Federal State Budgetary Educational Institution of Higher Education
«Siberian State Medical University»
Ministry of Healthcare of the Russian Federation

V.S. Kaveshnikov, T.V. Andropova, V.N. Serebryakova,
M.V. Gudina, I.Yu. Yakimovich

WATER SUPPLY SANITATION AND HYGIENE IN POPULATED AREAS

Tutorial

Tomsk
Siberian State Medical University
2022

Authors:
V.S. Kaveshnikov, T.V. Andropova, V.N. Serebryakova,
M.V. Gudina, I.Yu. Yakimovich

Water supply sanitation and hygiene in populated areas: tutorial / V.S. Kaveshnikov et al. – Tomsk: SSMU, 2022. – 42 p.

The tutorial is prepared in accordance with the Federal State Educational Standard of Higher Professional Education, for students studying in the medical specialty. The textbook is based on the publication in Russian "Guide to Practical Training on Hygiene". The tutorial has been revised and supplemented.

The tutorial highlights the hygienic principles of water supply of populated areas. In presenting the material, the current regulatory documents – State Standards and SanPiNs were used.

Reviewer: I.N. Odintsova, PhD, Associate professor at the Hygiene Department, SSMU.

Approved and recommended for publication by the methodical commission of the in the specialty "General Medicine" of the SSMU (protocol No. 8 from 27.12.2021)

Федеральное государственное бюджетное образовательное
учреждение высшего образования
«Сибирский государственный медицинский университет»
Министерства здравоохранения Российской Федерации

В.С. Кавешников, Т.В. Андропова, В.Н. Серебрякова,
М.В. Гудина, И.Ю. Якимович

Гигиена водоснабжения населенных мест

Учебное пособие

Томск
Сибирский государственный медицинский университет
2022

УДК 614.777(075.8)
ББК 51.215я73
Г 463

Авторы:
В.С. Кавешников, Т.В. Андропова, В.Н. Серебрякова, М.В. Гудина,
И.Ю. Якимович

Г 463 **Гигиена водоснабжения населенных мест**: учебное пособие / В.С. Кавешников и [др]. – Томск: СибГМУ, 2022. – 42 с.

Учебное пособие подготовлено в соответствии с Федеральным государственным образовательным стандартом высшего образования, для студентов, обучающихся по специальностям: лечебное дело, педиатрия, стоматология, медицинская биохимия, медицинская биофизика, фармация. В основу учебного пособия положено издание на русском языке «Руководство к практическим занятиям по гигиене», пособие переработано и дополнено.

В учебном пособии изложены гигиенические принципы водоснабжения населенных мест. При изложении материала использованы действующие нормативные документы – ГОСТы и СанПиНы.

УДК 614.777(075.8)
ББК 51.215я73

Рецензент: доцент кафедры гигиены, доктор медицинских наук, Одинцова Ирина Николаевна.

Утверждено и рекомендовано к печати методической комиссией по специальности «Лечебное дело» СибГМУ (протокол № 8 от 27.12.2021 г.)

1. WATER AS A FACTOR OF HEALTH. HYGIENIC REQUIREMENTS TO QUALITY OF DRINKING WATER

PURPOSE OF THE LESSON: is to familiarize students with impact of the quality of drinking water on public health and with modern hygienic standards for basic indicators of water quality.

THEORETICAL PART. According to WHO experts, low-quality drinking water is the second risk factor for people's health after poverty. Optimizing water use conditions and providing the population with sufficient quantities of good quality drinking water are important state tasks. Availability of drinking water for a population is one of the life quality indicators.

In the world today about 800 million of people or 13% of the world's population suffer from diseases transmitted through water of inferior quality every year. Consumption of unsuitable water and lack of basic sanitation are the causes of death of about 25 million people annually.

In the body of an adult human being water contributes about 65–70% to the body weight. Its physiological significance lies in the fact that all processes in the body (assimilation, dissimilation, diffusion, osmosis, resorption, hydrolysis, oxidative deamination) occur in water solutions or with its participation. The daily need in water for an adult human body is about 2.5 liters, but when performing heavy physical work or in hot climatic conditions this amount can increase up to 10–15 liters. In case of water loss in amount of 6–8% of the body weight, the thermoregulation, cardiovascular and respiratory system functioning is disrupted; with a loss of 10% of the body weight, irreversible changes in the body may follow, and a loss of 15–20% may cause death.

The microelement composition of drinking water has a great physiological significance. About 1–10% of the body's need for mineral substances comes with water. Such an important trace element, like fluoride, is mainly supplied to the body with drinking water. Up to 60% of people in Russia consume water with low fluoride content.

Water used for domestic and drinking purposes if not meeting the standards for chemical and microbiological indicators may be the factor of a negative impact on public health (tab. 1).

Table 1

Diseases and intoxications associated with water transmission factor

Epidemic outbreaks	Endemic diseases	Intoxications
Intestinal infections: cholera, typhoid fever, paratyphoid A and B, dysentery. Anthropozoonotic infections: tularemia, leptospitrosis. Viral diseases: enterovirus, rotavirus infection, hepatitis A Protozoal infections: amebiasis, balantidiasis, giardiasis Helminthiases: ankylostomiasis, ascaridosis, fasciolosis tricalchosis	Dental caries Fluorosis Strontium rickets; Molybdenum gout Nephrolithiasis	Water-nitrate methemoglobinemia. Intoxication with lead, arsenic, selenium, chromium, mercury, cadmium, etc. Beryllium rickets

Use of poor-quality drinking water can be the cause of: 1) infectious and parasitic diseases due to pollution of water sources with domestic fecal wastewater, sewage, farming livestock, containing pathogens; 2) non-infectious diseases associated with the peculiarities of the natural chemical composition of water – insufficient or excessive content of certain elements and compounds in the territories of biogeochemical provinces relative to the body's need; 3) diseases of non-infectious etiology associated with presence in water of toxic substances as a result of industrial, agricultural, domestic or other pollution, as well as with the water reagents added during its processing.

