Development of protective measures providing environmental safety in areas affected by water-intake constructions of urban households

V L Bondarenko¹, E.D. Khetsuriani²*, A.I. Ilyasov³, E.A. Semenova⁴

¹Novocherkassk Engineering And Land Reclamation Institute Of Don State Agrarian University, 111, Pushkinskaya str., Novocherkassk, 346428, Russian Federation
²M.I. Platov South-Russian State Technical University (Novocherkassk Polytechnic Institute), 132, Prosvesheniya str., Novocherkassk, 346428, Russian Federation
³Director of the branch WTL (USA) in Asia, 7A, Novatorov str., Moscow, 119421, Russian Federation
⁴North-Caucasus Federal University (Branch in Pyatigorsk), 56, 40-lelet Oktyabrya, Pyatigorsk, 357500, Russian Federation

E-mail: goodga@mail.ru

Abstract. The article represents the results of integrated studies of development of protective measures providing environmental safety in areas affected by water-intake technological complexes as a technological component of specified type of natural-technical systems (NTS) ‘natural aqueous medium – water intake technological complex – multiple-use water supply system’ (NAS-WITC-MUSS) concerned with a stable residential water supply of urban households.

1. Introduction
Contemporary stage of social development in a global system ‘nature-society-person’, as well as at local hierarchic levels of river basin geosystems, where almost all kinds of economic and other activity are conducted (including potable water provision of residential sphere of urban households), is deeply concerned with providing the environmental safety in areas affected by WITC as a part of NTS ‘NAS-WITC-MUSS’.

Provision of environmental safety in WITC-affected areas, as the research shows, bring up the necessity of solving a number of important tasks regarding maintaining current variety of bioresources of waterbody as represented by ichthiofauna and flora; providing stable functioning of all hydro-technical constructions as a part of WITC; protecting urban household-MUSS of negative impact of cyanobacteria on qualitative indicators of potable water; keeping water-processing systems of pressure tubes from dreissena fouling in combination promote the solving of key problem of keeping the health of population.

2. Materials & methods
Water-intake technological complex (WITC) as a technogenic component of specialized type of natural-technical systems ‘natural aqueous medium – water intake technological complex – multiple-use water supply system’ (e.g., of a urban household) includes the water-intake hydro-technical construction, interacting directly with the NAM of a waterbody and conducting the selection of calculated consumption of water (Qm³/s) coming in water taking scoop from which the water gets into the technological system of water processing for MUSS of urban household (see Figure 1).

Resulting from the integrated research of the processes of interconnection, interaction and interrelation (3I) of water-intake complex with the natural aqueous medium of the waterbody considering river as a source of water, there were determined the negative effects regarding the safekeeping of bio variety of waterbody, such as whitebait of surface and benthic species of fish; taking of benthic and suspended pumps, stude ice and floating objects by a water-taking scoop causing damage of technological functioning of the water processing scoop of urban household-MUSS. The analysis of causative interconnection of WITC as a part of considered NTS ‘NAS-WITC-MUSS’ showed the necessity of evaluation of key role of separate constructive elements of WITC while conducting functional tasks, on the one hand, in stable selection of calculated water consumption for different river-bed hydraulic modes of the waterbody; on the other hand – in safekeeping the bio variety of waterbody represented by different species of fish and other ichthiofauna as an important factor of environmental safety [1,5].

**Figure 1.** Supposed placement of water-intake scoop of Rostov-on-Don, Aksay and Bataysk urban household-MUSS
Evaluation of the impact of the constructive elements of WITC on the level of NTS-waterbody’s safety aimed at safekeeping of bio variety of ichthiofauna, flora and vital interests of the population caused the necessity of justification of environmental factors for distinction the benchmark criteria of environmental safety of currently functioning and newly created WITC as a part of specialized type of NTS ‘NAS-WITC-MUSS’.

At the section of Lower Don from Tsimlyansk storage pond to the outfall of Don (Azov town) where about 40 WITC as parts of NTS ‘NAS-WITC-MUSS’ are functioning, an integrated research on evaluation of the impact of chemical indicators of water quality and their influence on population’s health; evaluation of the level of safekeeping of natural aqueous medium for keeping the bio variety of ichthiofauna and flora of the Don river; evaluation of level of satisfaction of vital needs of population in potable water of normative quality as well as evaluation of functional and constructive effectiveness of water-intake constructions as parts of WITC.

