Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2023.29379

288 (2023) 159–164
March

Municipal wastewater management in Ukraine

Igor Vasylkivskyi[a], Vitalii Ishchenko[a], Halyna Sakalova[b,*], Garcia Camacho Hernan Ullianodt[a], Stepan Polyvanyi[b]

[a]*Department of Ecology, Chemistry and Environmental Protection Technologies, Vinnytsia National Technical University, Khmelnytske Shose 95, Vinnnytsia, Ukraine*
[b]*Department of Chemistry and Methods of Teaching Chemistry, Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Ostrozkoho St. 32, Vinnytsia, Ukraine, email: sakalovag@gmail.com (H. Sakalova)*

Received 20 January 2023; Accepted 10 February 2023

ABSTRACT

Efficient wastewater management is crucial for water quality and thus for ecosystem health in every country. Today, a large volume of untreated or insufficiently treated wastewater is discharged into natural waters annually in Ukraine. Over 13 million rural Ukrainian residents do not have an access to wastewater treatment facilities. 25,611 rural settlements (98%) do not have sewage systems. A total of 1,292 settlements in Ukraine (only about 5%) are provided with sewage systems. There are no sewage systems in some small towns, as well as in most private buildings of larger cities. A case study of wastewater management in Southern Bug Basin was analyzed. Over one million people in rural areas of Southern Bug Basin discharge household wastewater without any treatment. The annual volume of wastewater discharged in Vinnytsia region located in Southern Bug Basin is accounted for around 60 million m^3. Only 47% of this amount is treated. The main source of household wastewater in the Southern Bug Basin is the regional centers – Mykolayiv, Vinnytsia, and Khmelnytskyi. The analysis of water in three control sites in the Southern Bug Basin near Vinnytsia shows accumulation of nitrites in the water as the biggest problem for Southern Bug River since nitrites content exceeds the limit in all control sites.

Keywords: Wastewater; Southern Bug; Ukraine; Wastewater management; Municipal wastewater

1. Introduction

Water quality is the fundament of people health. The quality of natural waters changes significantly as a result of river pollution by wastewater from industry and households, surface runoff from farmlands, villages, towns, roads, etc. The ecological condition of rivers depends on the pattern of natural resource use and wastewater management. An important task is the treatment of wastewater discharged into small rivers. Small rivers determine the water regime, hydrological and hydrochemical indicators of medium and large rivers [1]. There is research on the water quality of Ukrainian rivers – not only the largest rivers (Dnipro, Dnister), but also smaller rivers like Ingul [2], Southern Bug [3,4]. The results indicate significant pollution of water environment, which is also caused by improper wastewater treatment. Today, more than 20 km^3 of wastewater are discharged annually in Ukraine both from industry [5] and households, of which almost 6 km^3 are untreated or insufficiently treated [6]. A significant share is related to municipal wastewater. Municipal wastewater often contains many chemicals [7], soluble organic substances and suspensions, which causes a decrease in the oxygen content in water resulting in significant degradation of ecosystems. The most common methods of wastewater treatment are aerobic and anaerobic treatment [8]. Modern municipal wastewater treatment requires

* Corresponding author.

Presented at the 15th Scientific Conference on Micropollutants in the Human Environment, 14–16 September 2022, Częstochowa, Poland

significant investments. Since it is non-profit business [9], the costs should be taken from local budgets which are often very limited (especially in developing countries). As a result, wastewater treatment plants in many municipalities are either inefficient or even do not exist. Many studies [10–13] show that the most effective wastewater treatment is that implemented taking into account a multi-criteria approach to the selection of the necessary equipment and the availability of a correct sewer system.

Municipal wastewater management has been studied by many authors in different countries. There are some similar shortcomings like underdeveloped sewers and sludge disposal facilities, low sustainability of the treatment processes, questionable wastewater treatment plant effluent discharge standards, and lacking global thinking on harmonious development between wastewater management, human society and the nature [14]. Low efficiency of municipal wastewater treatment is among the most susceptible environmental challenges in developing countries. In India, 70% of sewage from cities remained untreated [15]. Many other studies [16–18] also prove the low-efficient wastewater treatment resulting in enormous water pollution. Also, in Ukraine, the environment is polluted due to the damage of wastewater management infrastructure and sewage leaks [19]. According to Ukrainian "Water code of laws", wastewater discharging to water objects is allowed only if pollutant concentration is below the limit. Wastewater discharging has to be prevented in case of wrong operation of wastewater treatment facilities. Therefore, the goal of this work is to assess municipal wastewater management in Ukraine.