Contribution of water factor in the incidence of acute intestinal infections in population, the causative agents of which enter the water sources with wastewater and sewage, and in case of centralized water supply through an unsealed distribution network, has been studied in detail.

The danger to humans arises not only when consuming insufficiently purified water, but also as result of being in contact with water, contaminated with pathogenic microorganisms. Such bacteria as klebsiella, pseudomonads and legionella are able to reproduce themselves in habitual environments such as conditioners, inhalers, shower installations, on the surface of washbasins, in wet cleaning equipment.

Bacteria Legionella pneumophila, living in hot and cold water distribution systems, is notorious causative agent of respiratory diseases of varying severity – from mild forms to death inflicting. More than 100 outbreaks of diseases caused by these bacteria are described. Legionella are found in the water of swimming pools, especially with warm water. A study of the thermal waters of a mountain resort in Austria showed that legionella are sown in almost 80% of the samples. This problem also occurs in everyday life, in particular when using a shower with legionella present, wherein water aerosols can enter the person's airways.

Among viral infections transmitted through water, enteroviruses are of particular epidemiological significance. The term is used as a generic name for the large group of viruses that multiply themselves in the gastrointestinal tract, so they are also called intestinal viruses. These are the causative agents of poliomyelitis, poliomyelitis-like disease, coxsackie, ECHO, hepatitis A. In addition to enteroviruses, adenoviruses can be transmitted through water. Clinical manifestations of viral infection are various (tab. 2).

Table 2

Clinical manifestations of viral infections transmitted through drinking water

Virus	Clinical picture of the disease
Polioviruses	Poliomyelitis, serous meningitis
ECHO	Acute respiratory disease (ARD), serous meningitis, poliomyelitis-like diseases
Coxsackie	ARD, serous meningitis, herpetic angina, myocarditis, conjunctivitis
Hepatitis A, E	Hepatitis
Rotavirus, coronoviruses	ARD, gastroenteritis
Adenoviruses	ARD, serous meningitis, conjunctivitis
Astroviruses	Gastroenteritis

Enterovirus family has a significantly greater resistance to harmful effects of environmental factors compared to indicator bacteria, as well as to disinfectants. The methods of water treatment, while effective against bacterial contamination, are not so helpful with respect to viruses.

Water is a transport pathway for eggs of helminthes and cysts of pathogenic protozoa. The role of water in transmission of pathogenic fungi, in particular the causative agent of epidermophytia, has been noted.

Annually more than 6 × 109 m^3 of wastewater without post-treatment is discharged into open reservoirs of Russia and about 1.7 × 1010 m^3 is additionally discharged having not being post-processed in sufficient ways. All surface water resources located in the northwestern and central regions of Russia, as well as in the Far East, contain cysts of lamblia and other protozoa. At present, it can be noted a possibility of transferring through water of three protozoa species: Entamoeba histolitica, Giardia intestinalis, Balantidium coli, which can cause amebiasis (or amebic dysentery), giardiasis and balantidiasis, respectively.

Parasitizing in the human body in a vegetative form, these protozoa are excreted into external environment with feces in the form of cysts or oocysts, which are protected from unfavorable external factors by a dense shell. When they enter a reservoir with sewage or storm water, they can remain viable for a long time.

Amybiasis and balantidiasis are manifested as acute diseases, which turn into a chronic form, accompanied by diarrhea. Giardia does not violate integrity of intestinal mucosa, so the disease does not have a clear clinical picture – there can be abdominal pains, dyspeptic disorders, but often giardiasis goes asymptomatic. The average bacteria carrying rate for lamblia in population is about 15%. In children with unfavorable hygienic conditions it exceeds 30–40%. According to the WHO, in Asia, Africa and Latin America, about 200 million people are infected with giardiasis annually. In US, the prevalence is 9.4%, in Norway – 3.2%. In US, giardiasis is considered as one of the main water transmitted intestinal diseases.

Trophosits, or vegetative forms of giardia, do not survive long in an environment outside the host's body; they die under action of gastric juice. Infection occurs when cysts are ingested. Lamblia cysts are single cell unicellular parasites of the Flagellates class. They look like oval formations with a two-contour envelope having size of 6–8 × 10–14 µm, resistant to environmental factors and disinfecting agents, capable of prolonged survival (up to 6 months) in environment. SanPiN 2.1.4.1074-01-01 prescribes to control the content of lamblia cysts in drinking water.

The microorganisms, pathogenic for human and able according to WHO to be transmitted orally with drinking water, are given in table 3.

Table 3

Pathogenic microorganisms transmitted through water orally

Microbial agent	Persistence (vitality) in water supply systems*	Chlorine tolerance **	Relative infecting dose***
Bacteria			
Campylobacter jejuni; coli	Average	Low	Average
Patogenic Escherichia coli	Average	Low	High
Salmonella typhi	Average	Low	High
Shigella specius sub species	Short-term	Low	Average
Vibrio cholerae	Short-term	Low	High
Yersinia enterolitica	Prolonged	Low	High (?)
Pseudomonas aeruginosa	Can reproduce	Average	High (?)
Aeromonas specius sub species	Can reproduce	Low	High (?)
Viral agents			
Adenoviruses	(?)	Average	Low
Enteroviruses	Prolonged	Average	Low
Hepatitis A viruses	(?)	Average	Low
Hepatitis E viruses	(?)	(?)	Low
Norwalk virus	(?)	(?)	Low
Rotavirus	(?)	(?)	Average
Small round viruses	(?)	(?)	Low
Protozoa			
Entamoeba histolytica	Average	High	Low
Giardia intestinalis (lamblia)	Average	High	Low
Cryptosporidium parvum	Prolonged	High	Low
Dracunculus medinensis	Average	Average	Low

*Note. (?) – Unknown or unclear; * – period of detection in water (20°C) at the stage of infection: short – up to 1 week; average – up to 1 month; long – over 1 month; ** – high resistance is when the infectious agent stays in a free suspended state in the water processed at usual doses and contact time; medium resistance – when the pathogenic agent may not be completely destroyed; low resistance – when the pathogen is completely destroyed; *** – the dose that causes disease in 50% of adult healthy volunteers.*

Thus, quality of water to a great extent determines the state of human health, its sanitary and epidemiological well-being. A doctor of any profile needs appropriate knowledge on water hygiene for organizing and carrying out measures for prevention of water associated diseases.

