

WASTEWATER AS NON-CONVENTIONAL WATER RESOURCE

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ABSTRACT

This paper deals with theoretical part of wastewater use in agriculture and with results from one case study of wastewater application in northern part of Serbia (Vojvodina Province). The development of livestock breeding in Vojvodina Province is characterized by building up of large-capacity farms involving wet discharge technologies and wastewaters collected in lagoons. The applicability of these waters is determined by their characteristics, amounts, the natural characteristics of the region, and the possibility of growing particular crops. In the frame of a complex research project at the lizimeter station Rimski Sancevi the effect of irrigation with diluted wastewater from the pig-raising farm has been studied. The experiment encompassed investigation concerning the control of shallow groundwater quality, microbiological activity of the soil and shallow groundwater, chemical composition of the soil, as well as the observation of phenological stages of the crops. The obtained results point out to the possibility of wastewater use in agriculture under natural conditions of Vojvodina, without significant disadvantages.

1 INTRODUCTION

In many countries water is becoming an increasingly scarce resource and planners are forced to consider any sources of water which might be used economically and effectively to promote further development. At the same time, with population expanding at a high rate, the need for increased food production is apparent. Interest in irrigation with wastewater has not been confined to countries with arid climate. Increasing interest is being taken also as an ecologically satisfactory solution (Pescod, 1992). Along the same line, it is necessary, wherever it is possible, to dispose wastewater on the soil surface. Such undertakings are to be considered not only as a measure aiming at decreasing moisture deficit in the soil and providing certain crop nutrients, but also as a convenient solution in the environment protection. The applicability of these waters is determined by their characteristics, amounts, the natural characteristics of the region, and the possibility of growing particular crops. The choice of crops depends upon the local pedological, climatic, and market conditions, and especially on the degree of sensitivity of crops to the contents of macro and micro nutrients, as well as to some hazardous components present in these wastewaters (Pescod, 1992; de Hean, 1987).

The choice of the irrigation method is a measure in health protection, along with other measures such as plant selection, wastewater treatments and the control of the exposure of workers to the direct contact with wastewater. Evaluation of certain irrigation methods from the aspect of use of the treated wastewater, based on the analyses of Kandiah (1990), is mentioned by Pescod (1992).

Health protection measures are very important here, and should be included in use of wastewater in agriculture. A combination of health protection measures needs to be taken that will produce overall pathogen reduction and that differ by system component (WHO, 2006).

Monitoring and system assessment, sociocultural and environmental aspects, economic and financial considerations, and policy aspects also should be taken into consideration in case of wastewater use in agriculture (Westcot, 1997).

The success in the use of wastewater in plant production depends on the coordination of the adopted strategies which all aim at the optimum plant production (both quantity and quality), preservation of the productivity of soil and protection of the environment (Belic et al, 1996).

There are different methods of irrigation. Which method will be chosen depends in the first place on finances, but the possible harmful effects of the method have to be taken into account, too (Westcot, 1997; Chang et al, 1995).

Modern management on pig breeding farms in Vojvodina Province introduction of liquid discharge technology conditioned the accumulation of wastewater into lagoon which could be used for irrigation of growing plants. By this land reclamation measure is possible to close production on the farms, having in mind some useful characteristics of this kind wastewater. There are around seventy pig breeding farms in Vojvodina where the daily production of wastewater amounts to 1200m³. This paper shows the results of the analysis of wastewater from these farms and possibility of its reuse in irrigation analyzed on lysimetric station Rimski Sancevi near Novi Sad.

2 MATERIAL AND METHODS

With the aim of obtaining a better insight into the composition of wastewaters from a pig-breeding farm collected into a common lagoon, an investigation has been carried out on lagoon located in Temerin settlement. Close to the farm, a slaughter-house was erected, and the wastewater was collected jointly with that originated from the farm. To determine the characteristics of the wastewater, samples have been taken four times a year during three-year period. In these samples the following parameters were analysed: pH, EC, BOD₅, COD, TDS, alkalinity - m, hardness, HCO₃⁻, CO₃²⁻, SO₄²⁻, Cl⁻, Mg²⁺, Na⁺, K⁺, PO₄³⁻, NH₄⁺, NO₃⁻, N_{org}, and N_{total}. The analyses of these samples were carried out in the laboratory of the Hydro meteorological Institution at Sremska Kamenica, using standard analytical methods. Only part of obtained results is presented here.

In the frame of a complex research project, at the lysimetric station Rimski Sancevi the effect of irrigation with diluted waste water from lagoon on shallow groundwater quality has been studied (lysimeters IV and VII). Lysimetric station - drainage type with continuous levels consists of ten pots. The crops grown in the lysimeters were irrigated with the waste water from lagoon. The irrigating norms were determined on the basis of

bioclimatic coefficient. During the experiments the water table was maintained at a level of 120 cm. In the lysimeters, a soil monolith was formed of the *czernozem* corresponding to the pedological profile of the surrounding soil. Besides, the experiment encompassed some additional investigations concerning the control of microbiological activity of the soil and shallow groundwater, chemical composition of the soil, as well as the observation of phenological stages of the crops.

