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Water Quality Assessment in the Mining and Industrial Region on the Example of Karachunovskyi Reservoir in Ukraine

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Keywords: water quality assessment; mining and industrial region; degree of tension ecological situation; degree of ecological problems; health status.

Abstract. Quality of water from surface water source – Karachunovskyi reservoir for a long period of observation during 1965-1979, 1980-1990, 1991-2001, 2002-2012 years was studied. In water taken from Karachunovskyi reservoir was shown negative trend for increasing salt composition, by the content of general rigidity, dry residue, sulfates, chlorides for a long period of observation: from 1965 to 2012 years, which is caused by the systematic discharge of a highly mineralized mine water from the mining enterprises of Kryvyi Rih into Ingulets and Saksagan rivers, and subsequent pollution of Karachunovskyi reservoir – the main source of centralized drinking water supply 94% of the urban population. Generally, salt composition of the water from Karachunovskyi reservoir in some years of observation belonged to the 4th class of danger, i.e. "limited usable, undesirable quality". Characteristic feature of the Karachunovskyi reservoir in Ukraine is the presence of priority heavy metals (Mo, Mg, Cd, Ni, Zn, Fe, Cu, Pb, Cr) in water sources, due to the intensive extraction of iron ore. For example, average iron content in 2010 was (0.342±0.003) mg/dm^3, which exceeded MPC (0.3 mg/dm^3) on 1.14 times. The average content of manganese exceeded the hygienic standard in 2008 (1.42 MPC), in 2009 (1.3 MPC) and in 2010 (1.54 MPC) years, due to a high background content of this chemical element in the environmental facilities of the industrial city, and the annual discharge of highly mineralized mine water into local water sources.

Introduction

Kryvyi Rih – is the largest in Ukraine and the world city with deposits of iron ore, the main mining center of the country, located in the Dnipropetrovsk region. In Kryvyi Rih are concentrated 21 billion tons of iron ore reserves, recoverable reserves of iron ore account 18 billion tons. The relevant industrial and economic complex of industrial region of Ukraine is formed based on the use of mineral resources, which significantly affected the production and led to a high territorial concentration and the priority development of mining and metallurgical industry. Each year, mining companies operating in the basin pumped about 40.0 million. m^3 of groundwater (mine, quarry), including 17-18 million m^3 of a highly mineralized mine water [1].

Lack of real alternatives to full utilization or disposal of excess mineralized mine water requires to discharge excess water of mining companies in Kryvyi Rih. Regulation provides discharge of excess return water from mining companies of Kryvyi Rih to Karachunovskyi reservoir on the river Ingulets, in order to dilute wastewaters [2]. Reset is carried out exclusively between vegetation period into the Ingulets river, downstream, intakes of drinking and household water supply available. At the beginning of discharge taking into account the completion of the vegetation season, when water temperature in the river is below +10^0 (in the early November). Completion of discharge takes into account the passage of a spawning period - no later than in early March, with a subsequent washing of the river with fresh water [3]. One of the most important components of the environment is a significant impact on the public health of drinking water. It plays a significant role in human life, in ensuring sanitary and epidemiological welfare of the population, but at the same time, poor quality drinking water can be a factor that influences the development of somatic and infectious diseases [4]. Monitoring quality of drinking water from centralized water supply systems, which is held in Ukraine shows that in some regions of the country drinking water on some indicators are not always correspond to regulatory requirements [5]. Increased mineral composition of underground drinking water is registered in Dnipropetrovsk, Kropyvnytskyi, Kherson, Odessa, Lviv and Ivano-Frankivsk regions [6].

One of the basic hygienic problems in Dnipropetrovsk region is contamination of water sources with heavy metals (HM), which comes mainly from effluent production of non-ferrous metallurgy and electroplating shops of machine-building industry [7]. In addition to serious body lesions, they lead to inhibition of aerobic microorganisms, providing self-cleaning of reservoirs, loss of fish and other aquatic organisms [8]. It was established that in the main water supply sources of the cities Dnipro, Kamianske, Kryvyi Rih are continuously determined HM: Cu, Fe, Mn, Cr, Pb, rarely - Zn, Ni, Mo [9]. Despite the fact that average concentration of all HM in the water supply sources did not exceed maximum permissible concentration (MPC), there is a tendency to increase concentrations of copper in the drinking water of city Dnipro, copper and chromium in the city Kryvyi Rih. In combination with other substances of natural water, HM can adversely affect on the human body through the effect of biological summation [10].

In drinking water of Kryvyi Rih is present majority of HM, although their concentrations correspond to MPC. In Karachunovskyi reservoir from year to year increased content of Mn, Cu, in Radushanskyi water supply system – increased Mn, Cu, Pb, Zn. At the standard MAC, it was noted that after purification of water in water plants, content of some HM increased: in the city Dnipro - Cu, in Kamianske - Al, Fe, sometimes in Kryvyi Rih - Cu, Fe, Al, Mn, Zn, Pb. The main reason of HM migration into the water is migration from metal equipment of sewage plants, their accumulation on the filters [11].

Water quality of Karachunovskyi reservoir, which provides with drinking water the central part of Kryvyi Rih had increased stiffness, especially in the late 80-years. The enterprise "Kryvbaspromwater supply station"obtained permission from Ministry of health of Ukraine to produce water for drinking centralized water supply with a hardness more than 10 mg/dm^3. During this period there was shown a high level of solids (1985-1997 years), caused by the discharge of saline water into the river. During 15 km of the Ingulets river flow through the city, it gets the flows from Saksagan river, industrial effluents of metallurgical, coke, mining and cement plants, two mining and processing plants (Southern and Novokrivorozhskyi). Reset of highly mineralized mine water in vegetative period of year is carried out with the permission of Ministry of Ecology of Ukraine, and in 1996 with the permission of State Committee on Emergencies, provided washing of rivers Saksagan and Inhulets [12]. Flushing mode is carried out only after discharge, and in recent years, the rivers feed on industrial effluents of the city. Their recovery requires a constant flow of fresh water between the mass discharges.

The results of our own research [13-15] in water of Karachunovskyi reservoir shown negative trends for increasing of salt composition, by the contents of total rigidity, dry residue, sulfates and chlorides for a long period of observation: from 1965 to 2012 years. It is caused by the systematic discharge of a highly mineralized mine water from the mining enterprises of the city Kryvyi Rih into the rivers Ingulets and Saksagan, and the subsequent pollution of the Karachunovskyi reservoir - the main source of centralized drinking water supply of the urban and rural population of the Kryvyi Rih region.

