ISSN 2409-9066. Sci. innov. 2015, 11(1): 80—84 doi: http://dx.doi.org/10.15407/scine11.01.080

Goncharuk, V.V., Baydachny, A.N., Kucheruk, D.D., and Balakina, M.N.

A.V. Dumansky Institute of Colloid and Water Chemistry, the NAS of Ukraine, Kyiv

STATE-OF-THE-ART TECHNOLOGIES AND EQUIPMENT FOR OBTAINING HIGH-QUALITY DRINKING WATER

A principally new concept of supply quality drinking water to the Ukrainian population have been proposed. It is based on a system of autonomous complexes for water purification directly at the area of consumption. Water treatment autonomous complexes for collective and individual use with biological testing and analytical quality control of drinking water have been developed. The methods for cleaning the tap and other water up to the genetically safe quality are based on a modular concept that provides the possibility of varying the number of modules depending on the composition of source water. The proposed technology and equipment have no analogues in the world by self-cost and complex of problems that have been addressed. Over thousand Vega modular installations and Promin disinfecting vehicles have been implemented in many populated localities throughout Ukraine.

Keywords: water purification, drinking water, new concept, autonomous complexes, and innovation projects.

A distinctive feature of drinking water supply in Ukraine is that the ratio of the surface water to the underground water in its structure is 70:30, respectively, while in Europe, the latter reaches 90%. The guaranteed water supply to rural regions remains very low. Only 24.5% of rural settlements have a centralized water supply system.

In Ukraine, the use of surface water sources for drinking water supply creates makes it difficult to ensure the appropriate quality of drinking water, as a result of specific chemical composition of water in the majority of watersheds, especially, in the Dnieper River basin. The reason is that the content of natural organic matter in water of the Dnieper basin exceeds many times this value in the rivers of Western and Eastern Europe and reaches 20—30 mg/dm^3. This leads to the formation of toxic organochlorine secondary products, as a result of water disinfection with chlorine, and to the emergence and growth of biofilm in distribution grids, which eventually entail a significant deterioration in the quality of drinking water.

The quality monitoring of surface water has showed that despite a significant decline in industrial production, in recent years, and a consequent decrease in sewage discharge, there has been a tendency to deterioration in the ecological status of surface drinking water sources. The hydrochemical, ecological, and hygienic indicators of surface water sources correspond mainly to the 3rd grade of quality; some reservoirs have the indicators belonging to the 4th quality grade which is not acceptable for drinking water.

At the same time, the water treatment technology at existing centralized water supply stations focuses mainly on production of 1st grade quality water. This leads to significant deviations of final drinking water product from the requirements of regulations. As of today, 72.3% of the total water supply systems does not meet sanitary standards because of the lack of sanitary protection zones; 17.4% reports the lack of required integrated treatment facilities, and 18% lacks disinfecting

plants. The rural water supply is of particular concern, about 660 of 7691 (8.6%) rural water supply systems fail to meet health standards.

The quality of drinking water is affected not only by poor sanitary condition of water supply facilities, their obsolescence (30 to 70%), but also by inadequate condition of water distribution networks where intense secondary contamination of drinking water occurs despite high concentration of active chlorine. The total length of water distribution networks throughout country is 140 216 km; 36 461 km or 26% of which require immediate replacement and large capital expenditure.

A fundamental solution of problems related to water supply is the use of innovative approaches. In Ukraine, on the average, water stations produce 350 liters of water per capita daily, while rate of drinking water consumption is about 3 liters per capita daily. Thus, the water is used mainly for sanitary and technical needs. From the economic point of view, it is infeasible to invest big money in improving the quality of drinking water on a scale that exceeds 100 times the actual needs of population.