The changes in mineralization of the shallow groundwater during the investigation period were monitored under the different production conditions (Abramov et al, 1985). In the lysimeters, the following crops were grown: maize, sugar beet, and sunflower. The wastewater for irrigation in the production process was used either concentrated or diluted with 6 parts of pure water. In the case irrigation was carried out with diluted waste water its use was practiced during the growing season, whereas undiluted waste water was used for irrigation before the crops sowing. In both cases, the irrigation with wastewater was treated as addition of nutrients, so that its amounts were determined by the N_{min} method. The amounts of nutrients were different in dependence of the growing variant applied, representing the values characteristic for the conditions of the productions process.

3 RESULTS AND DISCUSSIONS

The results of analysis of the characteristics of wastewaters collected in the lagoon were treated statistically and are presented in table 1. It is evident that there are certain variations in the quality of the analysed wastewaters, which can be generally explained by the effects of particular components of the production processes, as well as by the conditions of collecting and storage of the wastewaters. For the majority of parameters highest seasonal values were registered during spring. Also, it is characteristic that the majority of parameters attained their lowest seasonal values in the autumn period. This points out the importance of climatic factors, primarily of temperature and insolation on the process of stabilisation of the wastewater in the lagoon. This means that increased temperatures in the summer period caused intensification of biological processes, the consequence being lowered values of the majority of parameters in the autumn periods, what is also mentioned by Belic (1997). Analogously, the lower temperatures in the winter period caused a decrease in biological activity, which resulted in increased values of the majority of parameters in spring time. This observation is in agreement with the considerations of Loehr (1974), and Jahic (1990), concerning the effect of climatic factors on the processes of stabilisation of wastewaters in the lagoons.

On the basis of the presented results it can be concluded that the analysed wastewaters from lagoon is weakly alkaline, highly mineralised, and with substantial organic load, which is confirmed by the results of Loehr (1974). Especially characteristic are the chloride and sodium content of inorganic substances, but significant contents of sulphate have also been found.

One of the characteristics of the investigated wastewaters is a high content of nitrogen, whereby highest concentrations are present in form of ammonium, formed by decomposition of organic matter in the presence of bacteria. Naturally, the conditions and duration of wastewater storing in the lagoon influence the value of this parameter.

Table 1: Characteristic values of wastewater parameters

Parameter	Units	Characteristic values				
		min	max.	mean	Spring	Autumn
pH	-	7.30	8.20	-	-	-
EC	$\mu\text{S/cm}$	7400	16000	10910	12730	9610
BOD ₅	mg/L	160	2640	1150	1940	330
COD	mg/L	1520	13700	4990	8740	3520
TDS	mg/L	3800	8550	5620	6210	5450
Alkalinity	mg/L	3110	7900	5030	6010	4030
HCO ₃ ⁻	mg/L	3670	9640	6120	7330	4880
SO ₄ ²⁻	mg/L	38	442	144	189	122
Cl ⁻	mg/L	410	1350	764	752	858
Hardness	°dH	21.20	46.30	31.00	25.80	23.70
Ca	mg/L	87	353	163	227	123
Mg	mg/L	10	296	67	119	28
Na	mg/L	370	1080	660	590	740
K	mg/L	516	1350	740	730	630
Total P	mg/L	17	120	42	60	24
NH ₄ ⁺	mg/L	400	1280	742	978	500
NO ₃ ⁻	mg/L	0	2.06	0.55	0	0.37
Organic N	mg/L	210	900	415	417	484
Total N	mg/L	620	1820	1170	1397	984

Taking into account the above characteristics of the wastewater stored in the lagoon, the question of re-use of these waters arises. The contents of nitrogen, phosphorus and potassium may be a significant source of macro-nutrients for the crops. Also, a high content of organic matter in these wastewaters, being a factor of soil fertility, can contribute significantly to the increase in crop yields, which may be one of the main goals of their utilisation.

Apart from the usually known problems that may arise when using a bad-quality water (increased salinity and permeability of the soil, and toxicity to crops), sodium contents in these wastewaters could cause most serious problems with regard to their utilisation for irrigation purposes. The hazardous effect of sodium is evidenced by its toxicity to crops, when it is accumulated either from water or from the soil at such concentrations which can cause damages to the crops, and decrease their yields. It should be noticed that sodium toxicity is also influenced by the presence of calcium. Besides, there is an indirect effect of sodium accumulation which is evidenced through the worsening of the physical characteristics of the soil.

The wastewaters from a pig-breeding farm and similar sources may contain different pathogenic micro-organisms which may be hazardous when utilized. However, these problems have not been encompassed by the present investigations.