Physical-geographical characteristics of Karachunovskyi reservoir. Karachunovskyi reservoir is located on the river Ingulets in the central part of the Kryvyi Rih city. It is a major source of drinking water supply of the city and surrounding villages. Near the reservoir was built complex of Karachunovskyi water supply treatment plants with capacity 250 thousand m^3 / day with two pumping stations. The damb is located at the beginning of Ingulets river, 2 km downstream of the River Side. Karachunovskyi reservoir is a reservoir of fisheries. On the base of the reservoir area is situated fish farm.

Morphometric characteristics of Karachunovskyi reservoir: length - 35 km; width (maximum) - 5.3 km; width (average) - 1.28 km depth (maximum) - 19.1 m; depth (average) - 6.88 m; coastline - 91.6 km; surface area - 46.92 km^2; reservoirs: full - 342 million m^3, useful - 288.5 million m^3. The main hydrological characteristics of Karachunovskyi reservoir: water intake area - 6550 km^2; rate of flow - 1,25 l / sec from 1 km^2; maximum flow - 500 million m^3 / year; minimum flow - 33 million m^3 / year. The nature of power drain – is snow, rain, soil; average long-term flow- 256 million m^3 / year; estimated volume of water yield-77 million m^3 / year. Republican water intake points– 6 (right, left bank, middle of the reservoir, surface and depth); the total volume of water loss for water consumption – 78.4 million m^3 / year. The banks of the reservoir is low-lying flat ledges, processing shores observed. The coastline - 91.6 km, land area of the reservoir is 44.8 hectares. Karachunovskyi reservoir has 3 zones of sanitary protection. The first zone (regime): on the nearby shore - 400 meters from the water's edge; upstream - 400 m; downstream - 100 m; on waters in all directions - 400 m. On the right bank of the reservoir is located intake - tower bottom water outlets. Distances from intake mounted on the adjacent coast - 200 m, upstream - 400 m. The zone of sanitary protection (SPZ) are: part of the reservoir - 12.5 hectares; left-bank band - 1.5 hectares; band of right bank – 8 ha; ground water treatment plants - 14 hectares; damb and below the damb area - 1.0 hectares. Total area is 37 hectares, including on water - 12.5 hectares, on land - 24.5 hectares, perimeter is 2700 m. The second zone SPZ (restrictions) installed on both sides of the river Ingulets: downstream - 250 m; on waters from all directions - 5 km; from the water edge in 500 m – 2 km; up from the water intake and further along the border of the existing forest belt - 3 km. Area of II zone is 1750 hectares, including water – 200 hectares and perimeter 20 km of the upper and lateral border of III SPZ (observations) in the waters of the reservoir combined with the boundaries of zone II, the lateral border on a distance 3 km from the shoreline parallel to the boundaries of zone II. The area is 5600 hectares (Fig. 1).

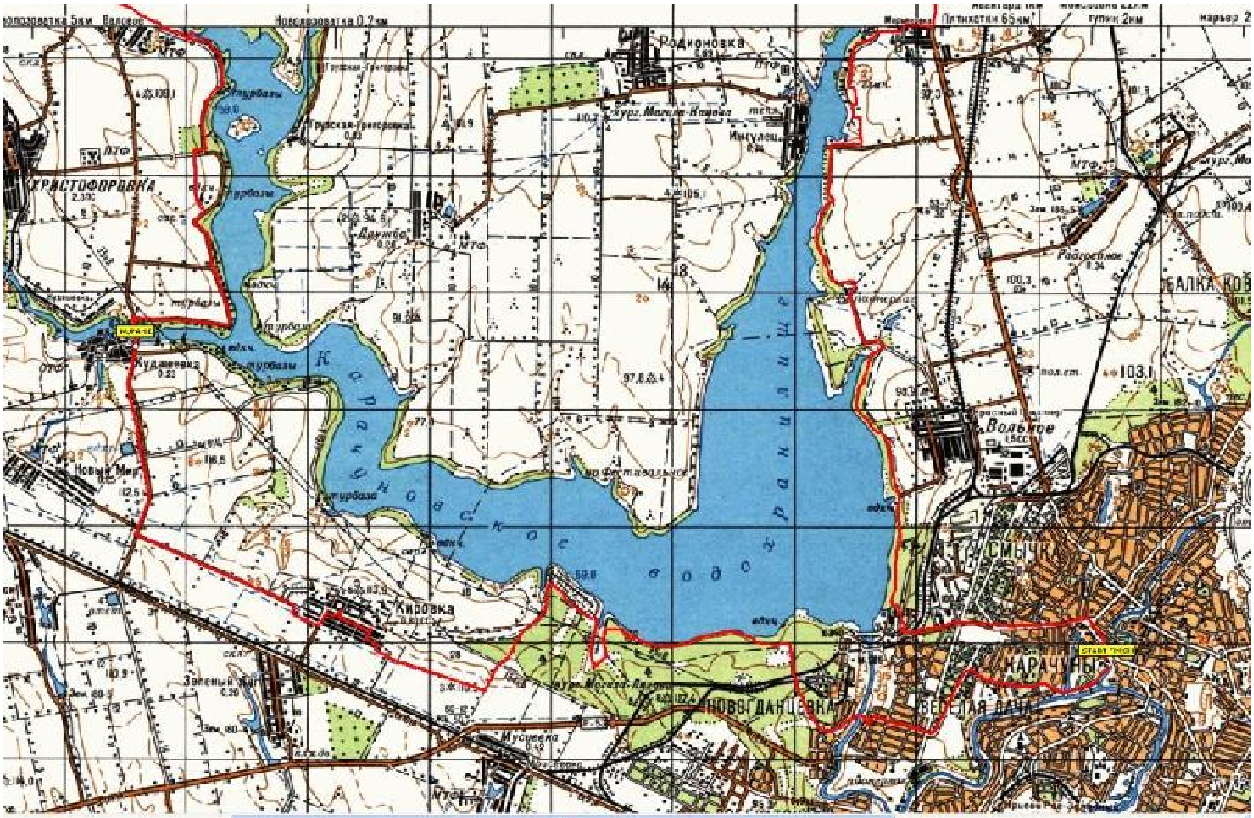

Fig. 1. Map of Karachunovskyi reservoir in Ukraine.