Given the above, the A.V. Dumansky Institute of Colloid and Water Chemistry of the NAS of Ukraine (ICWC) under the direction of Full Member of the NAS *Vladyslav Goncharuk* has conducted basic research that allows the researchers to determine fundamentally new ways of supplying high quality drinking water to Ukraine's population. The researchers have created innovative methods and processes for deep extract of toxic organic and inorganic impurities from water. They have proposed methods for disinfection and analytical control of water and a new technique for integrated assessment of water quality on the basis of bioassay. The basic fundamental researches conducted by ICWC staff are summarized in [1—3].

Proceeding from these fundamental studies, a new approach to supply of quality drinking water to Ukraine's population has been proposed. It is based on the creation of autonomous units of well-room type for water treatment in the area of its consumption. Such units have relatively small output (1—5 m^3/h) and are located in each district of the city or in rural areas to produce water for drinking and cooking only. Thereby, this approach leads to a significant saving of budget funds. The drinking water in these units is of high quality, insofar as it does not run through outdated water supply systems and is treated using a chlorine-free water disinfection technology. Under these conditions, it is advisable to maintain the existing water supply network for treating water for industrial and domestic use. This concept has been supported by the Cabinet of Ministers of Ukraine and by the National Security and Defense Council and used as a framework for a new version of the Law of Ukraine on Drinking Water and Water Supply Ukraine.

To address this problem, the ICWC researchers have developed autonomous units of various capacities for collective and individual use. The methods for water treatment to the world standards are chosen depending the composition of water in source. The unites are based on a flexible modular principle which makes it possible to vary the number of modules depending on the composition of water. The above tasks have been solved using several methods protected with patents of Ukraine [4-8]. These methods are based on the use of membrane techniques that today are among the most promising for producing high-quality drinking water in combination with other methods of purification. The autonomous unites were designed on the basis of international experience and results of ICWC research works.

Much attention is paid to the pre-treatment of water, including removal of iron by deep aeration under pressure, adsorption of organic substances by domestic mineral adsorbents and ultraviolet disinfection of source water in order to extend the service life of membranes. A general view of local units designed by ICWC staff is showed in Figs. 1—3 (see the color inset).

The proposed technology and equipment are unmatchable by self-cost and the number of problems that have been addressed. The ICWC researchers have elaborated comprehensive programs for imple-

menting the above mentioned well-room type autonomous systems to produce genetically safe water in Vinnytsia, Kherson, Sumy, Chernihiv, Zhytomyr, and Donetsk Oblasts (DTEK).

The quality of water purified by autonomous complexes is controlled by ICWC methods of bioassay at organismal and cellular levels. The tests make it possible to comprehensively analyze its toxicity and the impact of pollution on the human body, as well as to assess the quality of aquatic environment.

To determine the standard indicators of quality of drinking water in situ, each autonomous unit can be provided with *Aqua-test* portable laboratory designed by ICWC. This laboratory is a combination of low price and broad functionality; it ensures an easy, comfort, rapid, and environmentally safe onsite analysis of water samples.

The underground water sources are known to be better protected from contamination. The share of underground water sources in the total water supply accounts for about 30%. However, they are very unevenly distributed throughout the territory of Ukraine. Most of the groundwater sources (60%) are located in Lviv, Kyiv, Poltava, Rivne, Sumy, and Chernihiv Oblasts, while Zhytomyr, Ivano-Frankivsk, Kirovohrad, Mykolayiv, Odesa, and Chernivtsi Oblast have very scarce underground water resources.

Throughout Ukraine, the groundwater is widely used mainly for technical needs. However, it should be pointed out that for the fresh groundwater being a national strategic reserve, its use for household and industrial needs is unacceptable. Insofar as the new concept provides for a significant reduction in the extraction of groundwater, its implementation will ensure not only supply of high quality drinking water to the population, but also improvement of the condition of groundwater resources and saving of Ukraine's strategic reserve of fresh water.

The use of well-room type autonomous systems allows us to address the problem of supplying high quality drinking water to the rural population, and consequently, to decrease the incidence rate. About 1200 villages with the total population of about 800 thousand, for some natural or technical reasons, use imported water. The implementation of new concept eliminates the need in imported water, inasmuch as well-room units produce high quality drinking water from water source of arbitrary composition. It should be noted that in Kyiv, about 300 drinking water well rooms have been launched for the first ever time in world practice.