The main normative documents in the field of hygiene of domestic and drinking water supply in Russia are:

1. "Drinking water. Hygienic requirements for water quality of centralized drinking water supply systems. Quality control". Sanitary and epidemiological rules and regulations. SanPiN 2.1.4.1074-01.
2. "Hygienic requirements for water quality of non-centralized water supply. Sanitary protection of water sources". Sanitary and epidemiological rules and regulations. SanPiN 2.1.4.1175-02.
3. Hygienic requirements to the quality of drinking water for centralized water supply.

According to the current SanPiN, drinking water must be safe in epidemic and radiation aspects; harmless in chemical composition; have favorable organoleptic properties.

Ideally, drinking water should not contain a microflora pathogenic to human. Due to complexity of monitoring all the pathogens known to be causative, since the beginning of the 20th century sanitary practice came to conclusion that it is advisable to monitor the content in water of so-called “sanitary indicators” or “indicative microbes” that are of fecal origin and therefore indicative of a possibility of presence in water of pathogens causative for infectious, mostly intestinal diseases.

Safety of drinking water in epidemic aspects is determined by its compliance with the standards for microbiological and parasitological indicators, presented in table 4.

As to bacterial indicators, in the SanPiN 2.1.4.1074-01 it is prescribed to monitor content in drinking water of Enterobacteria family, and in case of detection – further to determine the number of thermotolerant coliforms. As well content of sulfite-reducing clostridia is controlled as integral indicator of bacterial contamination by the total microbial count.

The common coliform bacteria are gram-negative bacteria, which do lactose fermentation at the temperature of 35 or 37°C with formation of acid, gas and aldehyde for 24–48 hours. They do not contain cytochrome oxidase and do not form a spore.

As the sources of such microorganisms bacterial carriers and patients with intestinal infections may play a role.

Table 4

Microbiological and parasitological indicators of drinking water quality

Index	Unit of measurement	Standard
Thermotolerant coliforms	The number of bacteria in 100 ml (3-fold study)	Absence
Common coliform bacteria *	The number of bacteria in 100 ml (3-fold study)	Absence
Total microbial count *	The number of colony forming bacteria in 1 ml	No more than 50
Colophages **	The number of plaque forming units (PFU) in 100 ml	Absence
Spores of sulfide-reducing clostridia ***	Number of spores in 20 ml	Absence
Cysts of lamblia **	The number of cysts in 50 liters	Absence

*Note. * - The excess of the standard is not allowed in 95% of the samples taken at the points of intake of the external and internal water supply network within 12 months, with the number of samples under study not less than 100 per year; ** - the determination is made only in water supply systems from the surface sources before supplying water to the distribution network; *** - the determination is made when assessing the effectiveness of water treatment technology.*

Pathogenic microorganisms are more difficult to detect in water, since their content is lower than of saprophyte microbes, also they are less stable in an environment. A negative result obtained by bacteriological analysis of water does not guarantee a complete absence of pathogens, since the methods of their direct detection are not perfect enough. Therefore, a presence of coliforms, thermotolerant bacteria, and coliphages in 100 ml of water means that the water is contaminated and is epidemically unsafe, regardless of whether it is due to insufficient initial treatment of water or its further contamination along the distribution network.

The total microbial count (the amount of saprophytes in 1 ml of water) characterizes the total microbial content in water without their qualitative characteristics. It increases when surface, storm water, or domestic sewage enter the water and indirectly indicates contamination of water.

When thermotolerant and/or common coliform bacteria, and/or coliphages are determined in the samples of drinking water, then the water must be repeatedly sampled again in an emergency manner. In such cases, to determine the causes of pollution, analysis of chlorides, ammonium nitrogen, nitrites and nitrates content is simultaneously carried out. If total coliform bacteria count of more than 2 in 100 ml and/or thermotolerant coliform bacteria and/or coliphage is repeatedly detected in the water samples, then the water is further examined to analyze presence of intestinal group pathogenic bacteria and/or enterovirus family.

As to indicators of virus contamination the SanPiN 2.1.4.1074-01 prescribes to regularly determine in drinking water of coliphags, the number of which is expressed in plaque-forming units (PFU). Coliforms – Escherichia coli viruses are indicators of the barrier function of the water intake systems with respect to viruses.

Due to constantly increasing pollution of natural water reservoirs, the problem of disinfection of water does not lose its relevance. Harmlessness of drinking water in terms of chemical composition is determined by its compliance with the standards for content of substances most frequently found in natural waters, as well as substances of anthropogenic origin that have become global. Table 5 presents the maximum permissible concentration for chemicals in drinking water, the hazard indicators and hazard class.

Maximum permissible concentration (MPC) is the maximum concentration at which a substance does not have a direct or indirect influence on the state of human health (when exposed to the body throughout life) and does not impair the hygienic conditions of water.

The maximum permissible concentration of a chemical substance is established by the indicator of harmful effect, which is characterized by the lowest threshold concentration – according to the limiting indicator of harmfulness.

When regulating certain harmful substances in water (sulfates, chlorides), those threshold concentrations are determined, causing a deterioration in organoleptic properties, thus they are regulated by the organoleptic hazard index (in tab. 5 – "org."); other substances (aluminum, selenium, fluorides) are regulated through threshold concentrations that exert a toxic effect, i.e., according to the sanitary-toxicological hazard index (in tab. 5 – "s.t."); for radionuclides present in water, the limiting factor is of the radioactivity indicators (tab. 8).