Purpose of research – assess the quality of water, taken from surface water source - Karachunovskyi reservoir for a long period of observation 1965-1979, 1980-1990, 1991-2001, 2002-2012 years.

Materials and methods. We determined the average annual indicators of water quality in the surface water supply source - Karachunovskyi reservoir, which is located in the industrial urbanization zone. The Kryvorozhska zone of urbanization (9 % of area of Dnipropetrovsk region, with the population 740 thousand people, which includes 94 % of urban population) covers city

Kryvyi Rih, territory of Karachunovskyi reservoir with SPZ areas; rural areas of Dnipropetrovsk region.

The class of water supply source for each of the indicators was determined by ISO 4008: 2007 [31], and water quality from the Karachunovskyi reservoir was analyzed according to Sanitary Rules and Norms № 4630-88 [32]. Among indicators of water quality from Karachunovskyi reservoir were the following: organoleptic - smell, taste and aftertaste, turbidity; total hardness, dry residue, sulphates, chlorides, permanganate oxidation, pH, bichromatic oxidation, soluble oxygen, total organic carbon, chemical content: Mo, As, Ni, Zn, Na–K, Ca, Mg, Fe, Mn, Cu, F, cyanides, calcium phosphate, ammonia nitrogen, nitrite, nitrates, silicic acid, synthetic surfactants, polyphosphates, petroleum products. Totally 33 indicators of water quality were studied. The majority of water quality indicators from Karachunovskyi reservoir were carried out during (2008-2012) years, salt composition of water (content of total hardness, dry residue, sulfates, manganese) was studied according to the data of long-term indicators for 1965-1979, 1980-1990, 1991-2001, 2002-2012 years.

Results of research and discussion. In the water from Karachunovskyi reservoir total hardness increasing, according to the levels of average annual indicators: from 6.76±0.40 mg/dm^3 in 1965-1979 years to 10.28±0.44 mg/dm^3 in 2002-2012 years (Fig. 2).

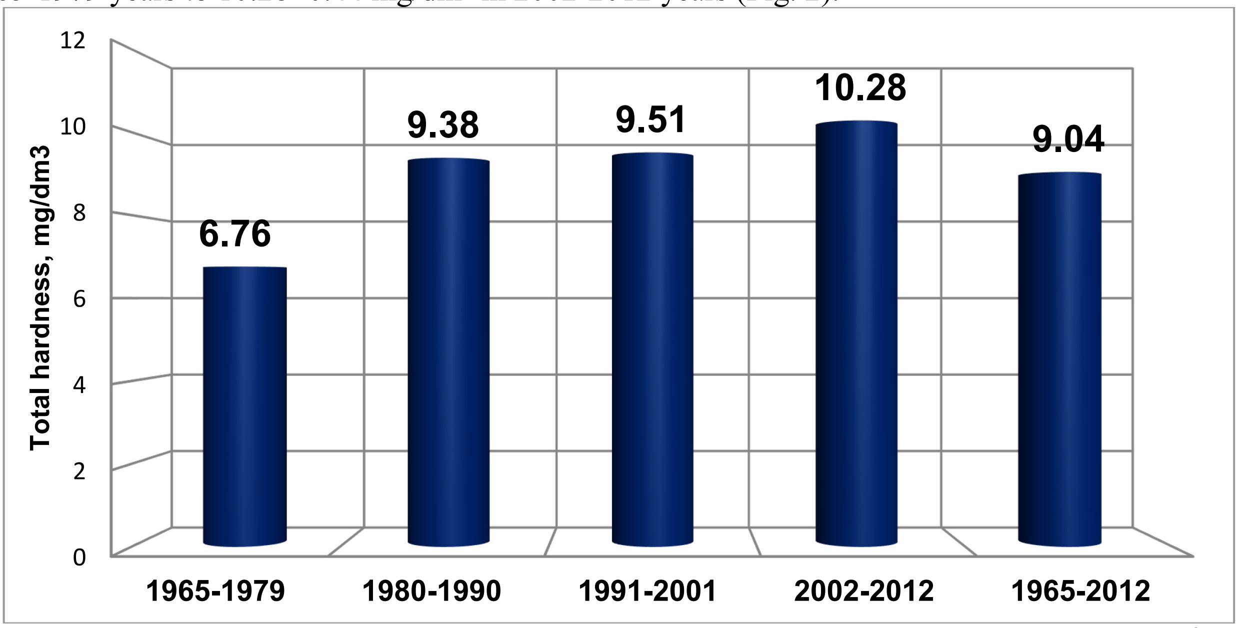

Fig. 2. Level of total hardness in the water of Karachunovskyi reservoir (M±m), mg/dm^3.

During 1965-1979 years in summer period, according to the level of total hardness water from the reservoir concerned to the 3rd class of surface water sources, according to ISO 4008:2007 "satisfactory, acceptable water quality". By the levels of average annual indicators during 1980-1990, 1991-2001, 2002-2012 years, total hardness exceeded its recommended value (7.0 mg/ dm^3). Water from Karachunovskyi reservoir belongs to the 4th class of surface water, quality of which is characterized as "limited suitable, undesirable water quality". Dry residue for 1965-1979, 1980-1990 years did not exceed the established hygienic standard (1000 mg/m^3), according to Sanitary Rules and Norms [32], but water from this reservoir belonged to the 3rd class, according to the classification of surface water ISO 4008:2007 [31]. However, from 1991 to 2012 year water quality according to the dry residue content deteriorated and belonged to the 4th class of surface water sources. Over the same period of observation, dynamics to increase a dry residue exceeding hygienic norm: in 1991-2001 years – on 1.04 times, in 2002-2012 years – in 1.23 times. In particular, level of the average index of dry residue 1005.31±3.12 mg / dm^3 exceeded the hygienic standard on 1.0 time in 1965-2012 years (Fig. 3).

