Geo-management in organic agriculture

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5.3. The research of possibility of using sewage of urbosystem in forage crop rotation for organic livestock farming

Modern development of society is characterized by significant negative changes in water environment, which is caused by uncontrolled use of water resources. Continental surface water is the most unprotected element of hydrosphere, therefore, the overall scarcity, gradual depletion and intense pollution of surface waters may be observed in many countries of the world. At the present stage, humankind has faced the problem of the limited quantity and quality of this strategic resource. Despite the fact that the total volume of water on the planet is 1385 mln m^3, only a small part of it is suitable for human use [1]. This volume depends on the total amount of water resource stocks and the recovery rate of a source of freshwater in the process of global hydrological cycle.

The matter of quality of the aquatic environment becomes particularly important due to the intensive development of urban agglomerations. Since the functioning of urban ecosystems is a powerful factor in the destruction of hydro ecosystems, which is intensified due to the influence of wastewater and surface sewage during snow melting and rainfalls. This matter of pollution of water course is particularly acute in the lower areas of the flow of the Dnieper river, where almost all natural and human-made components of the river runoff, which change the hydrological and hydrochemical regime of the reservoir, are accumulated. Man-made reservoirs in the middle and lower parts of the Dnieper, which constitute an intensive source of secondary detritus production of organics, cause additional matter for local hydro ecosystems.

Considering low water supply with local water resources (1 thous. m^3 per year per inhabitant) and discharge of sewage, which is purified and treated to standard quality, to the waters of the Dnieper river within Kherson city, we offer water protection measures for polishing treatment and reuse of surface sewage of Kherson city for subsurface irrigation of agricultural crops in urban and suburban lands. World and domestic practice of applying sewage in agriculture shows a constant increase of its proportion in irrigation, which provides increase of crop yielding capacity, improvement of the environmental status of rivers due to elimination of discharges of urban sewage, and saving fresh water.According to data of the International Water Management Institute (IWMI) irrigation with sewage covers about 20 million hectares of land, which constitutes 7.1% of the total irrigation area. The example of effective use of sewage in irrigation of agricultural crops is Israel: 90% of 500 mln m^3 of the generated sewage is purified to the intermediate and high level for irrigation of vegetables, forage crops [2].

Kherson region has a great potential of land and climatic resources for growing environmentally safe agricultural products and developing organic farming. The ecological and economic analysis of the current state of development of organic agricultural production indicates increase of certified land areas to 92.1 hectares, increase of the domestic consumer market and volumes of sales of manufactured products, rise of consumption culture of food products and growth of interest in their quality. Such a situation of intensive development of organic farming is caused by the improvement of soil fertility due to refusal of using mineral fertilizers, pesticides and herbicides, reduction of propagation of pesticides and disease of population [3]. In addition, the development of organic farming coordinates environmental social and economic directions in the agrarian sector of economy; it is a priority factor of constant development of urban and suburban areas. However, despite significant benefits, organic farming is a water industry. Agricultural production accounts for 86% of water footprint. At the same time, the volume of water required for growing organic agricultural products is received due to:

- green water resources are the indicators of use of rainwater that evaporates and is absorbed by crops during growing;
- blue water resources are the indicators of use of surface or ground water for growing agricultural crops, the volume of which should not exceed the amount of available local water resources;
- grey water resources are the indicators of water use for dilution of pollutants, which enter the natural aquatic ecosystems as a result of anthropogenic activities, to get water quality criterion

that meets the established international, national standards and regulations.

Under conditions of growing of organic yield of crops the figures of the grey water footprint will be minimum due to use of only organic fertilizers, the main pollutant of which will be natural nitrogen [4].

High figures of water footprint are the indicators of irrational use of water resources and its distribution in terms of space and time. They are caused by the lack of material resources for use of water-efficient technologies and unfavourable pricing policy for water. The condition required for trade of virtual water is the value of the water scarcity index (I_{ws}) that is calculated by the formula [4]:

$$I_{ws} = \frac{V}{V_n}, \quad (5.2)$$

where *V*- the total volume of fresh water used in the region, m^3/year;

V_n - the need for water for various purposes, m^3/year.