Table 5

Basic physical and chemical indicators of drinking water quality

Indicator	Units	The standard (MPC), no more than	Hazard indicator	Hazard class
Generalized indicators				
The hydrogen index	pH	within 6–9		
Total mineralization (dry residue)	mg/l	1000 (1500)		
Total rigidity	meq/l	7.0 (10)		
Oxidizing property, permanganate	mg/l	5.0		
Petroleum products (in total)	mg/l	0.1		
Surfactants (surfactants), anionic	mg/l	0.5		
Phenolic index	mg/l	0.25		
Inorganic substances				
Aluminum (Al^{3+})	mg/l	0.5	s.t.	2
Barium (Ba^{2+})	mg/l	0.1	s.t.	2
Beryllium (Be^{2+})	mg/l	0.0002	s.t.	1
Boron (B, total)	mg/l	0.5	s.t.	2
Iron (Fe, total)	mg/l	0.3 (1.0)	org.	3
Cadmium (Cd, total)	mg/l	0.001	s.t.	2
Manganese (Mn, total)	mg/l	0.1 (0.5)	org.	3
Copper (Cu, total)	mg/l	1.0	org.	3
Molybdenum (Mo, total)	mg/l	0.25	s.t.	2
Arsenic (As, total)	mg/l	0.05	s.t.	2
Nickel (Ni, total)	mg/l	0.1	s.t.	3
Ammonia (NH_3)	mg/l	2.0	s.t.	3
Nitrite (NO_2^-)	mg/l	3.3	s.t.	3
Nitrates (NO_3^-) in nitrogen	mg/l	45	s.t.	3
Mercury (Hg, total)	mg/l	0.0005	s.t.	1
Lead (Pb, total)	mg/l	0.03	s.t.	2
Selenium (Se, total)	mg/l	0.01	s.t.	2
Strontium (Sr^{2+})	mg/l	7.0	s.t.	2
Sulfates (SO_4^{2-})	mg/l	500	org.	4
Fluorides (F^-)				
- I and II climatic region	mg/l	1.5	s.t.	2
- III climatic region	mg/l	1.2	s.t.	2

Table 5 (continued)

Chlorides (Cl^-)	mg/l	350	org.	4
Chromium (Cr^{6+})	mg/l	0.05	s.t.	3
Cyanides (CN^-)	mg/l	0.035	s.t.	2
Zinc (Zn^{2} +)	mg/l	5.0	org.	3
Organic substances				
Lindane	mg/l	0.002	s.t.	1
DDT (sum of isomers)	mg/l	0.002	s.t.	2
2.4 – D	mg/l	0.03	s.t.	2

Note. The value in parentheses can be determined for a particular water supply system through decision of the local chief sanitary officer.

Hazard Class. Depending on the properties of the chemical pollutants, specifically – toxicity, accumulation capacity, capability to cause long-term effects, hazard index, all regulated chemicals are classified into 4 hazard classes: class 1 – extremely dangerous; class 2 – highly dangerous; class 3 – moderately dangerous; class 4 – low dangerous.

For fluorides in drinking water MPC is regulated taking into account the climatic region: for I and II regions (cold and moderately cold) MPC is 1.5 mg/l; for III region (warm) – 1.2 mg/l; for IV – 0.7 mg/l. The MPC depends on the amount of water consumed per day: in the northern regions, daily demand for water is about 2 liters, in the southern ones – 4 liters, accordingly. To maintain a normal functioning of the body, a person should consume 2.5–3.5 mg of fluoride per day. With an average water consumption of about 2 liters per day, the fluorine content in it should be 1.5 mg/l (tab. 5).

During processing of natural water, coagulants, flocculants, disinfectants are added to it, so residual quantities of them are present in drinking water. In table 6 the MPCs for these chemicals are given.

Table 6

Content of harmful chemicals that enter or form in water during its processing in water supply systems

Index	MPC, no higher than, mg/l	Hazard indicator	Hazard class
Residual free chlorine	0.3–0.5	org.	3
Residual bound chlorine	0.8–1.2	org.	3

Table 6 (continued)

Chloroform (with chlorination of water)	0.2	s.t.	2
Ozone residual (with ozonation of water)	0.3	org.	
Formaldehyde (with ozonation of water)	0.05	s.t.	2
Polyacrylamide *	2.0	s.t.	2
Activated silicic acid (in silicon) *	10	s.t.	2
Polyphosphates (by PO_4^{-3})	3.5	org.	3
Residual amounts of aluminum and iron-containing coagulants	Refer relevant data for aluminum and iron in table 5		

*Note. When water is disinfected with free chlorine, the time of its contact with water must be at least 30 minutes; if with a bound chlorine – not less than 60 minutes. The content of residual chlorine is monitored before the water is supplied to the distribution network. With the simultaneous presence in water of both free and bound chlorine, their total concentration should not exceed 1.2 mg/l (the MPC for bound chlorine). In some cases, after approval by the State Sanitary Service it may be allowed an increased concentration of chlorine in drinking water. * – polyacrylamide and activated silicic acid are flocculants, which are used to accelerate the coagulation of water.*

Table 7

Requirements for organoleptic properties of drinking water

Index	Units of measurement	Norm, no more than
Smell	Points	2
Aftertaste	Points	2
Color	Degrees	20º (35º)
Turbidity	UT (units of turbidity)	1.5 (2.0)

Note. The value in parentheses can be determined for a particular water supply system by decision of the chief local sanitary officer.

Radiation safety of drinking water is determined by its compliance with the standards for indicators of total radioactivity (alpha, beta), presented in table 8.

