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Original research article

Assessment of drinking water quality as a factor affecting human health in Zhytomyr Region

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ABSTRACT

The objective of the paper is to assess drinking water quality based upon analyses of water quality indexes from different sources in rural settlements of Zhytomyr Region. *Materials and methods:* The research data was taken from the national reports about the environmental situation in Ukraine, national reports about drinking water quality and current water supply state in Ukraine, Zhytomyr sanitary-epidemiological authority reports, and reports of the Zhytomyr main statistics department. The analyzed period was between 2003–2011. During the research the methods of systemic analyses and logical generalization were used to systemize the obtained information. Quantitative and qualitative analyses were used for data assessment.

The dynamics of drinking water qualitative changes of the first and second category, centralized and non-centralized water supply objects in Zhytomyr Region according to the epidemic safety, radiological, sanitary and chemical indexes were assessed. The regions with the highest percentage of negative samples were defined. *Conclusion:* The quality and safety of drinking water; its pollution levels sufficiently influence all physiological and biochemical processes that occur in the human body and negatively impact people's health in Zhytomyr Region. Therefore the morbidity rate is steadily growing and the average life expectancy is stably low. It was found that the state of subsurface water drinking objects' in rural territories of Zhytomyr Region is much worse than all over Ukraine. This advances the demands for implementing innovative technologies, financing the projects of diversification drinking water sources, and raising the rural population's motivation for using the safe drinking water and making healthy choices.

Introduction

Water is of vital importance for the life-sustaining activity of all living beings in the world. The access to safe drinking water is essential to human health; it is one of the basic human rights and the constituent of an effective health protection policy [1, 2]. Its importance and significance are underlined and legislated in the EU Water Framework Directive 2000/60/EC [3], International Decade for Action [4], as well as at a sufficient number of health-and water-oriented international symposiums and conferences [2, 5].

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Nowadays Ukraine has many environmental and health concerns, stipulated by unsatisfactory water conditions and water supplies in rural areas [6, 7, 8].

The topic of rational water consumption connected with the necessity of water saving and ecologization is grounded in the works of Alimov [9], Galushkina [10], Golian [11], Zinovchuk [12], Matzenko [13], Iatzyk [14] and others. The tractates of Goncharuk [15], Zhykinskii et al. [16], Netrobchuk [17], Snizhko [18], Feshchenko [19], Cherniavska and Bondarchuk [20] are dedicated to the problems of assessing drinking water quality and its impact on human health.

The objective of the paper is to assess drinking water quality based upon analyses of water quality indexes from different sources in rural settlements of Zhytomyr Region.

Materials and methods

The research data were taken from the national reports about the environmental situation in Ukraine, national reports about drinking water quality and current water supply condition in Ukraine, Zhytomyr sanitary-epidemiological authority reports, and reports of Zhytomyr main statistics department. The analyzed period was 2003–2011. During the research the methods of systemic analyses and logical generalization were used to systematize the obtained information. Quantitative and qualitative analyses were used for data assessment. Statistical processing was done using MS Excel software.

Results and discussion

It is worth mentioning that the Ukrainian water resources are allocated unequally over the whole territory. Providing water in different regions is caused by an interbasin redistribution factor. Thereby almost all surface water sources, including the first water-bearing bed, are contaminated. The main pollutants are toxic chemicals, petrochemicals, heavy metals and phenols. Only 8% among the full-flowing rivers meet ecological standards, 9% are satisfactorily conditioned, 40% are in a bad (unsatisfactory) condition, 26% are very badly conditioned, and 17% are catastrophic [21]. Thus, 80% of the surface water objects are poorly conditioned [22, 23, 24].

The main problem of Ukrainian rivers is their excessive regularity – reservoir cascade, lakes, losing designated water areas and the absence of coast tree-belt areas. Water reservoirs break down the ecological balance by means of slowing water exchange: compared to a natural environment it is 14–30 times slackened, and in turn this factinitiates the processes of soil salination [22]. Almost 10% of the contaminated water objects are caused by precipitation. The considerable amount of pollutants joins the water objects from the agricultural areas. A strong source of water objects' contamination is chemicals and mineral salts that get through the drainage water and water facilities.

