm/s. The water table aquifer level fluctuations during the time of investigation were observed in six piezometers. The results show that water table aquifer level was settled with slight fluctuations due to the local conditions. There is no direct connection between precipitation end water table aquifer levels. The groundwater flow is under influence of canal located next to the experimental field.

8.4 Groundwater quality characteristics

In order to see the changes of particular groundwater quality parameters, samples were taken from four piezometers 1, 2, 3 and 4. Changes of some characteristic parameters, from piezometers 3 and 4, are shown on Figure 2.

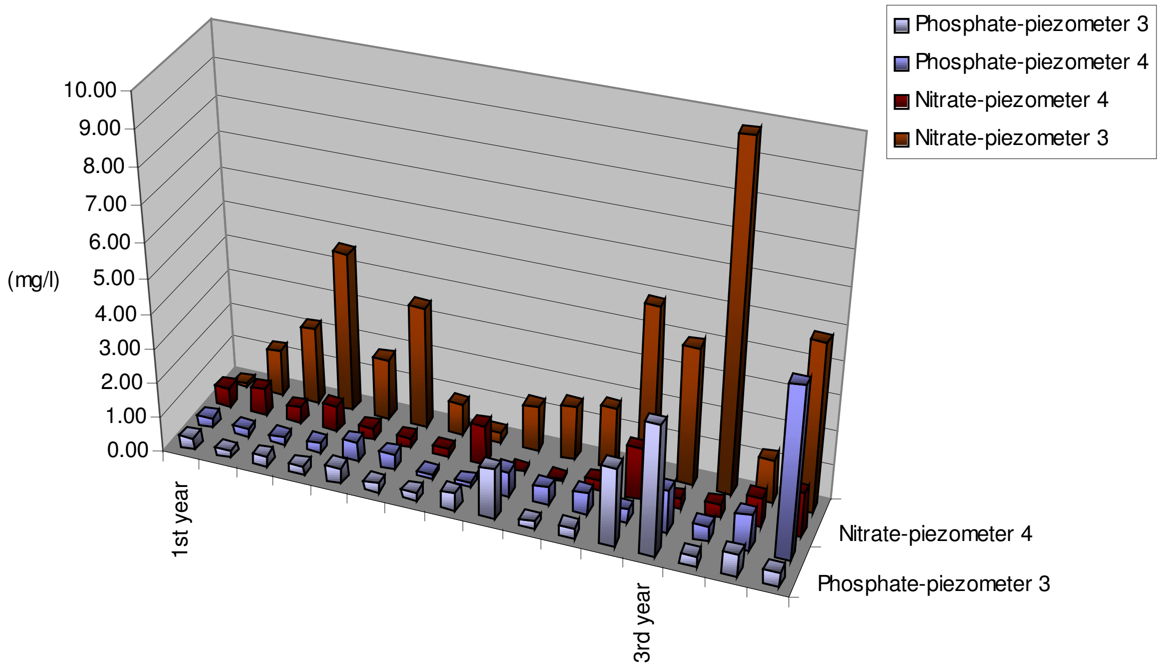

Figure 2. Values of nitrate and phosphate on piezometers 3 and 4

Chemical analysis of groundwater samples includes 23 parameters from which 12 parameters, analysed in detail, make the establishing effect of applied wastewater possible. Analysed parameters have different behaviour, which depends on place and time of sampling. Taking into consideration cycle of particular parameters it is possible to give a summary estimation of their state:

- Potassium and sodium show the tendency of decreasing because of their adsorption by soil and parent material, and in case of potassium also because of fixation;

- Calcium and magnesium show changeable state as the result of one dynamic balance between liquid and solid soil phase, or their deposits because of forming harder soluble salts;

- Chloride end nitrate show tendency of decreasing what is more expressive in case of chloride. Nitrate is more soluble but its inflow into cycle is larger;

- Sulphate and phosphate show changeable state in all localities. For sulphate its degree of solubility and mobility can be the explanation, while for phosphate also important its presence in mineral manure and wastewater from the farm;

- Organic matter shows seasonal changeability what is the effect of different conditions for its mineralization. Ammonium end total nitrogen (which are in composition of organic matter) show analogy regularity. Ammonium nitrate also has tendency of decreasing because of its transformation, while total nitrogen follows nitrate behaviour;

- Remain solid after heating till vapour, shows predominantly quantitative balance during investigation time.

According to the theoretical assumptions and practical results of soil investigation, hydrology characteristics, balance of water table aquifer and results of groundwater quality analysis from piezometers we can conclude that irrigation with treated end dissolved wastewater from the farm, does not produce, in this condition, undesirable effect. For precise definition of balance of particular parameters it is necessary to take into consideration the up taking by plant what makes investigation much more complex. Taking into consideration the preliminary shown facts it follows that quality of water table aquifer depends on water quality for irrigation and disposed treated wastewater from the farm and growing plant, intensity of using mineral manure, climate conditions and other factors. This problem is complex and requires new efforts for separation effects of disposal agricultural wastewater.

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