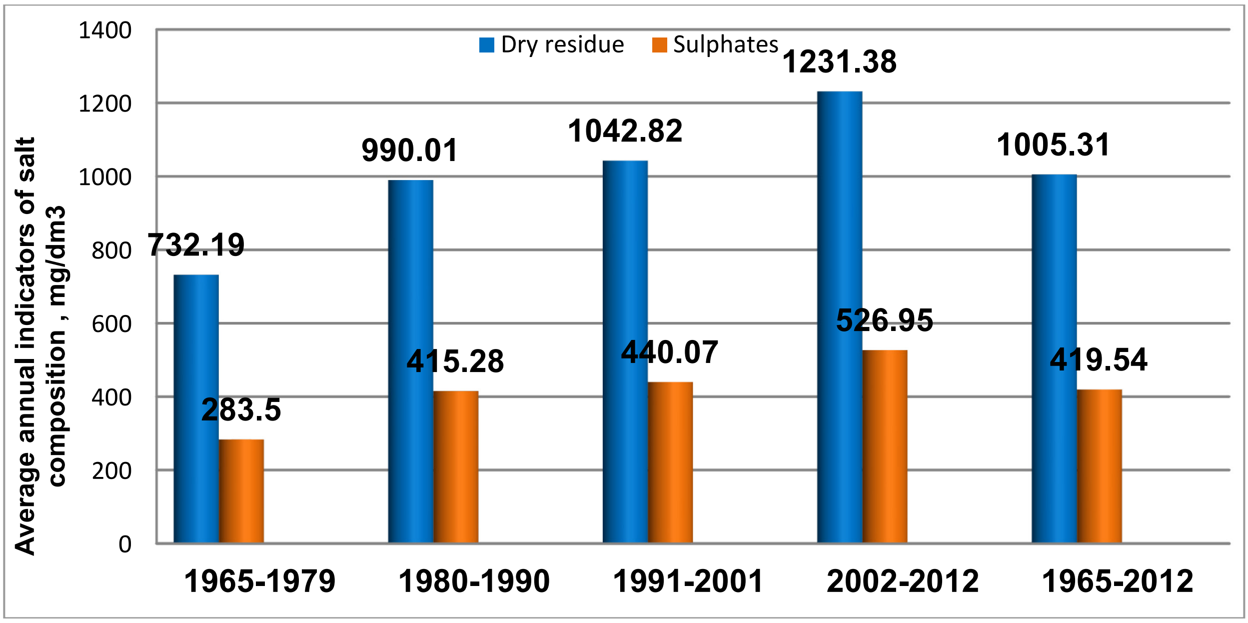

Fig. 3. Levels of average annual indicators salt composition of drinking water in Karachunovskyi reservoir in 1965-2012 years (M±m), mg/dm^3.

It was shown a tendency to increase average regional indicator of sulfate content in water from Karachunovskyi reservoir. In this case, concentration of sulphates increased rapidly from 283.50±8.50 mg/dm^3 in 1965-1979 years, which exceeded MPC on 1.13 times to 526.95±6.27 mg/dm^3 in 2001-2012 years with exceeded MPC on 2.11 times. The sulphate content of water from this reservoir was classified as 4 class of hazard for the period of observation 1965-2012 years.

By to the content of chlorides was observed dynamics of reduction on 1.34 times: from (139.58±2.49) to (104.33±1.80) mg/dm^3. In 2008-2012 years chlorides never exceeded MPC (250 mg/dm^3) in water of the reservoir. Water quality belonged to the 3rd class (101-250 mg/dm^3). The highest content of manganese was observed during (1980 – 1990), (1991-2001) years, i.e. it content was increased (2.2 - 2.1 MPC). In general, the water quality from this reservoir belongs to the 3rd class and was on the level 0.162±0.018 mg/dm^3 for the period of observation (1965-2012) years. The best quality of the surface water source was registered by the content of manganese: 2 class "good, acceptable water quality" in 1965-1979, 2001-2012 years, and was lower than MPC (0.1 mg / dm^3).

By the smell (t 20^0 – 60^{0}C) water belonged to 1 class "excellent, good quality" in 2008 – 2012 years (<1 point), except 2009 year (1 point). Generally, average regional indicator of the smell in water from Karachunovskyi reservoir belonged to the 1st class of water quality 0.77±0.05 points. Taste and aftertaste of water never exceeded the hygienic standard and was on the level (0 points). Quality of water from this reservoir belonged to the 1st class of surface water sources. The hydrogen index was established on the standard level for surface sources of 2 class (pH=7.6–8.1), except 2010 year – 8.21±0.06, so quality of the reservoir belonged to 3 class: pH=8.2-8.5. The tendency to increase color of water from 55.50±5.53 degrees in 2008 year to 67.25±6.57 degrees in 2012 year was shown. Water belonged to the 2nd class of surface water sources (20-80 degrees) for all period of observation. It was registered dynamics to increase of water turbidity in the reservoir from 2.22±0.34 mg/dm^3 in 2008 year to 3.23±0.42 mg/dm^3 in 2012 on 1.45 times. However, according to the level of this indicator it was the best quality of water, which belonged to the 1st class of water supply sources (<20 mg/dm^3). The alkalinity showed a tendency to decrease during 2008-2012 years: from 4.50±0.05 to 4.19±0.06 mmol/dm^3 (on 1.07 times). Totally, water from Karachunovskyi reservoir by this indicator belongs to the 3rd class of quality 4.1 – 6.5 mmol/dm^3 (Fig. 4).