Table 8

Indicators of radiation safety of drinking water

Indicator	Units	Norm	Hazard indicator
Total alpha-radioactivity	Bq/l	0.1	Radiation
Total beta-radioactivity	Bq/l	1.0	Radiation

Note. When the norms for general radioactivity are exceeded, identification of radionuclides present in the water, measurement of individual concentrations and their assessment according to hygienic standards are carried out.

Hygienic requirements to quality of drinking water of non-centralized (local) water supply

Non-centralized water supply is the use for drinking and domestic needs of the population of groundwater derived with the help of various structures and devices, without supplying it to the place of end-use. It can be for general or individual use either. The most common water intake facilities in populated areas are mines and tubular wells of various designs and depths, as well as springs. Mine well is designed to produce groundwater from a surface non-pressurized water source, is a round or square shaft and consists of a head, trunk and water intake device. Tubular wells are designed to produce groundwater from water sources lying at different depths ranging from 8 to 100 m. They consist of a casing of various diameters, a pump and a filter.

The captage (from the French captage – capture and lat. capto – catching) is a specially equipped chamber with watertight walls to collect the groundwater wedging to the surface or the descending springs.

According to the sanitary rules for arrangement and maintenance of wells and for sprinkling of springs, the place for their installation is chosen above the ground water flow in uncontaminated elevated areas, at least 50 m away from existing or possible sources of pollution – outhouse latrines, cesspools, cattle yards, burial places of humans and animals, warehouses of fertilizers and pesticides.

The walls of the wells should be dense, without cracks, isolating the well from a penetration of a water surface with rain and thawed waters. It is recommended to use concrete and reinforced concrete rings, stone, wood for facing the well shaft. When constructing a wooden log (alder, larch, elm, oak), the logs should be at least 15 cm thick, the quality of the tree should not spoil the taste of water. The top of the well should be 0.8 m above the ground. Around the well it must be arranged a "lock" made of clay 2 m deep, 1 m wide and stone or brick paving, concreting, asphalting with a width of 2 m with a slope of 0.1 m, and a fence. The top of the well is closed with a lid, a canopy is arranged. To prevent appearance of turbidity in the water and ensure cleaning, the bottom of the well is covered with a filtering layer of coarse sand, gravel or rocky crushed stone 20–30 cm thick. For lifting water, pumps are used; gates or "crane" with a bucket attached. Around the well they arrange a bench for buckets. In a radius of 20 m from the well or spring, rinsing and washing of laundry, washing of objects, watering of animals is not allowed.

The water sources of non-centralized water supply, as a rule, are used by people without preliminary treatment. Therefore, it must meet all the basic requirements for drinking water and ensure safety for public health.

However, it is unrealistic to require from the water of wells and springs the same quality as from a centralized water system, so in practice of sanitary and epidemiological surveillance, a limited list of indicators established by SanPiN 2.1.4.1175-02 (tab. 9) is used.

Table 9

Drinking water quality standards for decentralized water supply

Index	Units of measurement	Standard
Smell	Points	No more than 3
The aftertaste	Points	No more than 3
Transparency	cm of Snellen's font	No less than 30
Color	degrees	No more than 30
Oxidizing property, permanganate	mg/l	No more than 7
Total microbial count	The number of colony forming bacteria in 1 ml	100
Ammonia (by nitrogen)	mg/l	2.0
Nitrite	mg/l	3.3
Nitrates (by NO_3^-)	mg/l	45

Note. The requirements for the remaining indicators correspond to those for centralized water supply. If necessary, at the discretion of the sanitary and epidemiological supervision authorities, the list of indicators can be extended.

Investigation of organoleptic indicators of water quality. Determination of transparency of drinking water under laboratory conditions is carried out according to a special standard scale, however, when choosing a water source in the field and for non-centralized water supply it can be used simple technique proposed by Snellen at the end of the nineteenth century.

The test water sample is shaken and poured into a cylinder with a well-ground flat bottom. The cylinder is graduated in height in centimeters. At the base, it has a tube for discharging water. A special Snellen font or another font with a letter height of 2 mm and a letter line thickness of 0.5 mm is placed under the cylinder so that it is 4 cm from the bottom of the cylinder (Figure 1). Gradually drain the water until the font is readable and so determine the degree of its transparency in Snellen's centimeters with accuracy of 0.5 cm. Water is considered transparent if the standard font is read through a column of water of 30 cm or more. Determining of transparency is done under conditions of a good daylight scattered light at a distance of 1 m from the light-bearing wall.

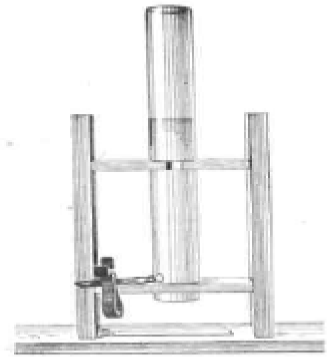

Figure 1. Installation for determination of water transparency

Hygienic value of water transparency: when the transparency is less than 30 cm suitability of water for drinking is limited; reducing the transparency of natural waters indicates their contamination; transparency of water is indicator of how effective is the process of clarification of water by the water treatment plants.

Determination of smell of water. A 200 ml flask is filled with 2/3 volume of water, covered with a fouled stopper or watch glass, heated in a water bath to 20°C and shaken vigorously.

Opening the cork, quickly determine the nature and intensity of the smell. To increase the intensity of the odor, the flask with water is heated up to 60°C, agitated by rotation and, by sliding the glass, quickly determine the odor. The nature of the smell is determined by the following terms (tab. 10):

Table 10

Qualitative assessment of water odors

Nature of the smell	Approximate source of odor
Aromatic	Cucumber, flower
Swamp green	Thick, muddy
Putrefactive	Fecal, sewage
Woody	Wet chips, wood bark
Earthy	Freshly plowed land, clay
Moldy	Musty, stagnant
Fish	Fish oil, fresh fish
Hydrogen sulfide	Rotten eggs
Grassy	Mowing grass, hay
Oil	Petroleum products
Chlorine	Chlorinated preparations
Uncertain	Not suitable for the listed definitions

A smell is caused by dissolved in water chemical compounds and gases, algae, decomposition products of plants and animal organisms. The intensity of the odor is determined from the point scale given in table 11.