The natural water objects still have the potential for renewing, but their functioning greatly depends upon a rational usage. A hydrological cycle is the effective mechanism of self-renewing.

A number of legislative acts and hygienic norms are being gradually adopted in Ukraine. They are focused on decreasing water pollution and renewing quality control. Thus the state Sanitary norms and rules, "Hygienic Demands for Drinking Water", were adopted in Ukraine, and are aimed at improving the quality of drinking water. The given standards set up the demands for its quality, as well as the rules of an in-process monitoring, state, sanitary and epidemiological compliance monitoring [25].

According to the state sanitary norms and standards, drinking water is water that in its organoleptical, physical, chemical, microbiological, parasitological and radiological indexes meets the state standards, sanitary requirements, and is used for the satisfaction of physiological, sanitary, hygienic, household and domestic usage needs [26].

Zhytomyr Region is situated in the Northwest part of Ukraine, embracing an area of 29.8 thousand km^2, or 4.9% of the whole territory (the 5th place), and is completely situated within the Dnieperland. In comparison with other regions, it belongs to the deficit water area. Geographically, the region's rate of stream flow is rather intermittent – 1.5–2 times higher in the north than in the south. The main source of water supply for the population and multiprofiled enterprises is surface water – up to 90% of the general amount of water diversion. Subsurface waters in the general structure of Zhytomyr Region water consumption make up nearly 10%. Drinking underwater, available for households, drinking and manufacturing needs, is found in 36 areas, and their total storage makes 329,343 min m^3 [24, 27, 28].

As of January 1, 2012, only 174 rural settlements in Zhytomyr Region have water conduits (10.8%), and 27 communities have sewerage systems (or 1.7%). Altogether the percentage of the rural population that employs centralized water supply services is 16.1% [24]. In comparison with all-Ukrainian indexes, the number of rural settlements that have water conduits makes up 22.2%, and only 2.5% have a sewerage system, which is a considerably low index [27].

The data of monitoring the quality of underground water objects in Zhytomyr Region testify to the negative tendency of the deterioration of the water bodies of the first and second categories according to the sanitary, chemical and epidemiological indexes, in spite of the low level of industrial activity in the region (Table 1).

In 2011, the ratio of the examined samples of the first category water bodies that did not pass the sanitary and chemical requirements was 15.5%, and the indexes of epidemic safety were 9.4%. The share of the negative samples in comparison with the previous period has risen considerably: 12.5 points more for the sanitary and chemical indexes – up to the year 2003, and 5.3 points – up to 2010, according to epidemic safety 2.6 points more – up to the year 2003, and 3.3 points – up to 2010.

The biggest deviation percentage for the sanitary and chemical indexes is found in the Berdychiv (33.3%) and Korosten (20%) regions, and considerably exceeds

Table 1 – Water bodies' condition in Zhytomyr Region

Indexes	Years							
	2003	2005	2007	2009	2010	2011		
						Tests number	+/– to 2003	+/– to 2010
The first category water bodies								
Samples examined according to:								
• Sanitary and chemical indexes	165	201	229	166	187	200	35	13
– do not meet the norms[a]	5	10	25	12	19	31	26	12
– negative samples ratio, %	3.0	5.0	11.0	7.2	10.2	15.5	12.5	5.3
• Epidemic safety indexes	161	195	178	142	147	170	9	23
– do not meet the norms[a]	11	22	11	4	9	16	5	7
– negative samples ratio, %	6.8	11.3	6.2	2.8	6.1	9.4	2.6	3.3
The second category water bodies								
Samples examined according to:								
• Sanitary and chemical indexes	658	577	781	622	588	658	0	70
– do not meet the norms[a]	104	73	115	66	62	94	–10	32
– negative samples ratio, %	15.8	12.7	14.7	10.6	10.5	14.3	–1.5	3.8
• Epidemic safety indexes	979	938	788	915	772	745	–234	–27
– do not meet the norms[a]	132	128	162	105	72	87	–45	15
– negative samples ratio, %	13.5	13.6	20.6	11.5	9.3	11.8	–1.7	2.5

[a] According to SSRN 4630-88 "Sanitary Rules and Norms of Surface Water Protection from Contamination" [29].