2. Results and discussions

2.1. Wastewater management

The volume of municipal wastewater is in direct dependence from population. In Ukraine, the distribution between urban and rural population also influence wastewater amount. Population of administrative regions in Ukraine is not uniform (Table 1). Urban population prevails significantly in industrial regions (Dnipropetrovsk, Kharkiv regions, etc.), while other regions have more or less equal distribution.

Urban population usually generates much more wastewater amount and diversity requiring more sophisticated methods of wastewater treatment. While rural population in Ukraine usually generates much smaller wastewater volume but is not provided with sewer systems.

There are around 3,000 wastewater treatment plants in Ukraine (including industry) with capacity of 17 million m^3/d. Most of them were built more than 50 y ago and are thus of low efficiency. There are no reliable data on the quality and efficiency of wastewater treatment plants. Overall situation of water supply and municipal wastewater treatment can be seen from Figs. 1 and 2 (the data retrieved from [20]).

As one can see, the most pressing situation is in rural area and small towns: over 13 million rural residents do not have an access to wastewater treatment facilities. 25,611 rural settlements (98%) do not have sewage systems. A total of 1,292 settlements in Ukraine (only about 5%) are provided with sewage systems. Besides, there are no sewage systems in some small towns, as well as in most private buildings of larger cities. Chernivtsi, Luhansk, Ternopil and Kirovohrad regions are among the least provided with wastewater treatment facilities.

European countries apply the "polluter pay" principle in their national legislation on environmental protection. According to this principle, individuals and companies responsible for pollution must provide funds for measures to avoid or reduce pollution. Therefore, a fair fee for wastewater treatment is a necessary condition to protect the environment and maintain the quality of water ecosystems. There is a fee for wastewater collection in Ukraine. However, the cost distribution is unclear. If the costs are intended only for wastewater collection, without treatment, then the process of water treatment is obviously free. Free wastewater treatment leads to the discharge of untreated wastewater and the lack of funds for the reconstruction of old and outdated wastewater treatment plants.

Control of water quality in Ukraine is provided by periodic sampling and analysis of surface water. The number and location of samples are determined depending on the hydrological and sanitary characteristics of water bodies and are coordinated with local authorities. At the same

Table 1
Population in Ukraine, 2021

Administrative region	Population		
	Total	Urban population	Rural population
Vinnytsia	1,545,416	799,385	746,031
Volyn	1,031,421	539,179	492,242
Dnipropetrovsk	3,176,648	2,668,744	507,904
Donetsk	4,131,808	3,754,349	377,459
Zhytomyr	1,208,212	716,457	491,755
Zakarpatska	1,253,791	465,904	787,887
Zaporizhzhia	1,687,401	1,306,231	381,170
Ivano-Frankivsk	1,368,097	606,764	761,333
Kyiv	1,781,044	1,105,383	675,661
Kirovohrad	933,109	591,944	341,165
Luhansk	2,135,913	1,859,590	276,323
Lviv	2,512,084	1,534,040	978,044
Mykolaiv	1,119,862	768,022	351,840
Odesa	2,377,230	1,597,062	780,168
Poltava	1,386,978	867,201	519,777
Rivne	1,152,961	548,088	604,873
Sumy	1,068,247	741,430	326,817
Ternopil	1,038,695	473,727	564,968
Kharkiv	2,658,461	2,158,121	500,340
Kherson	1,027,913	631,317	396,596
Khmelnytskyi	1,254,702	720,752	533,950
Cherkasy	1,192,137	678,682	513,455
Chernivtsi	901,632	390,551	511,081
Chernihiv	991,294	649,063	342,231
Crimea*	–	–	–
Ukraine	44,256,964	30,735,929	13,521,035

*Data are not available.