The ICWC technologies make it possible to produce high quality drinking water from four fundamentally different types of source water:

- Tap water from centralized water supply system, which usually contains toxic impurities, aluminum, iron, and manganese compounds, chlorine organic and microbiological contaminants, etc. (the technology makes it possible to remove not only the above toxicants, but also toxic algae wastes);
- Fresh groundwater that contains high concentration of iron, manganese, fluorides, nitrates, carbonate-hardness salts, ammonium salts, hydrogen sulfide, etc.;
- Underground water with a high salt content (up to 5.8 g/dm^3); and
- Sea water.

For each type of source water, innovative technologies and equipment for their treatment have been designed. As of today, the units with a capacity of 20, 200, 500, 1000, and 5000 dm^3 per hour have been created.

The new approach to provision of the population with quality drinking water was developed thanks to the introduction of more than 150 *Vega* modular settings and *Promin* disinfecting apparatuses in 30 cities and villages of Ukraine (Lviv, Kharkiv, Dnipropetrovsk, Odessa, Uzhgorod, Mukachevo, Pavlograd, etc.). At present, in Kyiv, *Vega-150* and *Vega-500* have been installed at more than 250 pre-school and educational institutions, government offices, and private houses. Using the ICWC technology a water treatment plant having a capacity of 4400 m^3/daily has been built and launched in Mukachevo, on

Rosvyhovo water intake; the city of Boryspil, Kyiv Oblast, has fully shifted to the well-room type water supply.

The ICWC of the NAS of Ukraine is actively involved in innovation projects. In recent years, its researchers have succeeded in the following activities:

- Manufacture of multi-functional modular units for production of high-quality drinking water for cities and towns where drinking water does not meet the applicable standards (2004);
- Production of autonomous water treatment systems for rural regions (2007);
- Development and production of membrane systems for concentration and separation of salts within the framework of the creation of a non-waste technology for desalination of saline water (2009);
- Development of technique for water purification from nitrates and new methods for monitoring of drinking water using the cytogenous approach (2010);
- Testing and pilot implementation of innovative membrane and sorption technologies using nanomaterials and activated carbon made of raw material from the Donetsk Basin for the production of safe drinking water from natural sources (2011); and
- Development and production of domestic ceramic membranes for water treatment (2013).

In 2013, the team of ICWC researchers consisting of *V.V. Goncharuk, O.M. Baydachny*, and *D.D. Kucheruk* was awarded with the Prize of the Cabinet of Ministers of Ukraine for the development and introduction of new technologies and equipment in the sphere of high-quality drinking water production.

New approaches to supply of high quality drinking water to the population should be developed and implemented on the basis of reasonable regulatory requirements for both water supply sources and drinking water. For implementing the Law of Ukraine on *the Drinking Water of Ukraine* Government Program for 2006—2020, the ICWC experts together with the *Quality of Drinking Water* Technical Committee of Standardization (TC-147) in cooperation with specialists of ministries, departments, and research institutes have elaborated the government standard of Ukraine 4808:2007 *Sources for Centralized Drinking Water Supply. Hygienic and Environmental Requirements for Water Quality and Rules for Selection*. The proposed modern environment and hygienic classification of water quality in surface and groundwater facilities and sources of centralized drinking water supply includes 4 grades of water quality (previously, it had 3 grades). This classification makes it possible to give an objective assessment of water quality in ecosystems of water bodies and to conclude on the suitability of water for centralized water supply.

Upon request of the Ministry for Housing and Municipal Economy of Ukraine, the ICWC has developed the government standard of Ukraine *Drinking water. Requirements and Methods for Quality Control* and harmonized it with the EU Directives 98/83. The project was completed in 2008. For the first time in world practice, it has included three regulations with respect to the requirements for tab water, packaged water, and high quality drinking water agreed with all stakeholders and supported by the National Security and Defense Council of Ukraine.