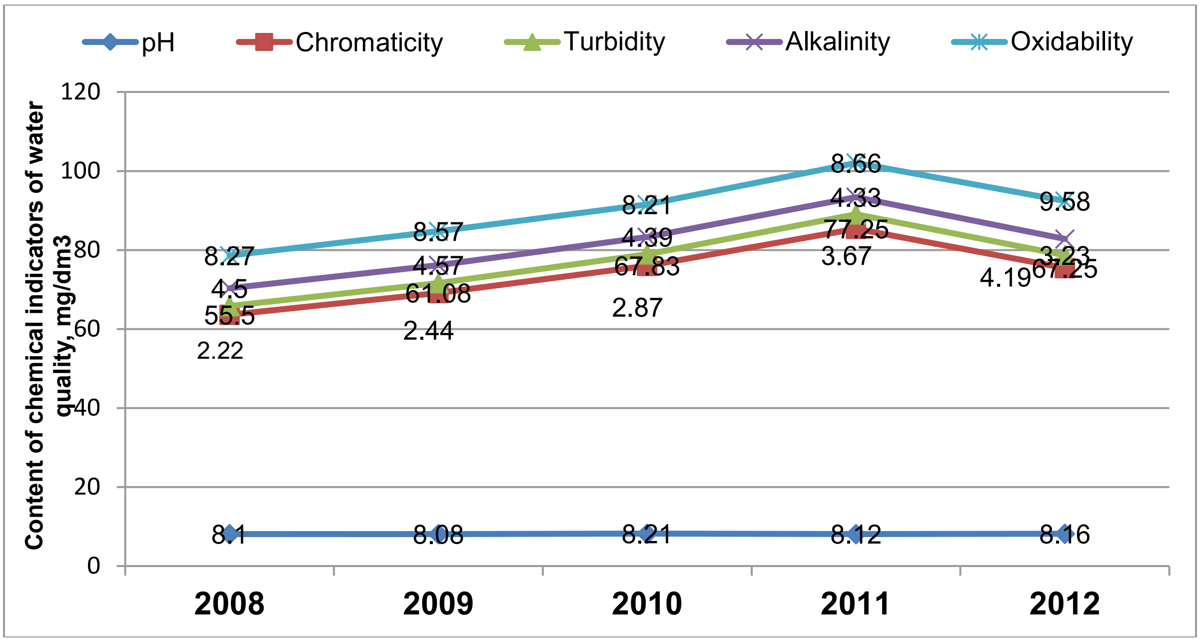

Fig. 4. Dynamics of the content of chemical indicators of water quality from Karachunovskyi reservoir in 2008-2012 years (M±m), mg/dm³.

Permanent oxidability ranged from 8.27±0.19 to 9.58±0.27 mgO/dm³ with the highest value in 2012, and a pronounced tendency to growth. However, in 2008-2012 an average long-term rate of oxidation permanganate was on the level of 2 class and varied from 3.0-10.0 mgO/dm³ to 8.65±0.11 mgO/dm³. In water of Karachunovskyi reservoir was shown decreased of oxidation permanganate (on 1.38%) for 5 – years observation period: from 21.72±0.67 mg/dm³ in 2008 year to 15.75±0.79 mg/dm³ in 2012 year. However, during 2008-2012 years water quality from the reservoir belonged to 2 class 21.06±0.58 mgO/dm³, and was on the level of established hygienic standard 9.0-30.0 mgO/dm³. According to the content of biological need of oxygen (BNO) there is a tendency to increase for 2008-2012 years, with the highest level of indicator in 2011 year 2.81±0.35 mgO_2/dm^3. At the same time, the average index of BNO 2.58±0.18 mgO_2/dm^3 did not exceed the standard limits established for the 2nd class of surface sources 1.3-3.0 mgO_2/dm^3. Soluble oxygen in water from the reservoir did not exceed the standard limits for the 1 class (>8.0 mgO_2/dm^3). However, during the 5–year observation period there is a tendency to increase its content in water: from 9.15±1.03 to 9.57±0.97 mgO_2/dm^3. According to the level of the average index of dissolved oxygen, water belongs to the 1st class of water supply sources 9.09±0.45 mgO_2/dm^3 (Fig. 5).

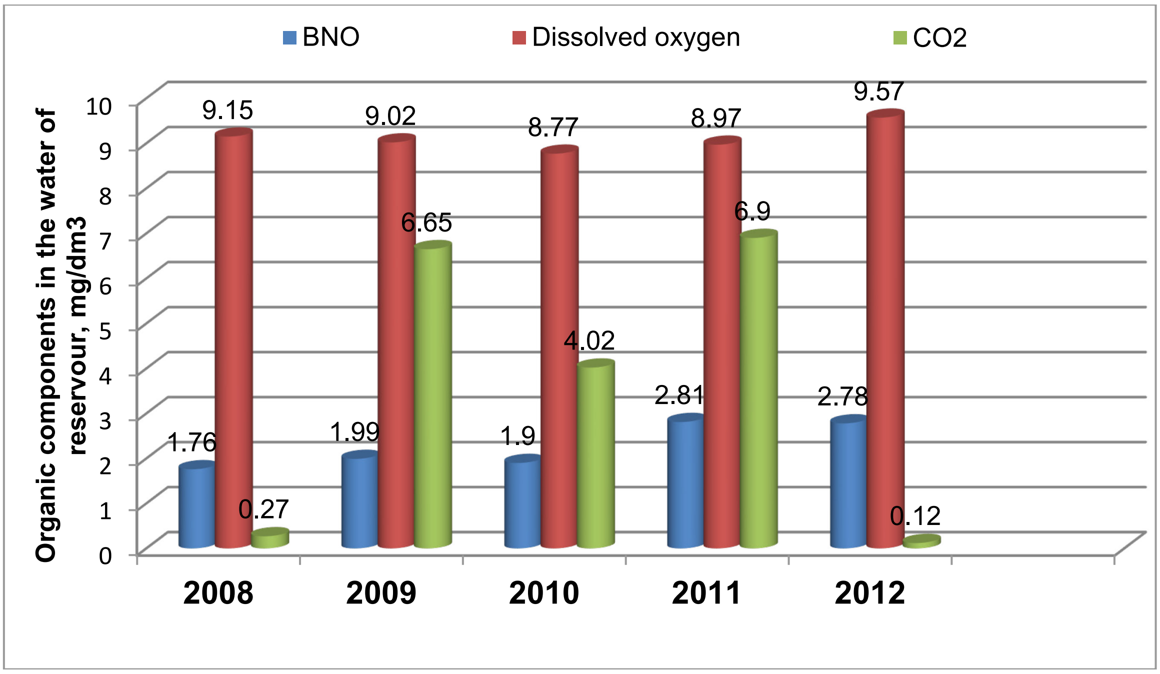

Fig. 5. Dynamics of the organic components of water quality from Karachunovskyi reservoir in 2008-2012 years (M±m), mg/dm³.

The average content of total organic carbon in water fluctuated berween 1-2 classes, but according to the level of average index, water from Karachunovskyi reservoir belongs to the 1st class of quality (<5.0 mg/dm³) and was on the level 2.77±0.63 mg/dm³. The highest value of total organic carbon was registered in 2011 year 6.90±0.96 mgC/dm³ (2 class), the lowest – in 2012 year 0.12±0.08 mgC/dm³ (1 class).