At the same time, the resources of the local river runoff are not always the priority indicators of obtaining water-containing organic products. The green footprint is the most commonly used in organic farming. It depends on the average annual rainfall and available moisture for agricultural crops. Its figures are less than the total amount of rainfall due to evaporation, infiltration into the soil and formation of surface water of the territory. Therefore, the necessity for irrigating agricultural crops is defined as the difference between the volume of water required for growing organic crops and the potential amount of rainfall that is absorbed by plants [5]:

$$IR = CWR - Peff \quad (5.3)$$

Surface water is most commonly used among the types of virtual water in the studied region. In this case, it is necessary to use large volumes of water, the source of which is mainly the Dnieper River. Only 50 % of the total amount of surface water taken for the needs of agriculture in the amount of 913.8 mln m^3 is returned to the environment. It is restored in the process of the global hydrological cycle. However, the high rates of export of virtual water (95.6 mln m^3) are observed despite the limited water resources, low water availability and dry climatic conditions in the Kherson region. The crops with the largest need for water footprint are the main agricultural products that are exported. So, 1000 m^3 of water that is removed beyond the boundaries of the studied area is required for growing 1 kg of cereal crops, herewith a tendency for negative water balance is formed. About 10 % of virtual water comes to other countries and the import of virtual water is only 0.02 %.

Therefore, the development of organic agriculture in conditions of dry climate and limited water resources is be aimed at reducing water dependence through import of water-containing products, use of the latest water-efficient technologies and alternative sources of irrigation. Implementation of management of rational use of water resources will ensure development of the water sector and organic agricultural industry, improvement of quality of life of society, rational use and preservation of water resources of the Dnieper River [6]. In this case the effective direction of agricultural industry is the provision of reduction of the content of virtual water in organic products through optimized rotation and application of resource-saving crop irrigation regimes. We offer application of surface sewage that is treated to regulatory standards. It will increase ecological, social and economical effects in organic farming, increase the volumes of virtual water content without changing the indicators of water consumption during growing of organic products, as alternative sources of irrigation (Fig. 5.9).

The water suitability for irrigation is determined by mineralization, calcium indicator, pH, toxic alkalinity, total chlorine content, chemical compounds, rate of ion exchange and pathogenic microorganisms. According to the standard DSTU 2730:2015 «Environmental protection.The quality of natural water for irrigation. Agronomic criteria» the water for irrigation has three degrees of suitability:

1st degree: suitable, accompanied by changes in the ionic-salt composition of soils, but these changes do not lead to increase of

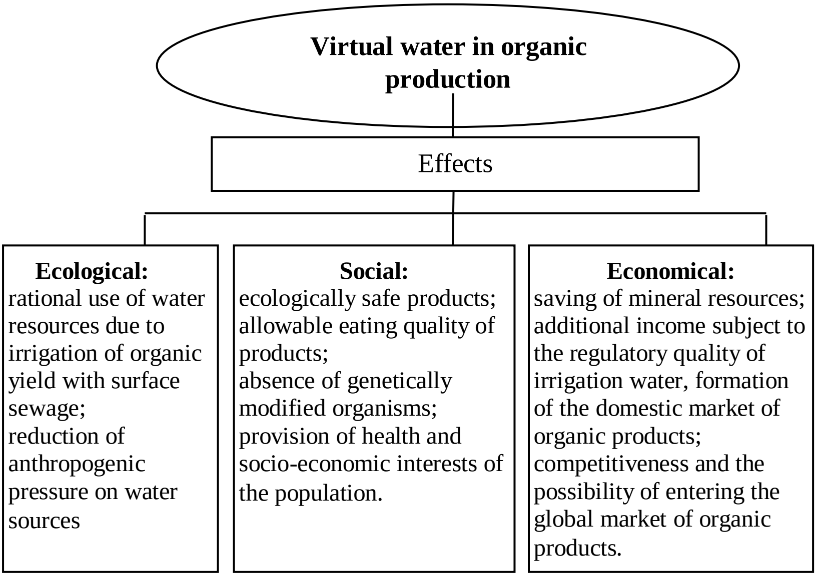

Fig. 5.9. Possible effects of application of surface sewage under the conditions of organic farming development

salt content, the sum of exchangeable sodium and potassium, alkalinity;