The *Quality of Drinking Water* Technical Committee (TC 147) of the State Committee for Technical regulation and Consumer Policy based on ICWC is regularly studying and analyzing the regulations and elaborating new regulations for the quality of water and water sources. The Committee collaborates with the International *Water Quality* Committee I80/TC147 of the International Organization for Standardization in the development of regulatory documents and standards.

The ICWC has created a research and engineering center for water test accredited by UkrCEPRO. It deals with monitoring of water reservoirs and drinking water (including, well rooms in Kyiv) and ensures the implementation of a set of works related to the improvement of drinking water quality (methodological and analytical sup-

port of the implementation of national standards on drinking water and potable water supply, the development of effective methods for analytical control of water quality).

By virtue of the Order of the Presidium of the NAS of Ukraine of 13.03.2002 no.151, the ICWC was appointed as a leading institution of the NAS of Ukraine on issues related to the research, methodology, organization, and technical coordination of the activities on supply of quality drinking water to the population, with V. Goncharuk, ICWC Director, Full Member of the NAS of Ukraine, and Academic Secretary of the Department of Chemistry of the NAS of Ukraine being a coordinator of the NAS of Ukraine on scientific issues of quality and safe drinking water supply to population.

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В.В. Гончарук, А.М. Байдачний,
Д.Д. Кучерук, М.М. Балакіна
Інститут колоїдної хімії та хімії води
ім. А.В. Думанського НАН України, Київ

НОВІТНІ ТЕХНОЛОГІЇ Й УСТАТКУВАННЯ ДЛЯ ОТРИМАННЯ ВИСОКОЯКІСНОЇ ПИТНОЇ ВОДИ

Пропонується принципово нова концепція забезпечення населення України якісною питною водою. Концепція ґрунтується на системі автономних комплексів для очищення води в місцях безпосереднього її споживання. Розроблено автономні комплекси водопідготовки для колективного й індивідуального використання з біотестуванням і аналітичним контролем якості питної води. Вибір методів очищення водопровідної та інших вод до якості генетично безпечної здійснюється відповідно до її складу і базується на блочному принципі, що забезпечує можливість варіювання кількістю блоків залежно від складу вихідної води. Запропоновані технології й обладнання за собівартістю та комплексом проблем, які вирішуються, не мають аналогів у світі. Понад тисячу блочних установок «Вега» та знезаражуючих апаратів «Промінь» впроваджено в багатьох населених пунктах усіх регіонів України.

Ключові слова: водоочищення, питна вода, нова концепція, автономні комплекси, інноваційні проекти.

В.В. Гончарук, А.Н. Байдачный,
Д.Д. Кучерук, М.Н. Балакина
Институт коллоидной химии и химии воды
им. А.В. Думанского НАН Украины, Киев

НОВЕЙШИЕ ТЕХНОЛОГИИ И ОБОРУДОВАНИЕ ДЛЯ ПОЛУЧЕНИЯ ВЫСОКОКАЧЕСТВЕННОЙ ПИТЬЕВОЙ ВОДЫ

Предложена принципиально новая концепция обеспечения населения Украины качественной питьевой водой, основанная на системе автономных комплексов для очистки воды в местах непосредственного ее потребления. Разработаны автономные комплексы водоподготовки для коллективного и индивидуального использования с биотестированием и аналитическим контролем качества питьевой воды. Выбор методов очистки водопроводной и других вод до качества генетически безопасной осуществляется в соответствии с ее составом и основывается на блочном принципе, что обеспечивает возможность варьирования количеством блоков в зависимости от состава исходной воды. Предложенные технологии и оборудование по себестоимости и комплексом решаемых проблем не имеют аналогов в мире. Свыше тысячи блочных установок «Вега» и обеззараживающих аппаратов «Промінь» внедрено во многих населенных пунктах всех регионов Украины.

Ключевые слова: водоочистка, питьевая вода, новая концепция, автономные комплексы, инновационные проекты.

Received 12.11.14