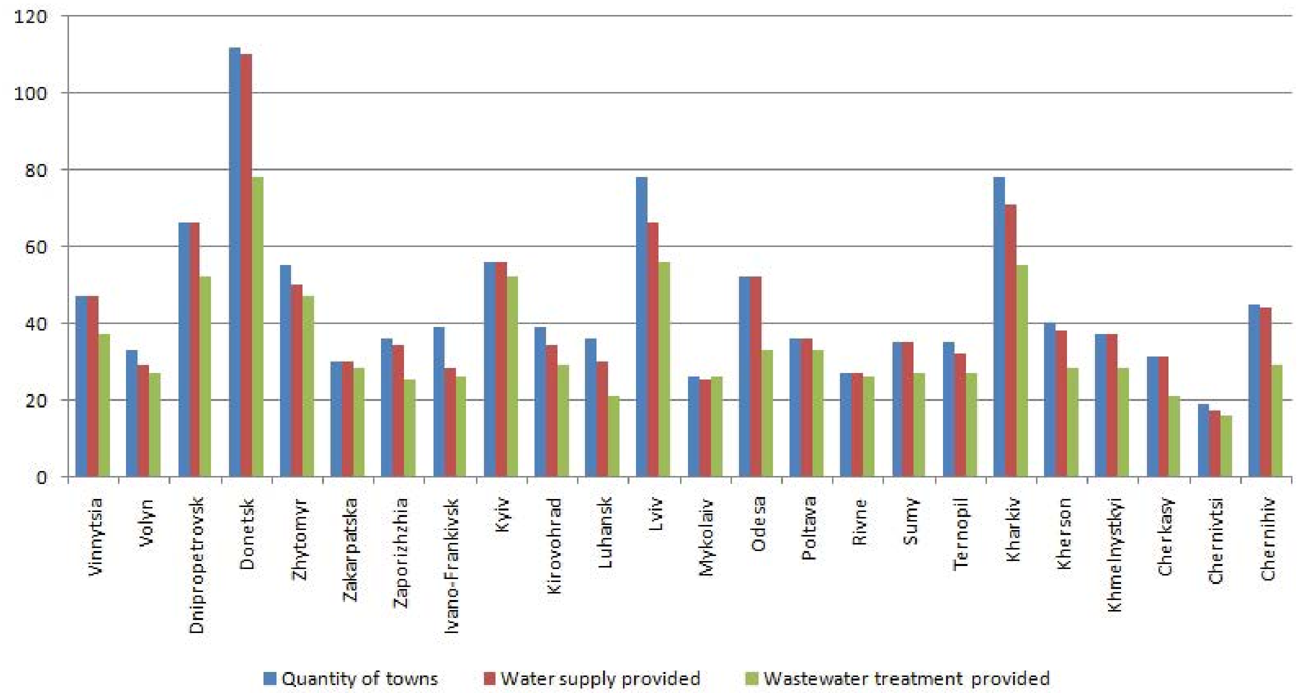

Fig. 1. Water supply and municipal wastewater treatment in Ukrainian regions (towns).