Source: Calculated by the author according to the data of the State Sanitary and Epidemiologic Service of Ukraine.

the average district index (15.5%); as for the indexes of epidemic safety, Korosten (26.1%) and Novograd-Volynskyi (21.4%) regions are at the top of the list.

The ratio of the examined samples of the second category water bodies that did not meet the sanitary and chemical requirements in 2011 was 14.3%, and the indexes of epidemic safety were 11.8%. Compared to 2003, the part of the negative samples went down by 1.5 for the sanitary and chemical indexes, and 1.7 for the epidemic safety indexes; compared to 2010 they increased by 3.8 and 2.5 respectively. The biggest deviation percentage for the sanitary and chemical indexes is registered in Andrushivka (92.3%), Korosten (56.7%) and Zhytomyr regions, and considerably exceeds the average district index (14.3%), as for the epidemic safety indexes; Radomyshl (69.2%), Novograd-Volynskyi (58.3%) and Iemelchino (51.6%) regions demonstrate the highest numbers.

It is worth mentioning that in 2011 the average region rate marks exceeded the statistical average index all over Ukraine neither for the sanitary and chemical indexes (16% for the first category water objects and 22.5% for the second category water bodies), nor for the epidemic safety indexes (14% for the first category water objects and 15.6% for the second category water bodies).

Surface water objects are not used in Zhytomyr Region as the sources of centralized water delivery system for the rural settlements, but sometimes the improper servicing and technical state of rural engineering may endanger the safety and quality of drinking water in these places. Therefore, due to the absence of a rural sewerage system in the village called Gulsk, we can expect a possible contamination of the Sluch river and its further negative influence upon the town of Novograd-Volynskyi. The water-intake regime for the rural population is guaranteed by introducing a centralized water supply system and a borehole water diversion, as well as by using the non-centralized water supply sources like pit wells, tubular wells (individual boreholes), interceptions etc.

In 2011, an inspection of the drinking water quality in 134 rural water conduits was conducted. 24 water conduits did not meet the sanitary norms; 10 demonstrated deviation from the sanitary indexes, 20 did not have complex pollution control facilities, and 11 did not have neutralizing devices (Table 2). The share of the rural water conduits that did not meet the hygienic norms was 17.9%, which is 1.7 points less than in 2005 (Chart 1).

The ratio of the samples taken in 2011 from the centralized water supply systems in Zhytomyr Region rural territories that did not pass the sanitary norms was 17.7% for the sanitary and chemical criteria, and 7.6% for the epidemic safety criteria. Radiological index was not detected (Table 2).