Table 11

Assessment of intensity of the smell of drinking water in points

Intensity of odor, scores	Odor intensity	The nature of the smell
0	No smell	Lack of tangible smell
1	Very weak	Smell not noticed by the consumer, but detected by a specialist
2	Weak	The smell detected by the consumer, if you pay attention to it
3	Perceptible	The smell, easily detectable, the water is unpleasant for drinking
4	Distinct	A smell that attracts attention can make you refrain from drinking
5	Very strong	Smell so strong that it makes water unsuitable for drinking

Determination of water taste is undertaken only if the safety of water at the previous steps is sure. Water with a temperature of 20°C is poured into the mouth in small portions and held for several seconds without swallowing. Note the presence of taste (salty, bitter, sour, sweet) and taste (alkaline, ferruginous, metallic, astringent, etc.) and their intensity in points on a scale (similar to the scale of odor determination). The taste depends on the dissolved chemicals and gases in the water and should not exceed 2 points.

Hygienic meaning of the smells and tastes of water is that when their intensity is above 2 points, water consumption capacity is limited; artificial smells and tastes can be indicators of water pollution by industrial wastewater; natural smells and tastes of intensity above 2 points indicate the presence in the water of biologically active substances released by blue-green algae.

Another organoleptic indicator of drinking water quality is chromaticity. This natural property of water is explained by the presence of humic substances, which give it a color in the range from yellowish to brown. Humic substances are formed when the organic compounds (humus) of the soil are destroyed, washed out of it and enter the water. For this reason, chromaticity is mostly a feature of open reservoirs water; it sharply increases during the flood period. The color of the water is determined by comparison of it with a standard color scale and is measured in conditional degrees of chromaticity. Of very high organoleptic properties the deep underground waters have a color below 5 degrees; the color of the conditioned drinking water should not exceed 20 degrees.

Practical part

1. Conduct a study of organoleptic properties, specifically – intensity, nature of odor and transparency in 3 water samples.
2. Evaluate the quality of water samples: compare the obtained values of organoleptic indicators with the corresponding hygienic standards.

Questions for self-control

1. Daily need in water of adults.
2. Endemic diseases associated with chemical composition of drinking water.
3. Bacterial infections, causative agents of which are transmitted with drinking water.
4. Groups of indicators, regulating the quality of drinking water.
5. Microorganisms – indicators of viral water pollution.
6. The norm of the total microbial count of water in case of decentralized water supply.

7. Fluoride norms in drinking water.

8. Hygienic requirements for site selection, design and operation of a mine well.

9. Norms of transparency of drinking water.

10. Norms of smell and taste of drinking water.

11. Standard of mineralization of drinking water.

Test tasks

Choose one correct answer

1. Norm for fluoride content in drinking water for II climatic region (mg/l):
    1) 0.7
    2) 1.0
    3) 1.2
    4) 1.5
2. Hygienic norm for dry residue of drinking water (not more than, mg/l):
    1) 300
    2) 500
    3) 1000
    4) 2000
3. Unit of measurement of water transparency:
    1) degrees
    2) mg/l
    3) cm
    4) points
4. When selecting a source of water supply, the preference should be given to the waters:
    1) ground
    2) artesian
    3) surface flowing through
    4) surface non-flowing through
5. Hardness of drinking water depends on content of the salts of:
    1) sodium and potassium
    2) iron and manganese
    3) calcium and magnesium
6. Osteal and chondral distrophy may be brought with higher content in drinking water of:
    1) iodine
    2) selenium

3) strontium
4) iron

7. Geochemical endemic disease of water origin:
   1) brucellosis
   2) fluorosis
   3) dysentery
   4) hepatitis A

8. Water is the factor of transmission of bacterial disease agents:
   1) cholera
   2) poliomyelitis
   3) hepatitis A
   4) giardiasis

9. Chemical index of water pollution by organic substances:
   1) oxidability
   2) rigidity
   3) iron
   4) total microbial count

10. Presence in the water source of the nitrogen triad says about:
    1) presence in this area of mineral fertilizer deposits
    2) black earth, humus soil
    3) constant contamination of water with organic substances

11. Acceptable microbial count for water from a centralized water supply (number of colonies in 1 ml):
    1) 50
    2) 100
    3) 150

12. Increased hardness of drinking water:
    1) does not adversely affect the body
    2) disturbs the conduction of a nerve impulse
    3) causes the development of calculi in the kidney and bladder
    4) increases cardiovascular morbidity

Situational problems

Problem 1

According to the protocol of analyzing the organoleptic properties of water in a centralized water supply source, it was found that the odor corresponded to 2 points, the aftertaste to 2 points, the chromaticity of 20°, and the turbidity was 1.5 mg.

1. Assess the organoleptic properties of water.

Problem 2

The water taken from the well had the following parameters: odor and taste – 3 points, chromaticity – 30º, transparency - 30 cm, nitrates content – 46 mg/l, TMC – 90.

1. Assess the quality of the well water.
2. Identify possible causes of increased nitrate concentration in the water.

Problem 3

The city is supplied with underground water, which is cleaned, disinfected and processed to remove iron surfeit. The study of water at the output of the supply system was carried out.

The results of the study: turbidity (by kaolin) – 1.35 mg/l, chromaticity – 14°, taste, odor – 2 points, hardness – 3.2 meq/l, ammonia nitrogen – 3.3 mg/l, nitrogen of nitrites – 0.009 mg/l, nitrogen of nitrates – 1.41 mg/l, iron – 0.28 mg/l, dry residue – 800 mg, residual free chlorine - 0.3 mg/l, TMC – 10.