3. Results and discussion

The research determined that complex interconnection, interaction and interrelation (3I) of water-intake complex with the natural media limited by the basin geosystem of Lower Don, where quantitative and qualitative indicators of usable water resources are formed, with the NAM-component in the area of influence of WITC and MUSS of urban household or settlement as a part of considered environmental state determine the level of environmental safety with the following quantitative and qualitative benchmark indicators in following hierarchic succession:

1. Chemical indicator for the quality of potable water based on the requirements for the safekeeping the health of the population (\(I_{\text{hp}}\)), which should amount \(\geq 90\%\); 
2. Benchmark indicator for the level of protection of natural bio variety, ichthiofauna and flora (\(I_{\text{bw,fl}}\)) (whitebait and water plants) in NAM, which should amount \(\geq 80\%\); 
3. Benchmark indicator for the level of protection of water-intake scoop’s water medium from the studge ice and floating objects coming from the waterbody (\(I_{\text{w,fo}}\)) quantitatively and qualitatively should amount \(\geq 70\%\); 
4. Benchmark indicator for the level of protection of water-intake scoop’s water medium from benthic and suspended pumps coming from the waterbody (\(I_{\text{w}}\)) quantitatively and qualitatively should amount \(90\%\) and \(70\%-80\%\) accordingly; 
5. Benchmark indicator for the protection of water-intake scoop’s water medium from cyanobacteria (\(I_{\text{c}}\)) according to the SanPin prescriptions should amount \(\geq 95\%\); 
6. Benchmark indicator for the protection of technological water-processing system from dreissena (\(I_{\text{db}}\)), which should amount \(\geq 90\%\); 
7. Benchmark indicator for the protection of WITC from freezing-over (\(I_{\text{f}}\)), which should amount \(\geq 98\%\); 
8. Benchmark indicator for the impact of WITC on river-bed forming processes (\(I_{\text{rd}}\)), which is determined qualitatively with help of physical models in scale \(\geq 1:100\).

Integrated analysis of 3I-processes between constructive and functional elements of WITC as a part of NTS ‘NAS-WITC-MUSS’ conjectured that the implementation of demands of quantitative and qualitative benchmark indicators of environmental safety required new effective solutions with using modern high-strength synthetic textile materials of domestic production. Basing on the national experience of practical using of textile materials for constructing soft hydro-technical constructions (SHC) of different functional purpose, the author suggests a soft floating construction (SFC) of water-intake construction (see Figure 2) which includes systems of surface and deepened floats, flexible ties with anchor mechanisms, vertically-movable textile panel providing the taking of calculated water consumption and deepened textile panel, set on a particular distance in front of water-intake window.
4.

Figure 2. Constructive scheme of higher SFC and lower SFC in a head of water-intake scoop

As national experience of production tests of SFC connected to the water-intake constructions with productiveness about 40 m3/s, functional interaction of movable vertical panel and deepened panel ensure the solving of number of protective problems based on qualitative and quantitative benchmark indicators $I_{s.hp.}$, $I_{bv.&f.}$, $I_{si.&fo.}$, $I_{p.}$, $I_{fo.}$, $I_{rbf.}$. Protection from cyanobacteria (benchmark indicator $I_c$) is performed with usage of so called ‘bottle brushes’ which play a role of soft surfaces for gathering cyanobacteria placed in the aqueous medium of water-intake scoop (Figure 3).

Figure 3. Placement scheme of ‘bottle brushes’ in water-intake scoop’s aqueous medium

Protection of tubes of water-processing pumping plants (see Fig. 1) from dreissena fouling of inner surface of tubes which causes decreasing of capacity and increases energy consumption for water-taking to the water-processing treatment facilities of MUSS. In order to protect tubes from dreissena an electric hydropercussive method tested at Stavropol MUSS.

Functioning of WITC as a part of considerable NTS ‘NAS-WITC-MUSS’ as of an open non-equilibrium system is supplied by a constant income of substance - in form of calculated consumption of water taken from waterbody, energy – kinetic and potential energy of water stream, sunlight radiation and information contained in river-bed stream of NAM which is formed in space limits of considerable basin geosystem where the water resources are formed. Selection of calculated water consumption from the waterbody as from the natural component (NAM) is conducted by WITC which should ensure stable functioning of MUSS and environmental safety in areas of their influence. 3I-system of considerable natural component NAM and technogenic components WITC and MUSS as the parts of considerable NTS ‘NAS-WITC-MUSS’ on the one hand, should provide all required needs in water of normative quality for urban household, on the other hand should ensure the environmental safety in areas of impact of WITC as of the key technogenic component [10-15].