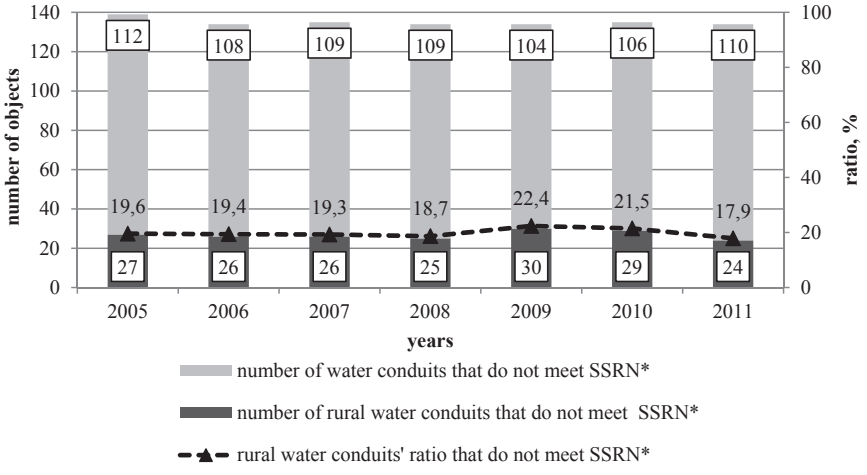
Therefore, compared to 2005 the percentage of the negative samples rose up to (+2.0) for the sanitary and chemical characteristics, and (+4.2) for the epidemic safety indexes. The changes in a radiological component were not found. In comparison with 2010, the percentage of the negative samples rose significantly (+0.8 for the sanitary and chemical factors, +3.7 for the epidemic safety indexes), and again there were no changes in the radiological indexes. The biggest percentage of deviations for the sanitary and chemical criteria was defined in Romaniv (44.9%), Zhytomyr (34.1%), Andrushivka (24.3%) and Ovruch (19.7%) regions, which considerably exceeded the average district index (17.7%). The biggest epidemic safety indexes deviation was presented in Zhytomyr (12.5%), Ruzhyn (10.0%), Romaniv (9.3%) and Lugyny (9.1%) regions.

Table 2 – The state of the centralized drinking water supply systems in Zhytomyr Region

Indexes	Years						
	2005	2007	2009	2010	2011		
					Number	+/– to 2005	+/– to 2010
The number of inspected objects	138	135	134	135	134	–4	–1
The number of water conduits that did not satisfy the requirements of SSRN[a] also due to the absence of:	27	26	30	29	24	–4	–5
• *sanitary controlled zone*	12	11	14	13	10	–3	–3
• *complex pollution control facilities*	22	21	21	21	20	–2	–1
• *neutralizing devices*	13	12	13	13	11	–2	–2
						–2	
The number of the examined samples according to the sanitary and chemical indexes	1096	931	942	903	933	–163	30
– *did not meet the sanitary norms of SSPN*	172	88	122	153	165	–7	12
– *ratio of the negative samples, %*	15.7	9.5	13.0	16.9	17.7	2.0	0.8
The number of the examined samples according to the safety indexes	1248	1251	1156	1009	986	–262	–23
– *did not meet the sanitary norms of SSPN*	42	63	41	39	75	33	3
– *ratio of the negative samples, %*	3.4	5.0	3.5	3.9	7.6	4.2	3.7

[a] According to SSRN 4630-88 "Sanitary Rules and Norms of Surface Water Protection from Contamination" [29].

Source: Calculated by the author according to the data of the State Sanitary and Epidemiologic Service of Ukraine.



* 2010 according to SSRN 383-97 "Drinking Water. Hygienic Demands as for the Quality of Centralized Household Water Supply" and "Hygienic Demands for Drinking water" [26].

Chart 1 – The correlation dynamics of the controlled centralized water supply systems in Zhytomyr Region rural areas

The larger part of the rural population in Zhytomyr Region uses non-centralized drinking water. Nearly 17, 649 of non-centralized water intake objects are used officially [24]. The easiest to access are shaft wells. For the last few years tubular wells have become rather popular (the depth is up to 50 m). Sometimes deep wells are made to facilitate access to drinking water. Also rather popular among the rural population are equipped natural springs, or so called catchments [26].

A positive dynamics in terms of the number of non-centralized drinking water wells that were inspected in rural areas is observed in Zhytomyr Region (Table 3).

Thus in 2005, 2729 objects were examined and tested, while in 2011 this number rose to 3439 (+710). However, it is only the tip of the iceberg among those that supply 180 thousand private households with drinking water. Also it is necessary to emphasize the importance of a recurrent control of quality and safety of drinking water received from the objects of non-centralized water supply. The well owners are responsible for this procedure. Unfortunately, the rural population are not motivated to participate in such inspections, and are ignorant of the health consequences from the intake of a polluted or bad-quality water. The authorities of the State Sanitary and Epidemiological Services can only conduct selective planned checkups, or initiate extra ones in case of epidemic expansion in a certain rural settlement, as well as educate people about the health risks connected with using unsafe water [26].