The average content of molybdenum in water did not exceed MPC for surface water bodies (0.25 mg/dm³), but water quality by this indicator belonged to the 3rd class, except in 2009 year (<0.001 mg/dm³), water belonged to the 1st class (<1 mg/dm³). According to the level of average index of molybdenum 0.036±0.006 mg/dm³ water from this reservoir was characterized as "satisfactory, acceptable quality" (3 class). Arsenic in water of the reservoir did not exceed MPC (0.05 mg/dm³) during 2008-2012 years, water belonged to the 2nd class. Tendency to decrease the average arsenic content for 5–year observation period was established. The values of the arsenic ranged from 0.005 to 0.001 mg /dm³. The content of cyanides in water remained constant and fluctuated from (0.02 to 0.05) mg/dm³, while value of average index was on the level 0.035±0.015 mg/dm³. Thus, water containing cyanides belonged to the 3rd class of quality (11 – 50 mg/dm³), and did not exceed MPC (0.1 mg/dm³). The average nickel content in water of the reservoir is constantly fluctuated, with a characteristic tendency to increase on 15 times: from 0.004±0.002 mg/dm³ in 2009 year to 0.060±0.004 mg/dm³ in 2012 year.

At the same time, concentration of nickel in water never exceeded MPC (0.1 mg/dm³). For average month indicator of nickel 0.043±0.007 mg/dm³ water belongs to the 2nd class of quality (20 – 50 mg/dm³). Lead did not exceed MPC (0.03 mg/dm³) in water, while value of this chemical element was constantly on the level < 0.001 mg/dm³. Water from the surface water supply source was the best quality (1 class). The average zinc content in water did not exceed MPC (1.0 mg/dm³). Water from Karachunovskyi reservoir was characterized as "excellent, desirable quality" (1 class) from 2009 to 2012 year. Satisfactory water quality (3 class) was detected in 2008 year and was on the level <0.11 mg/dm³. According to the level of average zinc index, water from reservoir was characterized as "good, acceptable quality" (2 class). The average level of zinc concentration was 0.025±0.02 mg/dm³.

The average content of calcium phosphate exceeded MPC (3.5 mg/dm³) for the period of observation: from (26.0 to 23.5) MPC. There is a tendency to decrease an annual content of calcium compounds in water. The average long-term index of calcium phosphate was 90.25±1.19 mg / dm³ and exceeds MPC on 25.78 times. The content of magnesium compounds in water of the reservoir was constantly exceeded MPC for 2008-2012 years and was ranged from 76.57±1.19 to 58.85±2.64 mg/dm^3, i.e. on 3.82 – 2.94 times, with a tendency to decrease in 2012 year.

By the level of average index 71.59±1.36 mg/dm^3 magnesium compounds exceeded the hygienic standard (3.58 MPC), so water from Karachunovskyi reservoir belongs to the 3rd class of quality. The dynamics of reduction sodium – potassium compounds in water of reservoir was established: from 236.58±4.83 to 189.33±6.05 mg/dm^3. However, content of these compounds in water exceeded MPC during 2008-2010 years and varied 1.18 – 1.11 MPC, except for 2011 – 2012 years. The average index of Na-K compounds also exceeded MPC on 1.07 times and was on the level 215.0±4.31 mg/dm^3 (Fig. 6).

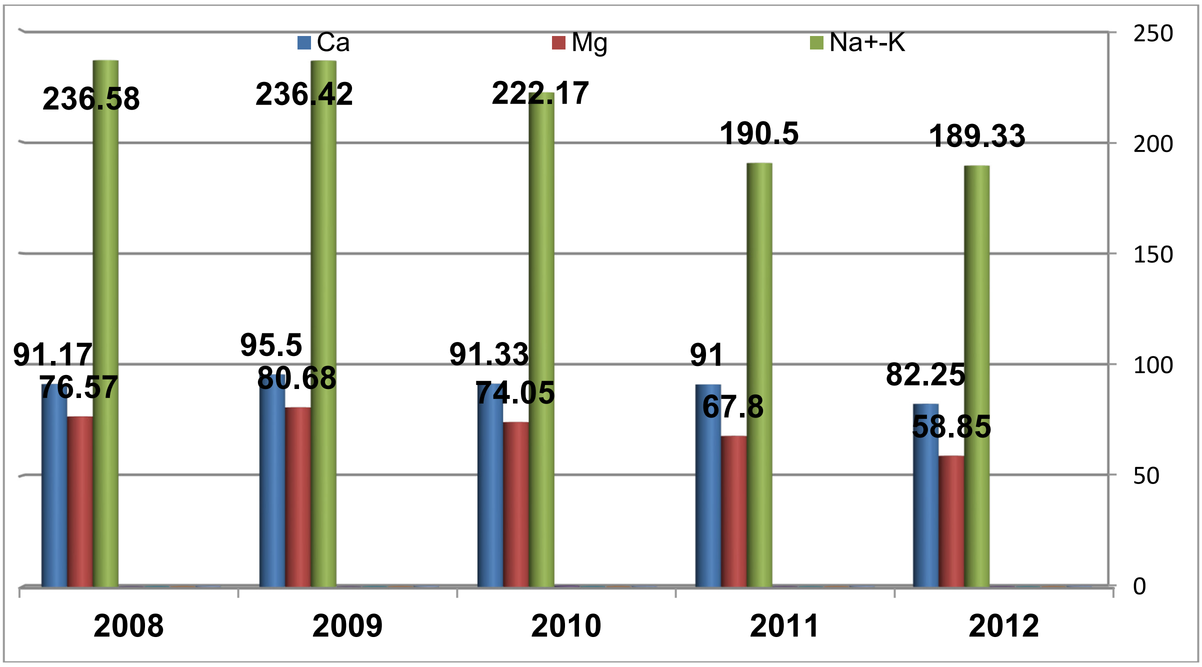

Fig. 6. Dynamics of toxicological indicators of chemical composition of water quality from Karachunovskyi reservoir in 2008-2012 years (M±m), mg/dm^3.

Ammonium nitrogen did not exceed MPC (2 mgN/dm^3), but there was a tendency to increase the content of this compound during 2008-2012 years in dynamics, with a high content in 2010 year – 0.393±0.025 mgN/dm^3. At the same time, water quality in 2010 – 2011 years corresponded to 3 class, whereas in the previous years – to 2 class. According to the level of average index 0.262±0.013 mgN/dm^3, ammonium nitrogen corresponded to the 2nd class of quality 0.10 – 0.30 mgN/dm^3. Nitrite nitrogen did not exceed MPC (3.3 mgN/dm^3) for all period of observation. Water belonged to the 3rd class of quality. However, in 2008 and 2010 years water from reservoir belonged to the 4th class (>0.050 mgN/dm^3), with the highest value of indicator in 2010 year – 0.061±0.021 mgN/dm^3. It should be noted that nitrate nitrogen content showed a negative trend during 2008-2012 years, but concentrations of these compounds did not exceed MPC (45 mgN/dm^3).