1. Evaluate the quality of water.

2. METHODS FOR WATER QUALITY IMPROVEMENT

PURPOSE OF THE LESSON: to familiarize students with the basic methods of water processing and quality improvement.

THEORETICAL PART. Russia has one fifth of the world's drinking water resources. One person in the country has 30 m^3 of fresh water a day.

Out of the total amount of water currently supplied to populated areas, about 80% of the water comes from the surface sources and less than 20% from the underground ones. The situation in the country with providing the population with good drinking water is quite alarming, and in number of regions there is a crisis. About 70% of rivers and lakes of Russia lost their quality as sources of drinking water supply due to anthropogenic pollution. Almost always the water taken from surface water sources in order to be usable for domestic needs and drinking requires pre-treatment.

Thanks to the process of technological treatment of water at water supply stations, its organoleptic, chemical and biological properties are improved. Bringing the quality of water to hygienic standards (so-called “water conditioning”) is carried out in various ways and methods, knowledge of which is necessary for a doctor or pharmacist for proper organization of preventive and recreational activities.

The methods of improving water quality are determined dependently on the characteristics of the water source and the properties of the water itself. They are divided into basic and special methods (tab. 12).

Water processing is conducted on water plants in large basins, adjacently situated on the territory of the station. There may be variations in design dependent on the water plant. From an initial reservoir raw water is drawn into a mixing basin, where special chemical reagents are added to the water to begin its cleaning.

Coagulation of water is the most effective way of cleaning it from less than 0.1 microns suspended particles and colloids. This is the process of coalescence of colloidal and dispersed particles under the action of intermolecular attraction forces. As result, this process makes for small particles sticking to one another, forming larger particles.

Coagulation is completed by formation of flakes visible to the naked eye. At the output of the coagulation phase, the water becomes more transparent and discolored.

Table 12

Methods for improving the quality of drinking water

Basic			Special
Cleaning (lightening, discoloration)	Decontamination		
	Chemical (reagent-based)	Physical (reagent-free)	
Sedimentation Coagulation Filtration	Chlorination Ozonation Iodination Silvering	Boiling Ultraviolet irradiation Ultrasonic treatment Gamma-irradiation Ultrahigh-frequency currents	Iron removal Softening Fluorination Defluorination Deodorization Deactivation Degassing Desalination Mineralization

Coagulation process is conducted by the means of chemical reagents – coagulants – salts of aluminum or iron (aluminum sulphate, ferric sulfate, ferric chloride) and high molecular flocculants (polyacrylamide, activated silicic acid).

Most often in the practice of water treatment, aluminum sulfate is used as a coagulant. In water, it reacts with bicarbonate calcium salts, responsible for hardness of water, and colloidal solution of aluminum hydroxide precipitates in the form of flakes, which have a large active surface and a positive electrical charge. Flakes of aluminum hydroxide, settling on the bottom of the sediment bowl, adsorb on its surface the smallest negatively charged suspension of microbes, colloid humic substances, mineral suspensions, imparting turbidity to the water.

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 = 2Al(OH)_3 + 3CaSO_4 + 6CO_2$$

This reaction is reversible and depends on pH, stiffness and water temperature. The pH value acceptable for hydrolysis is 4.3–7.6, the optimal pH is 5.5–6.5. Coagulant is used in doses from 30 to 200 mg per 1 liter of water. The dose of a coagulant is selected experimentally, as it depends on the turbidity, color of the water, the amount of coarse suspended matter, the particles of which serve as "coagulation nuclei".

Flocculants added to water in insignificant amounts (0.5–2 mg per 1 liter of water), they accelerate coagulation, save the dose of coagulant, reducing by that chemical load on the body when consuming conditioned water. Residual amounts of coagulants and flocculants are present in drinking water, and eventually enter the body of water consumers, so their MPCs were established (tab. 5).

Disadvantages of coagulation include the fact that when using a crude compound (not "chemically pure" alumina), it can be a source of arsenic, fluorine and copper in water.

Sedimentation is another step of water treatment, wherein the now-larger particles, formed during coagulation, become heavy enough to settle to the bottom of the water basin, wherefrom they are consequently removed. The water then can be filtered through layers of fine, granulated materials, either sand alone or sand and coal. As long as ultrafine particles are removed, turbidity decreases and water becomes clear. Nevertheless, at this stage up to 90% of microorganisms in water are retained. Some bacteria and viruses penetrate through the treatment facilities, still present in the filtered water, so the further processing is necessary – water disinfection.

Disinfection of water, ensuring its epidemic safety, can be carried out by chemical (with the use of reagents) and physical (reagent-free) methods (tab. 12). The most common, reliable, simple and cheap method for water disinfection is chlorination – the method of oxidative disinfection. Waterworks of large cities use gaseous liquefied chlorine, which is stored in tanks or cylinders under high pressure. When the pressure decreases, it passes from liquid to gaseous state and dissolves well in water. For disinfection of small volumes of water, chlorine-containing reagents are used: chloramines, hypochlorites of calcium and sodium, chloric lime, chlorine dioxide.

When chlorine or other chlorine-containing reagents are dissolved in water, hypochlorite acid, hypochlorite-ion and chlorine-ion are formed:

$$Ca(OCl)_2 + 2H_2O = CaCl_2 + Ca(OH)_2 +$$

$$2HOCl\ Cl_2 + H_20 \leftrightarrow HCl + HClO$$

$$HClO \leftrightarrow H^+ +$$

$$OCl^-\ 2OCl^- \leftrightarrow$$

$$2Cl^- + O_2$$

Bactericidal effect during chlorination is due to the chlorine present in the water in the hypochlorous acid (HClO), hypochlorite-ion ($OC1^-$) and active chlorine, which are considered as free active chlorine. Some authors also include atomic oxygen, which has a strong oxidizing effect. The small size of the hypochlorous acid molecule in combination with electrical neutrality allows it to quickly penetrate the bacterial cell membrane and inactivate cellular enzymes, in particular sulfhydryl groups, which regulate metabolism of bacteria and their growth process.