Table 3 – The condition of the non-centralized drinking water supply sources in Zhytomyr Region

Indexes	Years						
	2005	2007	2009	2010	2011		
					Number	+/– to 2005	+/– to 2010
The number of the inspected objects	2729	2878	2679	3475	3439	710	–36
Examined samples according to:							
• epidemic safety indexes	5802	5966	5695	16 637	7676	1874	–8961
– do not meet the norms;	1259	1077	754	4900	1402	143	–3498
– ratio of the negative samples, %	21.7	18.1	13.2	29.5	18.3	–3.4	–11.2
• sanitary and chemical indexes	7482	9783	9554	24 930	12 558	5076	–12 372
– do not meet the norms;	2827	3555	3300	11 016	4720	1893	–6296
– ratio of the negative samples, %	37.8	36.3	34.5	44.2	37.6	–0.2	–6.6
• radiological indexes	692	806	980	1281	771	79	–510
– do not meet the norms;	0	0	0	0	0	0	0
– ratio of the negative samples, %	0	0	0	0	0	0	0

The ratio of the samples (taken in 2011) from the objects of non-centralized drinking water supply that do not meet the sanitary norms was 37.6% for the sanitary and chemical indexes, and 18.3% for the epidemic safety indexes. The radiation deviation indexes were not detected. During that period, being still high, the epidemic safety indexes decreased in 2005 (–3.4) and 2010 (–11.2). The percentage of the samples according to the sanitary and chemical indexes is invariably high, but was reduced in comparison with the previous year (–6.6 compared to 2010).

The biggest deviation percentage for the epidemic safety indexes was observed in Romaniv (70.9%), Iemilchino (64.0%), Berdychiv (50.4%), Baranivka (40.1%) and Popilnia (39.8%) regions, which exceeded the average district index (18.3%). As for the sanitary and chemical indexes, Liubar (63.5%), Romaniv (61.6%), Baranivka (58.9%), Radomyshl (58.1%), Cherniakhiv (51.5%), Berdychiv (49.8%), Korosten (49.1%) and Narodychi (48.8%) regions are at the top of the list.

The worst condition of drinking water was observed in the pit wells, where the percentage of the negative samples for the sanitary and chemical indexes was 40.1% in 2011 (Chart 2) and decreased by 0.3 before the investigated period (2005) and by 6.1 the previous year (2010). The percentage according to the epidemic safety indexes was 22.2% (Chart 3) and decreased by 5.0 compared to 2005 and by 10.7 compared to 2010 respectively.

The situation with the tubular wells compared to the pit wells is twice as good regarding the sanitary and chemical indexes – 19.4% (Chart 2) and thrice as good for the epidemic safety indexes – 7.4% (Chart 3).