2nd degree: limited suitable water is available subject to constant monitoring of directions of soil processes and if a complex of agro-amelioration measures is applied;

3rd degree: unsuitable for regular irrigation, even if a complex of agro-amelioration measures is applied. At the same time, assessment of water for irrigation according to agronomic criteria is important for systems and sources of artificial irrigation, which are aimed at preserving soil fertility and quality of agricultural plants.

Sewage having amelioration and fertilizing value due to contents of 15-88 kg of nitrogen, 16-18 kg of potassium, 12-16 kg of phosphorus, 20-150 kg of calcium and magnesium in 1000 m^3 of sewage facilitates increase of crop yielding capacity with limiting nutrient elements, improve the qualitative characteristics of soil and organic agricultural products, provides obtaining of additional income in growing of winter wheat in the amount of 154.7 UAH/ha, spring wheat - 108.8 UAH/ha, maize grain - 186.5 UAH/ha, forage maize - 816.3 UAH/ha, sugar beets - 184.9 UAH/ha, sunflower - 202.1 UAH/ha [7]. It is determined in the direction of studying the possibilities of irrigation with such waters that the volume of annual formation of sewage surface urban runoffs of urban system Kherson of is 20.5 mln m^3.

The matter of reduction of the negative impact of runoff through collecting and using purified sewage for subsoil irrigation in the organic farming system is quite important. The expediency of application of sewage in agriculture in Ukraine is confirmed by the results of researches in the 90's of the last century. 1% of their volume was used in such a way. According to the preliminary data of the researchers, it is established that due to the deficit of local water resources the use of sewage surface runoff, which is purified according to the regulatory requirements, will allow to irrigate up to 1 mln ha of land for farming [8].

It is appropriate to use water prepared for irrigation near big cities and villages. According to the quality assessment of sewage runoff based on DSTU 2730:2015, it is established that water is suitable for irrigation subject to obligatory preliminary improvement (Table 5.6, Table 5.7).

Table 5.6

Salt composition of sewage of Kherson city

Years Season	Salt composition, mg/l						
	Cl	SO_4	HCO_3	Ca	Mg	Na+K	minera-lization
May2016	378.0	145.0	118.5	117.0	5.0	215	1170
June2016	381.0	159.0	517.9	211.0	3.0	270.0	1390
July2016	376.0	141.0	448.7	179.0	5.0	265.0	1040
August2016	290.0	165.0	738.4	205.0	4.0	302.0	1090
$\overline{x}$	356.2	152.5	455.7	178.0	4.2	263.0	1172.5
June2017	325.0	185.0	593.3	135.0	4.0	360.0	1470
July2017	390.0	190.0	403.2	89.0	7.0	380.0	1340
August2017	420.0	190.0	480.0	116.0	3.0	405.0	1500
$\overline{x}$	378.3	188.0	492.0	113.3	4.6	381.6	1436

Table 5.7

Suitability assessment of purified sewage according to agronomic criteria

Years season	Assessment as per indicators of DSTU 2730 : 2015					
	Na+K / Na+K+Ca +Mg	Mg / Ca	Cl	overall alkalinity / HCO_3	toxic alkalinity / HCO_3-Ca	Quality degree
May2016	60	0.07	10.66	1.94	3.91	2
June2016	52	0.02	10.74	8.49	2.06	2
July m2016	55	0.05	10.60	7.36	1.59	2
August	55	0.03	8.18	12.11	1.86	2
$\overline{x}$	55	0.04	10.04	7.47	1.43	2
June2017	69	0.05	9.17	9.73	2.98	2
July2017	77	0.13	10.00	6.61	2.16	2
August 2017	74	0.04	9.84	7.87	2.07	2
$\overline{x}$	73	0.07	7.67	8.07	2.40	2

The change of the hydrochemical properties of sewage runoff is characterized by distinct seasonal dynamics that is caused by change of volume of water use in household activities of population. Removal of the dry residues (salts, soil and sand components, biogenic-detrital particles) through the treatment systems in the autumn period is by 1.4 times lower than in summer period. Therefore, the efficiency of the treatment systems in Kherson city is 50.0-97.0% according to the difference in the parameters of the hydrochemical properties regarding entering and discharge of sewage. The results of the analysis of the hydrochemical characteristics of the status of purified sewage runoff at the discharge spot indicate significant reduction of pollutants that enter the treatment systems with the sewage water.