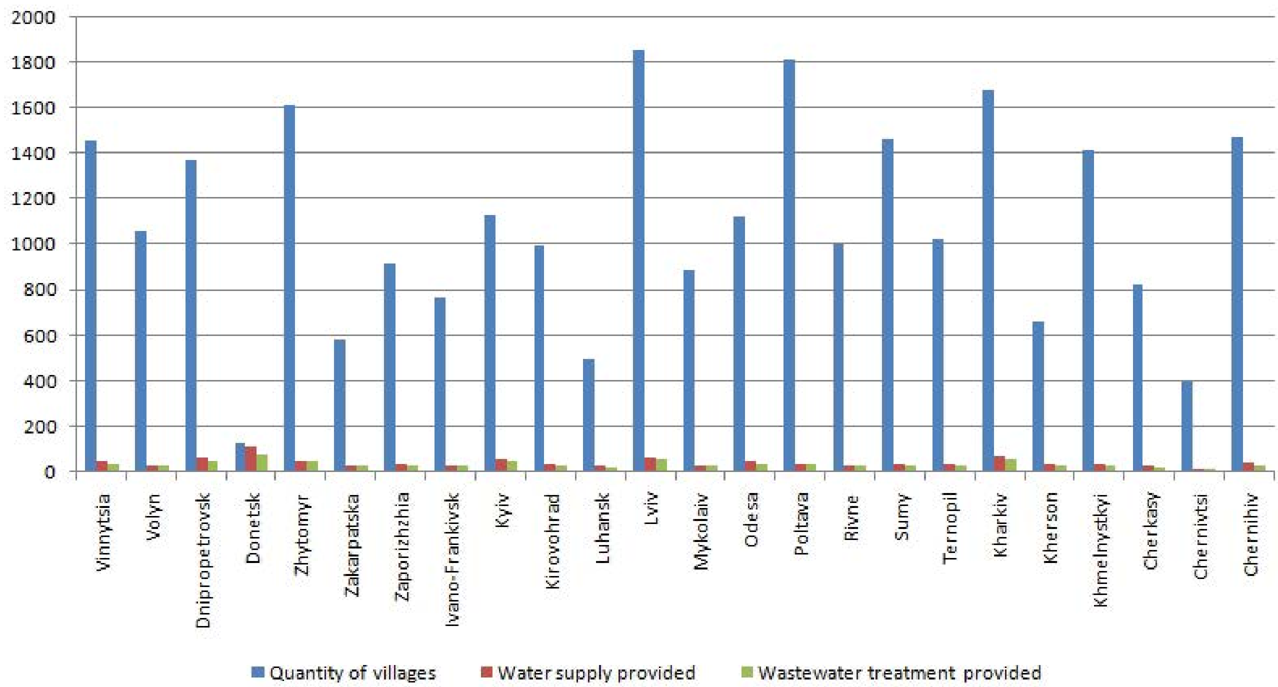

Fig. 2. Water supply and municipal wastewater treatment in Ukrainian regions (villages).

time, it is mandatory to take samples at the drinking water sources and 1 km upstream.

According to [21], the following parameters are controlled in wastewater: chemical oxygen demand, biological oxygen demand, suspended solids, chlorides, sulfates, ammonium nitrogen, nitrites, nitrates, oil products, fats, synthetic surfactants, phosphates, sulfides, total iron, chromium(III), zinc, copper, nickel.

Wastewater in Ukraine is treated mainly by old equipment. Usually, technologies used include flotation, sedimentation, and aerobic treatment. As a result of such a treatment, a large volumes of sewage sludge is generated. The use of sewage sludge as organic fertilizer is the most common method and requires a mandatory preliminary assessment of possible harmful substances (including heavy metals) accumulation in the soil after the fertilization. The quality of sewage sludge used as fertilizer is regulated by chemical, bacteriological and parasitological indicators. However, this method has a number of disadvantages: (1) according to technological regulations, decontamination and disinfection of sewage sludge is carried out by its placing on special sludge sites for at least 3 y, which contributes to the spread of unpleasant odors, etc.; (2) application of sewage sludge as fertilizers increases the background content of heavy metals in the soil.

2.2. Wastewater management: a case study of Southern Bug Basin

A distinctive feature of the Southern Bug River is very high level of water regulation. Southern Bug itself has 16 water reservoirs with a capacity of 316 million m^3. They are used for hydropower, water supply and recreation. In the Southern Bug Basin, there are 170 water reservoirs with a capacity of 578 million m^3, total surface area of almost 30,000 ha, and more than 10,000 artificial reservoirs (ponds) with a total area of over 56,400 ha and a total volume of 644 million m^3. This amount is almost equal to the Southern Bug streamflow value in a low-water year with 95th percentile of the flow duration curve. Dams or fish farming ponds are constructed at all the small rivers and streams in the basin of Southern Bug. This increases the volume of water evaporation and water pollution. Water from fishing ponds is discharged only during fishing period. As a result, the basins of small rivers and streams are excluded from the area of the Southern Bug Basin [22].

The centralized water supply and the availability of wastewater treatment facilities in Southern Bug Basin can be found in Table 2 (Khmelnytskyi, Vinnytsia, Kirovohrad, and Mykolayiv regions). Analysis shows that the majority of rural population do not have the access to sewage systems and wastewater treatment facilities.