Water from Karachunovskyi reservoir for the whole period of observation can be attributed to the 4th class of quality (> 1.00 mgN/dm^3), with a high content of nitrate nitrogen in 2008 year – 1.58±0.17 mgN/dm^3. Attention should be focused on the increasing in the dynamics the ammonium nitrogen content on a background of decrease nitrate nitrogen. It is clearly indicates about deterioration of self-purification in the Karachunovskyi reservoir during 2008-2012 years (Fig. 7).

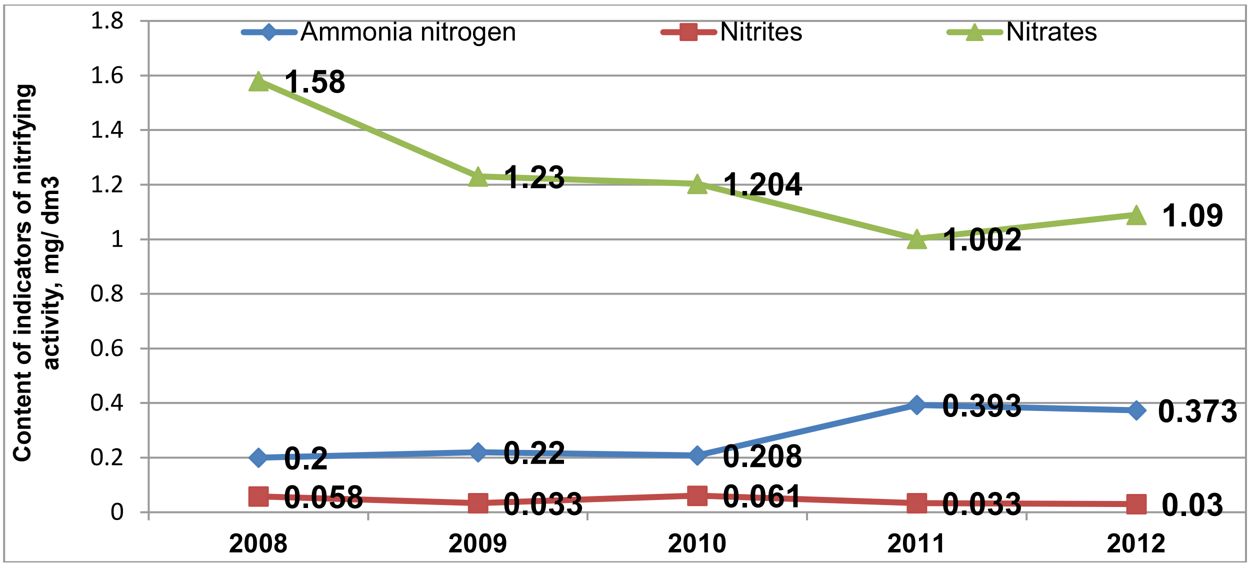

Fig. 7. Dynamics content of ammonia, nitrites and nitrates in water from from Karachunovskyi reservoir in 2008-2012 years (M±m), mg/dm^3.

Tendency of increasing average iron content in water of the reservoir during 2008-2012 years was established, with exceeding of MPC (0.3 mg/dm^3) on 1.14 times in 2010 year 0.342±0.003 mg/dm^3. The class of water quality in the surface source changed from 1 class in 2008-2010 years to 2 class in 2011-2012 years, the iron content varies from 0.060±0.009 to 0.083± 0.021 mg/dm^3. Cadmium in water was below MPC (<0.001 mg/dm^3) during all years of observation. The source of water supply corresponded to 3 class (0.6 – 5.0 mg/dm^3).

In water from Karachunovskyi reservoir during 2008-2012 years was found decreased of the copper content on 45 %: from 0.0056±0.001 to 0.0031±0.0006 mg/dm^3, but this chemical element did not exceed MPC (1.0 mg/dm^3). The quality of water corresponds to 2 classes (1 – 25 mg/dm^3). Fluorine in water of the reservoir did not exceed MPC (0.7 mg/dm^3), water concerned to the 1 class (< 700 mg/dm^3). During 5-year observation period, content of fluorine compounds reduced on 18 %: from 0.313±0.021 to 0.266±0.164 mg/dm^3, with the highest value in 2009 year 0.332±0.021 mg/dm^3. Chromium content does not exceed MPC (0.5 mg/dm^3) and was constantly on a level (<0.001 mg/dm^3). According to the value of the average index of chromium compounds - 0.030±0.006 mg/dm^3, water from reservoir belonged to the 1st class. A similar trend was observed in the content of phenols, which was below MPC (<0.001 mg / dm^3) during 2008-2012 years (1 class).

In water taken from Karachunovskyi reservoir discovered the contents of polyphosphates, significantly below maximum concentration limit (3.5 mg/dm^3), with a downward trend in 2008-2012 years. However, the highest level of polyphosphates was detected in 2008 year 0.53±0.05 mg/dm^3. A gradual decrease of these compounds has been observed since 2011 year 0.14±0.03 mg/dm^3. Synthetic surfactants from 2008 to 2009 years were on the level (<0.001 mg/dm^3), water belonged to 1 class (<10 mg/dm^3). In the subsequent years of observation, water belonged to the 2nd class of quality, because content of synthetic surfactants decreased on 47 %: from 0.047±0.012 in 2011 year to 0.032±0.009 mg/dm^3 in 2012 year. Oil products have never exceeded MPC (0.3 mg/dm^3). Over 5 – year period of observation, the dynamics of reducing content of these compounds on 20% in water of reservoir was shown: from 0.113±0.009 to 0.094±0.007 mg/dm^3, with the highest value in 2012 year. Thus, water from Karachunovskyi reservoir belongs to the 3rd class of quality 51-200 mg/dm^3 by the content of oil products.

The model of efficiency water resources management is presented in (Fig. 8). Its main criteria are: environmental, ecological–economic, economic, socio–economic, medical-ecological and hygienic. The hygienic criteria for the degree of tension an ecological situation is based on the assessment of multiplicity of exceeding indicator of total chemical pollution of drinking water:

< 1.0 MPC – corresponds to the "relatively satisfactory" degree of ecological tension; 1.5 – 2 MPC - "unsatisfactory"; 2.1 – 2.5 MPC – "tense"; 2.6 – 3 MPC - "critical"; > 3.0 MPC - "crisis".