It is established that water belongs to the second degree of suitability according to the performed assessment of the suitability of sewage water according to agronomic criteria for irrigation of cereal forage organic products. At the same time it is necessary to carry out polishing treatment through engineering infiltration facilities of a constructed wetland. The effectiveness of such biological polishing treatment is 80%. In order to avoid emergencies, it is necessary to build an emergency discharging containment pond that is able to accumulate and contain 5-7days city's runoff under insignificant daily volumes of sewage (45-50 thousand m^3). The emergency can be eliminated and the operation of the city's treatment system can be resumed during this time. After that, the sewage of constructed wetland is to be redirected for polishing treatment. It is also proposed to construct local treatment plants for mechanical treatment with the subsequent directing of surface rainfalls for polishing treatment at the municipal wastewater treatment plants, and afterwards - to a constructed wetland.

The prevalence of Na^+ and Cl^- in sewage indicates alkalinization and salinization of soil, so it is necessary to apply gypsum. In addition, the matter of choice of crop rotation using resource-saving irrigation regimes is quite important. It will reduce the environmental pressure on soil and save local water resources.

Tabl.5.8 shows the cereal and forage crop rotation, resource and energy-saving irrigation regulations that are adapted to local conditions.

Table 5.8

Cereal and forage crop rotation of agricultural crops with subsequent verification of their quality for organic livestock farming

No.	Rotation of agricultural crops	Irrigation rate m^3/ha
1	Alfalfa	3000
2	Alfalfa	2700
3	Winter wheat	1050
	Grass-legume mixture	1150
4	Grain maze	1250
5	Grain maze	1250
6	Spring wheat	1150
	Additional sowing of alfalfa	900

In addition, the structure of sown areas and the principles of crop rotation of irrigation systems with sewage differ from crop rotation of systems that use water from natural sources for irrigation. Alfalfa and forage agricultural crops are the most productive and resistant toharsh environment. Therefore, organic agricultural crops are to be grown subject to complete decontamination of biological components contained in sewage, and the animals are fed with plant products after silage making or heat treatment.

Forage crops constitute 33% and cereal crops constitute 67% in the offered structure of crop areas. At the same time, soil is additionally enriched with organic matter due to field residues. The average weighted net irrigation requirement is 2079 m^3/ha, considering the efficiency of the closed irrigation system (ŋ = 0.96, gross rate considering water losses - 2165 m^3/ha.).8314 ha may be irrigated according to the established volume of sewage water (18 mln m^3). The irrigated area can be increased to 9468 hectares, considering the additional surface rainfall runoff in the volume 2.5 mln m^3 per year.

The use of resource-saving crop irrigation regimes is one of the methods of optimization of irrigation. It is appropriate under conditions of water resource deficit and insufficient natural humidification of the studied territory. It provides effective absorption of nutrients and decomposition of pollutants within 20 days [2].

Considering the large capacity of virtual water in organic production in growing of agricultural crops with limited number of local water resources, the use of surface sewage water for their irrigation is a favourable alternative source. It is established that water belongs to the 2nd degree of suitability according to the performed assessment of suitability of surface sewage that is treated at urban wastewater treatment plants as per agronomic criteria. Therefore, it is necessary to improve its qualitative characteristics based on implementation of environmentally effective measures - biological polishing treatment of surface sewage on constructed wetland for the practical use of sewage in organic farming. Grown organic forage products can be used in livestock farming upon condition of thermal processing and silage making, which will allow to preserve quality of livestock products.

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