Household wastewater treatment facilities in the region under consideration were built in the 1960s and 1970s. Therefore, they are morally and physically outdated and do not fulfill water protection requirements. Even assuming that these facilities still provide normal wastewater treatment, more than 1 million people in rural areas of Southern Bug Basin discharge household wastewater without any treatment. That significantly affects water pollution.

Particular attention should be paid to the lack of modern stormwater sewers for collecting runoff from settlements and farmlands, which is mainly contaminated with heavy metals, fertilizer residues and pesticides.

Landfills are another unsolved issue in terms of water pollution. Steady increase in solid waste accumulation at landfills in Southern Bug Basin and lack of landfill leachate treatment are additional significant source of river pollution.

The quality of water supply and wastewater treatment in Southern Bug Basin is extremely important because it affects people health, conservation of biodiversity and ecosystems in river basin.

The annual volume of wastewater discharged in Vinnytsia region located in Southern Bug Basin is accounted for around 60 million m^3. Only 47% of this amount is treated: in 2019, 28.1 million m^3 of wastewater was processed at biological treatment facilities and 0.038 million m^3 of wastewater was treated at physical–chemical treatment facilities. In the same time, some wastewater was reported as contaminated and uncategorized –0.67 million m^3 and 0.89 million m^3, respectively. These constitute around 3% of total wastewater volume.

The main source of household wastewater in the Southern Bug Basin is the regional centers – Mykolayiv, Vinnytsia, and Khmelnytskyi (total population of about 1.2 million). For example, in Vinnytsia, the average daily load on the wastewater treatment plant is about 85,000 m^3 (55% of total capacity).

In the basin of Southern Bug River, within the Vinnytsia region (352 km length of the river within the region), there are only 12 permanent sampling sites for hydrochemical parameters. Obviously, this is not enough for efficient control of water quality.

The quality of water in the Southern Bug River is presented in the Tables 2–4. There are three control sites: (1) Stryzhavka village, Vinnytsia region, 5 km upstream before Vinnytsia; (2) drinking water source, Vinnytsia; (3) 1 km downstream after Vinnytsia.

Table 2
Pollution parameters of the Southern Bug River, control site 1 [23]

Parameter	Limit	Value (average annual)
Turbidity, mg/L	1.5	2
Color, °	35	24.5
pH	8.5	7.6
Hardness, mg/L	7.0	5.9
Chlorides, mg/L	350	27.5
Iron, mg/L	0.3	0.2
Ammonium, mg/L	0.5	0.3
Dissolved O_2, mg/L	>4	9.6
Biochemical oxygen demand, mg/L	6.0	4.6
Solids, mg/L	1,000	322
Sulfates, mg/L	500	24.3
Calcium, mg/L	180	92
Magnesium, mg/L	50	26
Aluminum, mg/L	0.5	0.08
Fluorine, mg/L	1.2	0.065
Nitrites, mg/L	0.08	0.15
Nitrates, mg/L	10.0	1.6
Manganese, mg/L	0.1	0.01
Phosphates, mg/L	3.5	0.22
Zinc, mg/L	5.0	0.0075
Copper, mg/L	1.0	0.0025
Lead, mg/L	0.03	0.0025
Arsenic, mg/L	0.05	Below detection limit
Molybdenum, mg/L	0.25	0.002
Odor, points	<1	1

Table 3
The pollution parameters of the Southern Bug River, control site 2 [23]

Parameter	Limit	Value (average annual)
Turbidity, mg/L	1.5	6.4
Color, degrees	35	30.5
pH	8.5	8
Hardness, mg/L	7.0	6.1
Chlorides, mg/L	350	36
Iron, mg/L	0.3	0.3
Ammonium, mg/L	0.5	0.7
Dissolved O_2, mg/L	>4	7.1
Biochemical oxygen demand, mg/L	6.0	4.2
Solids, mg/L	1,000	227.5
Sulfates, mg/L	500	87
Calcium, mg/L	180	4.4
Magnesium, mg/L	50	2.1
Aluminum, mg/L	0.5	0.015
Fluorine, mg/L	1.2	0.4
Nitrites, mg/L	0.08	0.2
Nitrates, mg/L	10.0	4.1
Manganese, mg/L	0.1	0.2
Phosphates, mg/L	3.5	0.1
Zinc, mg/L	5.0	0.007
Copper, mg/L	1.0	0.022
Lead, mg/L	0.03	0.004
Arsenic, mg/L	0.05	0.009
Molybdenum, mg/L	0.25	0.004
Odor, points	<1	1