Basing on the results of the integrated research of 3I-processes of constructive elements (Fig. 1-3) their hierarchy where the key role is played by the benchmark indicator ($I_{s.hp.}$) health of the population living in the area of influence of WITC. So, SFC of water-intake mechanism (Fig. 1) appears as a multifunctional one which interacts directly with the NAM of the waterbody and ensures the safekeeping of the bio variety of the waterbody through the keeping whitebait, water plants, studge ice and floating objects from getting into the water-intake scoop. SFC when interacting with the benthic layers of the water stream of NAM keeps benthic types of fish and entailed benthic pumps away from the water-intake window. In association, two constructive elements provide the protection of water-intake scoop on three most important benchmark indicators on the second, third and fourth hierarchic levels ($I_{bv.&f.}$, $I_p$, $I_{fo.}$) which maintain the environmental safety of WITC on the level under 65%.

On the fifth hierarchic position of functional importance there is a benchmark indicator $I_c$ protection of aqueous medium of water-intake scoop from cyanobacteria which contribute to the appearance and
development of toxic microorganisms coming to MUSS of urban household. MUSS-protection from toxic microorganisms provides the environmental safety of WITC under the level of 20%.

On the sixth hierarchic level of functional importance there is a benchmark indicator $I_{dr}$ protection of technological system of selection of calculated water consumption in the water-intake scoop (see Fig. 3) in NAM from negative impact of dreissena on the capacity of pressure tubes. The protection of pressure tubes from dreissena provides the environmental safety under 10%.

On the seventh hierarchic level of functional importance there is a benchmark indicator $I_{rbf}$, $I_{fo}$ SFC-protection from studge ice, floating objects and freezing-over during the autumn-winter period of exploitation of WITC which provides the environmental safety under 4%.

On the eighth hierarchic level of functional importance there is a benchmark indicator $I_{rbf}$ impact of river-bed forming processes of waterbody on functioning of WITC and accordingly impacts the environmental safety under the limit of 1% [15].

Basing on system analysis and synthesis of achieved results of research of 3I-processes of constructive elements WITC, NAM and MUSS, their benchmark indicators have been justified and basic definition of environmental safety of WITC as a part of specialized type of NTS ‘NAS-WITC-MUSS’ has been formed.

Environmental safety of currently functioning WITC as parts of specialized type of NTS ‘NAS-WITC-MUSS’ is determined by quantitative and qualitative benchmark indicators $I_{s,hp}$, $I_{bv}$, $I_{fo}$, which are formed by 3I-processes between WITC and NAM, MUSS.

Collected resulting data of the research on currently functioning WITC as parts of specialized type of NTS ‘NAS-WITC-MUSS’ is recommended for using when evaluating the level of environmental safety both of separate constructions and constructive complex and protective mechanisms in general. Using SFC on modern stage is more perspective in comparison with the current fish-protecting mechanisms of water-intake constructions WITC NAM.

4. Conclusions

- multifunctionality of WITC as a part of currently functioning NTS ‘NAS-WITC-MUSS’ is determined by 7 benchmark indicators; their quantitative and qualitative value define the level of environmental safety of considerable WITC;
- benchmark indicator $I_{s,hp}$ determines the first hierarchic level and defines the main biological factor of environmental safety of WITC which if represented by quality of potable water consumed by the population that keeps the health;
- basing on benchmark indicators, a basic definition of environmental safety of WITC as a part of specialized type of NTS ‘NAS-WITC-MUSS’.

References
[1] Bondarenko V L, Ylyasov A I, Khepuriani E D 2019 Science-methodological basics of the natural and technological systems in the water resources usage: the territories of the geosystems basins, monography (Platov South-Russian State Polytechnic University (NPI), Novocherkassk).
[2] Khetsuriani E D, Fesenko L N, Kostyukov V P, Khetsuriani I E 2017 Obtaining a regression equation and evaluating their adequacy for analyzing field studies (Norwegian Journal of International Science Development) 9 (2r) 69-72
[3] Bondarenko V L, Skibin G M, Azarov E A, Semenova E A, Privalenko V V 2016 Ecological safety in the environmental management, water use and constructing: the estimation of the ecological status of the basin geosystems (monography, Platov South-Russian State Polytechnic University (NPI)) p. 416.
[4] Saling P, Hover R 2009 Metrics for Sustainability as part of RSC Green Chemistry, Sustainable Solutions for Modern Economies (the Royal Society of Chemistry Series, Iowa State University) 4 25-37.
[5] Stefanenko I V, Semenova E A, Klimenko O V, Bondarenko V A 2018 Fundamentals of the methodology for the development of the technical theory of natural-technical systems in the use of water resources (Applied mechanics and materials) 875 141-144.