The first position – is a relatively satisfactory sanitary situation does not prevent the placement and development of industry in a city or in the rural area. To address the issue for a placement of construction geographical and environmental aspects are taking into account, presence zones of natural and focal diseases. The second position is unsatisfactory sanitary and hygienic situation. It requires elaboration already at the stage of engineering and technical solutions, environmental costs for the improvement of the territory in a case of recognition of its acceptable for other indicators. The third, fourth and fifth positions are the tense, critical and crisis sanitary and hygienic situation. It should be excluded from further development of the territory the construction or reconstruction, developing plans to optimize the socio-economic development of rural settlements and industrial cities.

It is recommended to characterize state of health after the above criteria, in connection with the chemical pollution of drinking water supply sources, as follows: with a relatively satisfactory sanitary and hygienic situation and a relatively satisfactory degree of environmental distress, there is a deviation of certain health indicators that are not associated with the action of environmental factors. In case of unsatisfactory or strained sanitary and hygienic situation and tense degree of ecological problems, there is a deviation of some indicators of health status, which depends on the ecological problems of the rural area and the possible deviation of demographic indicators. At critical or crisis sanitary and hygienic situation and critical degree of ecological problems congenital abnormalities in health indicators related to environmental factors are shown. The criteria of ecological and hygienic assessment of environmental quality are the indicators of total loading on a human body of man-made pollution – quantitative indicators of pollution related to their maximum permissible concentrations (MPC), taking into account the complex action of chemicals simultaneously present in water.

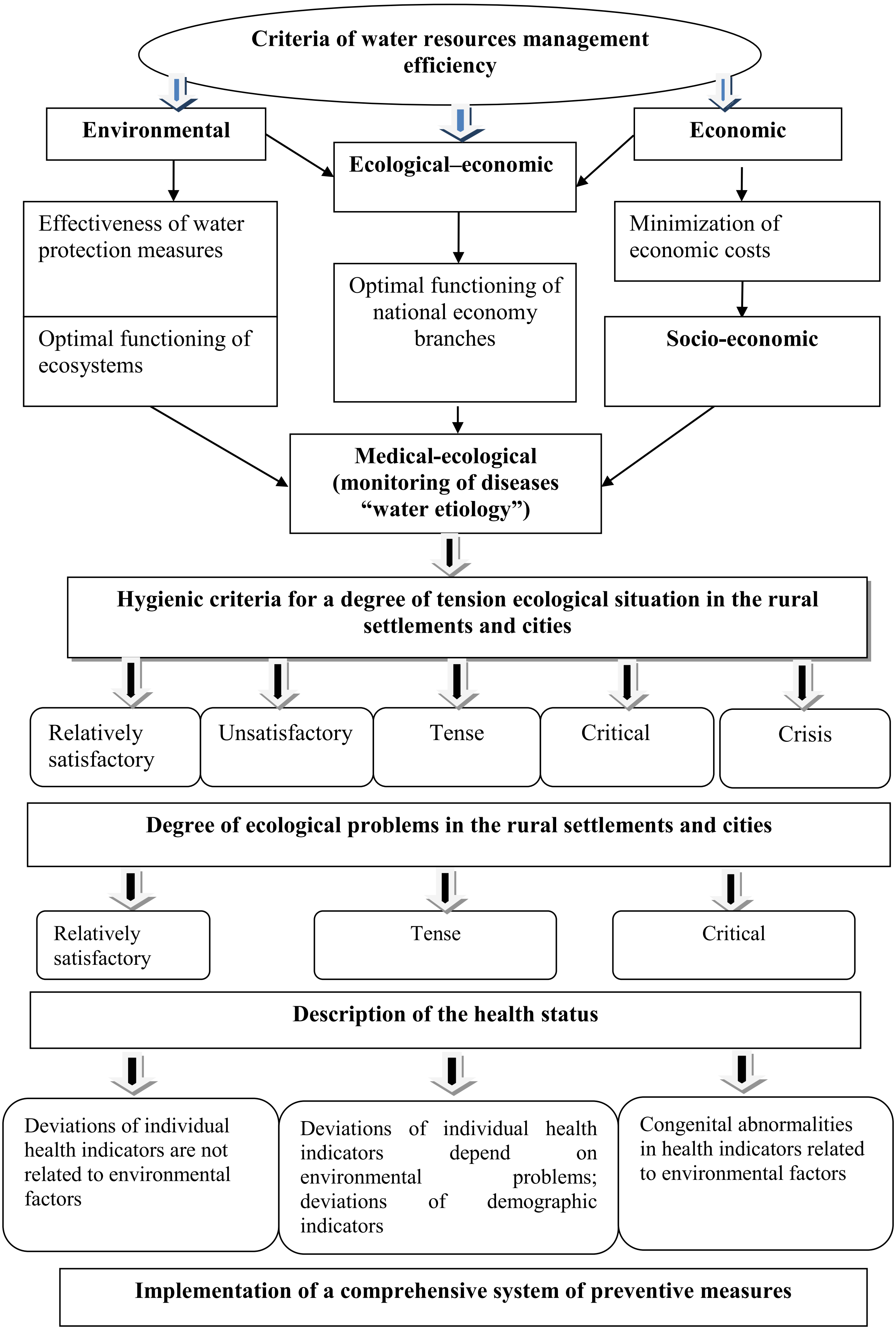

Fig. 8. Model of water resources management efficiency.

Conclusions

The proposed model efficiency of water resources management is focused on the main criteria: environmental, ecological–economic, economic, socio–economic, medical-ecological and hygienic. It is recommended to carry out degree of tension ecological situation in the rural settlements and cities and ecological problems differentially, using hygienic criteria.

It was found that water in Karachunovskyi reservoir is not conditioned by salt composition and belongs to the 3-4 class of water supply sources. It has a high content of total hardness, dry residue, sulfates, chlorides for a long time of observation 1965-2012 years, which is explained by the systematic discharge of highly mineralized mine waters from mining enterprises in the city Kryvyi Rih, pollution of the Ingulets and Saksagan rivers, and subsequent pollution water of the reservoir.

Unfavorable tendency to self-cleaning water of the reservoir, by the indicators of nitrifying activity during 2008-2012 years was shown. Periodically, there is an excess content of some heavy metals in water of this reservoir: Fe 1.14 MPC, Mn – from 1.42 to 1.54 MPC, calcium phosphate – from 26.05 to 23.5 MPC, Mg – from 3.82 to 2.94 MPC, Na+ – K+ 1.18 – 1.11 MPC.

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