Table 4
The pollution parameters of the Southern Bug River, control site 3 [23]

Parameter	Limit	Value (average annual)
Turbidity, mg/L	1.5	4.8
Color, degrees	35	31
pH	8.5	8.3
Hardness, mg/L	7.0	5.1
Chlorides, mg/L	350	34.8
Iron, mg/L	0.3	0.17
Ammonium, mg/L	0.5	0.5
Dissolved O_2, mg/L	>4	7.5
Biochemical oxygen demand, mg/L	6.0	4.4
Solids, mg/L	1,000	43.3
Sulfates, mg/L	500	56.8
Calcium, mg/L	180	75.5
Magnesium, mg/L	50	21.1
Aluminum, mg/L	0.5	0.02
Fluorine, mg/L	1.2	0.2
Nitrites, mg/L	0.08	0.12
Nitrates, mg/L	10.0	2.19
Manganese, mg/L	0.1	0.09
Phosphates, mg/L	3.5	0.3
Zinc, mg/L	5.0	0.002
Copper, mg/L	1.0	0.005
Lead, mg/L	0.03	0.007
Arsenic, mg/L	0.05	below detection limit
Molybdenum, mg/L	0.25	0.001
Odor, points	<1	3

In the control site 1, two parameters (turbidity and nitrites) were found exceeding limits (Table 3). Higher concentration of nitrites (by 1.5 times) in this control site may be associated with the active application of mineral fertilizers (e.g., nitrogen fertilizers) in rural area upstream before Vinnytsia. Another source of nitrites can be the decomposition of plant and animal remains.

The analysis of water quality in this control site indicates a better ecological condition in comparison to other control sites. This can be explained by the distance from industrial facilities and perhaps more intensive self-cleaning process.

As can be seen from Table 4, limits are exceeded for 4 parameters in control site 2: turbidity, ammonium, manganese, nitrites. The increase in turbidity (as in control site 1) is due to the suspended solids of organic and mineral origin. It can be harmful to human health and form toxic substances during chemical water treatment (e.g., chlorination). The ammonium content exceeds the limit by 40% leading to possible negative effect on the respiratory organs. Ammonium is used in the textile, food, and automotive industries. All these industries are found in Vinnytsia region and can be a source of high ammonium concentration in the Southern Bug River. One should note 2 times exceeding of manganese content that may cause liver disease.

Three parameters are found exceeding limits in control site 3: turbidity, nitrites, odor. Multiple exceeding of odor value is not acceptable due to deteriorating the organoleptic properties of water. Similarly to the control site 2, the turbidity index increases by 4 times leading to low quality of water.

The analysis of water in three control sites shows accumulation of nitrites in the water as the biggest problem for Southern Bug River since nitrites content exceeds the limit in all control sites. Comparing to EU countries regulations, nitrites (limit 0.03 mg/L) and ammonium (limit 0.04–0.2 mg/L depending on water object type) are also exceeded, while other parameters are mainly well below the limit.

3. Conclusions

The issue of qualitative water supply and efficient wastewater treatment is extremely relevant for Ukraine and any other country since it affects the quality of life, population morbidity, biodiversity and natural ecosystems conservation. Wastewater treatment facilities must be periodically reconstructed, otherwise the issue of conservation water bodies and human health cannot be resolved.

Most parameters of water pollution in the South Bug River in Vinnytsia region are found within the limits. But there still are some parameters exceeding the limits leading to unacceptable quality of water [24]. The content of nitrites in all control sites was over limit. Among the physical parameters, turbidity and odor have the largest deviations.

Analysis of water pollution in the Southern Bug Basin indicate the necessity of additional measures: infrastructure inventory in the area of sanitary protection of water bodies; strengthening the control over environment protection in industry near water bodies; reconstruction of outdated and construction of new wastewater treatment facilities eliminating the discharge of untreated wastewater.

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