[6] Scriabin A Yu, Popovyan G V, Tron I A 2017 Study of factors affecting the intensive development of microalgae in the Don River (Water supply and sanitary equipment) 4 2017.

[7] Barnes D, Galgani F, Thompson R, Barlaz M 2009 Stockpiling and fragmentation of plastic wastes in global conditions (Phil. Сделка R. Soc.) 364 1985–1998.

[8] Behrenfeld M J, Boss E 2006 Beam attenuation and chlorophyll concentration as alternative optical indices of phytoplankton biomass (J. Mar. Res) 64 431–451

[9] Behrenfeld M J, Falkovsky P G 1997 Photosynthetic rates derived from satellite-based chlorophyll concentration, Лимнол. Oceanogr. 42 1–20.

[10] Cole M et al 2013 Microplastic ingestion by zooplankton Environ 47 6646–55

[11] Dellnitz M, Froyland G, Horenkamp C, Padberg-Gehle K 2009 Sen Gupta A.

[12] Seasonal variability of the subpolar gyres in the Southern Ocean: a numerical investigation based on transfer operators (Geophys) 16 655–64.

[13] Froyland G, Padberg K, England M H, Treguier A M 2007 Detection of coherent oceanic structures via transfer operators (Physical Review Letters) 98 224503

[14] Gregory M R 2009 Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions (Philosophical transaction. Soc.) 364 2013–25.

[15] Lebreton L C-M, Greer S D, Borrero J C 2012 Numerical modelling of floating debris in the world’s oceans (Marine Pollution Bulletin) 64 653–61

[16] Thompson R C, Moore C J, Vom Saal F S, Swan S H 2009 Plastics, the environment and human health: current consensus and future trends (Фил. Сделка R. Soc.) B 364 2153–66.

[17] Van Sebille E 2014, Van Sebille E 2014 Adrift. org. au—A free, quick and easy tool to quantitatively study planktonic surface drift in the global ocean (J. Exp. Mar. Biol. Ecology) 461 317–22.

[18] Delworth T L et al. 2006, Delworth T L et al 2006 GFDL’s CM2 global coupled climate models. Part I: Formulation and simulation characteristics (J. Clim) 19 643–74

[19] Gnanadesikan et al 2006 Global climate models (Basic ocean modeling) 19 675–97.

[20] Khaarsma R J, Selten F 2012 Anthropogenic changes in the Walker circulation and their impact on the extra-tropical planetary wave structure in the Northern Hemisphere (Climate Dynamics) 39 1781–99

[21] Reindert J, Haarsma Email Frank Selten Geert Jan van Oldenborgh 2013 Anthropogenic changes of the thermal and zonal flow structure over Western Europe and Eastern North Atlantic in CMIP3 and CMIP5 models (Climate Dynamics., Дин) 41 2577–88.

[22] Makkaveyev N I, Belinovich I V, Khmeleva N V 1958 Riverbed processes in alternate overpressure areas (Riverbed processes, Moscow) 318-337

[23] Berkovich K M 2012 Riverbed processes in river impacted by the watershed, Moscow.

[24] Berkovich K M, Vinogradove N N Influence of big watersheds on hydrological and river-bed process of alternate overpressure (No resources) 6 81-87.

[25] Babiański Z 1992 Hydromorphological consequences of regulating the lower Vistula (Poland, Wroclaw-V-Warsaw-Krakow) 157 p. 172

[26] Williams G P, Wolman M G 1984 Downstream effects of dams on alluvial rivers 1286 p. 83.

[27] Rathburn S, Finley J, Klein S, Whitman B 2004 Assessing reservoir sedimentation using bathymetric comparison and sediment loading measurements 5 (36) 12.

[28] Set of rules for design and construction: SP 33-101-2003 “Determination of the main calculated hydrological characteristics”: regulatory technical material [Design and construction instruction: SP 33-101-2003. Determining the fundamental calculated hydrological characteristics: reference information] 2004 (Moscow: PNIIS publishing house of Gosstroy of Russia) P. 72