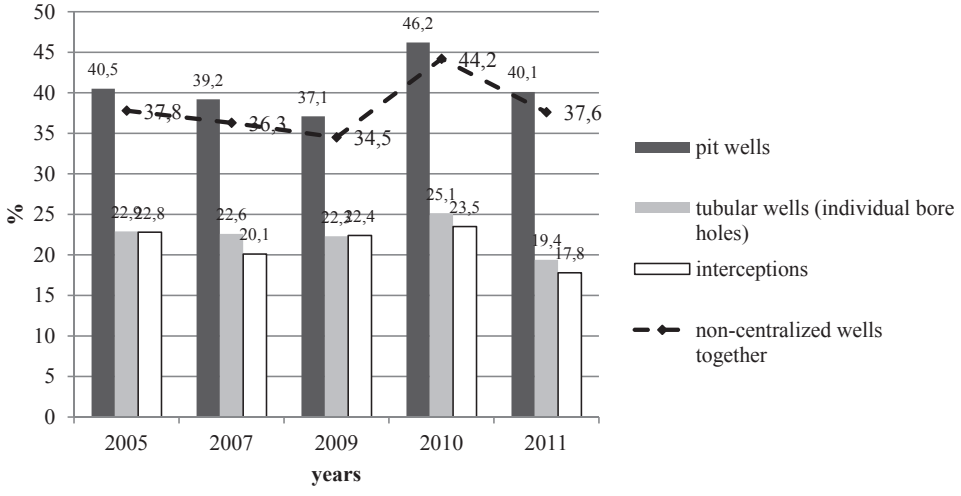


Chart 2 – The ratio of the samples due to the sanitary and chemical indexes, taken from the objects of non-centralized water supply that do not meet SSRN (Zhytomyr Region rural territories), %

Compared to 2005, the percentage of the negative samples decreased by 3.5 for the sanitary and chemical indexes and by 5.0 for the epidemic safety indexes. Consequently, before 2010 the negative samples ratio reduced by 5.7 (the sanitary and chemical indexes) and increased by 1.2 (the indexes of epidemic safety).

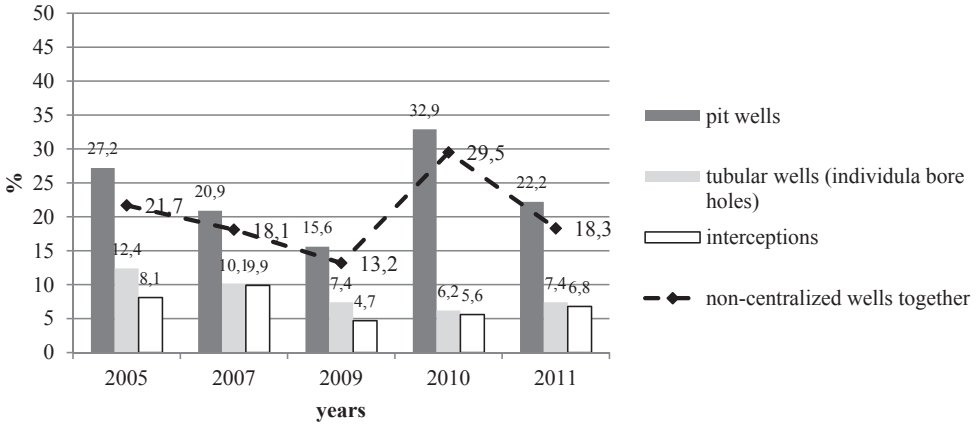


Chart 3 – The ratio of the samples due to the epidemic safety indexes, taken from the objects of non-centralized water supply that do not meet SSRN (Zhytomyr Region rural territories), %

The condition of drinking water from the interceptions was similar to that from the boreholes. In 2011 the ratio of the samples that pass the sanitary norms was as follows: sanitary and chemical indexes – 17.8% (Chart 2), reduced by 5.0 in comparison with the previous year; epidemic safety indexes – 6.8% (Chart 3), decreased by 1.3 before that period and increased by 1.2 before the previous year.

Conclusion

The research data analysis has shown that the rural population in Zhytomyr Region frequently uses unsafe and contaminated drinking water. The quality of the non-centralized drinking water objects in rural areas is very low. Nearly 40% of the samples according to the sanitary and chemical indexes, and 20% of the samples according to the epidemic safety indexes, do not meet the sanitary norms (mainly samples from the pit wells). This fact makes the issue a primary concern, both for the strategy of the state social development and human health preservation as well as the regional development policy. The given results have also shown the importance of the system analyses toward securing microbial safety of drinking water, built on the implementation of the new methods of water consumptions for householders. The introduction of the innovative water consumption technologies should be built on the principles of source protection and financing the projects of drinking water sources diversification. Finding the new, health targeted ways of improving the quality and safety of drinking water for rural populations is possible through using underground water reservoirs (including artesian wells), which will bring a tangible reduction in the overall level of water-transmitted diseases.

Conflict of interest

The authors have no conflict of interest to disclose.

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