For successful irrigation with wastewaters, it is necessary to meet the following basic conditions (Westcot, 1997; WHO, 2006):

- application of the optimum amount of wastewater
- acceptable quality of wastewater
- proper timing for irrigation
- appropriate method of irrigation
- prevention of the accumulation of salts around the root of the plant
- prevention by drainage of the rising of the level of groundwater
- maintenance of the optimum level of nutritious substances necessary for the plant

The choice of the irrigation method depends on the following factors (Westcot, 1997; Chang *et al*, 1995):

- choice of the plants
- part of the plant, which is in direct contact with wastewater
- distribution of water, salts and pollutants in the soil
- water potential of the soil
- efficiency of the application of the method
- its possible undesirable effects on people and environment

During the investigation period the wastewater used for irrigation at the lysimetric station was characterized by a pH value in the range 7.1-7.8. However, the shallow groundwater in the lysimeters, irrespective of the production conditions and the quality of nutrients added exhibited significantly higher pH values, being in the range of 7.6-8.8. The lowest pH values were measured in the filtered water of the control vessels in which a grass mixture was grown.

Electrical conductivity of the well water (EC_w) was 634 $\mu S/cm$. In contrast to this relatively low value, the shallow groundwater was characterized by significantly higher average values, ranging from 817 to 925 $\mu S/cm$. It can be noticed that in the experiment variants involving higher doses of nutrients the values of electrical conductivity of filtered water showed an increase. By analyzing total dissolved solids (TDS) a similar conclusion may be drawn as from the analysis of the EC_w values, whereby it should be mentioned that in the variant of the vessels IV and VII, where largest quantities of waste water were added in the beginning of the irrigation cycle, the TDS parameter had the highest values.

Content of calcium in shallow groundwater was the range of 0.97-5.38 meq, whereas this parameter for the well water was in the range of 3.63-4.48 meq. The highest average value (3.72 meq) was measured in the vessels I and X, as in the case of the previous parameters, and the lowest values in the vessels V and VI. In contrast to calcium, the analysis of magnesium content in the shallow groundwater did not show a tendency to be related to the production conditions. Magnesium content was in the range of 1.42-6.61 meq, whereas the average values were in the range of 3.05-4.03 meq. In the well water used for irrigation magnesium content was lower, the average value being 1.99 meq.

Sodium content in the shallow groundwater, with the average values being in the range of 2.51-3.85 meq was higher than that in the well water (1.01 meq). Although the measured extreme value amounted to 6 meq, it may be concluded that the value of sodium adsorption ratio (SAR) was below its critical value.

In the shallow groundwater, chloride content was in the range of 0.14-2.68 meq, whereas the average value of this parameter for well water was 0.70 meq, the range

being 0.37-0.82 meq. If mean values of chloride content are considered in relation to the experimental variant it can be noticed that the highest chloride contents were measured for the vessels IV and VII.

Sulphates content in the filtered water from the lysimeters were in the range of 0.94-7.35 meq, the highest mean values of 3.01 meq being registered in the experimental variants in the vessels I and X, and the lowest (1.51 meq) in the lysimeters with grass mixture. Content of sulphates was much lower in the well water, and the average value was 0.04 meq.

4 CONCLUSIONS

The amounts and properties of wastewaters from lagoon analysed during a three-year period indicate the need and the possibility of their utilisation for irrigation purposes, which should be accompanied by control measurements. This way it would be possible to ensure crop supply with nutrients, decrease of moisture shortage in the soil, environmental protection, and achieve significant economic effects.

However, the use of these wastewaters should be realised with additional precautions. Traditional requirements in respect of the quality of water for irrigation and the common classification methods are not sufficient. Neither, they can be applied in full in these instances as changed circumstances would require some additional criteria and restrictions. In this respect it would be necessary to point out that if irrigation requirements have been satisfied for a given location, this does not mean that these wastewaters can be used on another location, too. In other words, detailed analyses are needed concerning the specific local conditions.

Also, the obtained results from the lysimetric station point out to the possibility of closing the production circle on the farm without significant disadvantages to the quality of groundwater resources. The usage of wastewater for irrigation, under the controlled conditions of lysimetric station, indicates that pollution of shallow groundwater thus induced is not more significant than that caused by the unused (by plants) rationally introduced mineral nutrients. A rich microbiological activity in the soil, which can be considered a consequence of wastewater application for irrigation, as well as the economic effect lead to the serious consideration of introducing into a wider production such way of farming.

By analyzing the change in the quality of shallow groundwater in the lysimeters under conditions of growing maize and sunflower using the characteristic doses of fertilizers and waste water for irrigation it can be concluded that the mode of soil utilization can have a significant effect on the changes of the quality of shallow groundwater. A decisive role in this respect has the soil characteristics. The changes in shallow groundwater quality as a consequence of using wastewater, either in concentrated or diluted state, for irrigation purpose are not more pronounced than those observed when applying mineral fertilizers. This conclusion indicates the possibility that such a use of waste water may be considered as a solution acceptable from the environmental point of view, as far as the protection of shallow groundwater quality in agricultural areas is concerned. Besides, significant savings are thus achieved, as substantial amounts of nutrients, needed for crop growth and development, are introduced with the wastewater into the soil.

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