Sulfhydryl groups are part of the chemical structure of cysteine, an integral part of virtually all cytoplasmic membrane proteins, which is the most vulnerable target. As a result of the action of active chlorine, electron microscopy revealed damage to the bacterial membrane, violation of its permeability, and decrease in cell volume.

Microorganisms are characterized by different resistance to chlorine: tularemia pathogens, leptospirosis, dysentery, brucellosis, typhoid fever, paratyphus are less stable. Fecal coliforms are the most resistant to effects of chlorinated disinfectants, therefore E. coli serves as a sanitary-indicative microorganism in assessing the effectiveness of water disinfection. Chlorine is a weak agent in respect to hepatitis A virus and spore-forming microorganisms, for the destruction of which higher concentrations of chlorine-containing drugs are required, and the time of water treatment is increased.

The pH influences the oxidation potential and bactericidal activity of the chlorine-containing reagents – with increasing alkalinity of the medium, the bactericidal activity of chlorine decreases. The effectiveness of water disinfection depends on the degree of its initial contamination by bacteria and viruses: as the bacterial load increases, the disinfectant dose necessary for disinfection and the time of water treatment increase.

Important factors affecting efficiency of water disinfection with active chlorine are the mineral and organic compounds of natural water – a large number of inorganic and organic substances reduce the bactericidal effect of chlorine, since the bacteria inside the suspended particles are mechanically protected from the harmful effects of oxidants. Some organic substances (surface-active substances, pesticides) can stimulate the multiplication of microorganisms in water or interfere with the manifestation of the bactericidal effect of the oxidant.

When a chlorine-containing agent is introduced into water, the bulk of it (more than 95%) is spent on the oxidation of organic and inorganic substances contained in the water, and bactericidal action accounts for only 2–3% of the total amount of chlorine.

Along with the free forms of chlorine, the bound active chlorine can be in the water in the form of monochloramine (NH_2Cl), dichloramine (NH_2Cl_2), trichloramine (NCl_3), and compounds of organic chloramines.

Bactericidal effect of them is many times less than that of the free chlorine, but they last longer. This circumstance is used in the practice of public water supply to provide a disinfecting effect at a significant distance from the water treatment plant.

Thus, the effectiveness of disinfection of water with chlorine preparations depends on the biological characteristics of microorganisms, the bactericidal properties of disinfectants, the degree of water contamination and the conditions of chlorination.

The amount of active chlorine consumed for the oxidation of organic, easily oxidizing inorganic substances and for disinfection of bacteria is called *chlorine absorption capacity of water*. It is not the same in natural waters, depends on their chemical and physical properties and is determined experimentally by trial chlorination until the appearance of residual chlorine after 30 minutes exposure.

SanPiN regulates the need for a sufficient amount of residual active chlorine in the water supplied to the water supply network, which is a guarantee of the effectiveness of decontamination and creates preservative effect. Presence of a sufficient amount of residual chlorine is indirect indicator of water safety in the epidemic respect.

The total amount of chlorine, required to satisfy the chlorine absorption of water and to ensure presence of the necessary amount of residual chlorine (0.3–0.5 mg/l of free active chlorine, 0.8–1.2 mg/l of bound active chlorine) is called the *chlorine requirement of water*.

In the practice of water treatment several methods of water chlorination are used:

1. Chlorination by chlorine requirement (chlorination by normal doses). With this method, after the 30-minute contact of chlorine with water in summer and 1-hour in winter, 0.3–0.5 mg/l of residual free chlorine or 0.8 to 1.2 mg/l of bound chlorine should be present in water;

2. Chlorination with preammonization, when ammonia is added to the water before addition of chlorine in a ratio of 1 part of ammonia to 3–4 parts of the weight of active chlorine. In this case, chloramines appear in the water. This method of chlorination is used to prevent unpleasant odors that appear when chlorinating water containing phenols (chlorophenol, "pharmacy" smells). The rate of disinfection of water with chloramines is less than the rate of disinfection with chlorine, therefore the duration of

disinfection of water during chlorination with preammonization should be at least 2 hours.

3. Super-chlorination (over- or hyper-chlorination) or chlorination with large (excessive) doses of chlorine is used in extreme situations, in particular in expeditionary conditions, for water supply of troops in the field, in case of use of bacteriological and chemical weapons, and during the water epidemics of infectious diseases. An increased amount of active chlorine is added to the water, much higher than its chlorine absorption capacity (from 5 to 30 and more mg/l). This method increases the efficiency of disinfection, the time of contact between chlorine and water is reduced to 10–15 minutes, the chlorination technique is simplified, since instead of carrying out trial chlorination the chlorine dose is determined approximately depending on the type of water source, water quality (turbidity, color), a specific epidemic situation. The chlorine dose is selected in the range of 10 to 100 mg per liter of water.

Excess of chlorine preventing use of this water for drinking, is eliminated by filtration of water through active charcoal or by addition of sodium hyposulphite (thiosulfate) in the ratio of 3.5 mg of sodium hyposulfite to 1 mg of residual active chlorine.

4. Double chlorination. On river-based water resource stations, chlorine is fed into the water for the first time before the sedimentation stage, the second time after the filters. So, introduction of chlorine before sedimentation improves coagulation and discoloration of water, suppresses growth of microflora in treatment plants, increases reliability of disinfection, but there is a likelihood of formation of so-called secondary pollutants of drinking water – organochlorine compounds (chloroform, carbon tetrachloride, etc.) that have toxic and carcinogenic properties.

Disinfection of water in wells. Preventive disinfection of wells is carried out after its cleaning by a volumetric method. The well is freed from water, accumulated sludge, the log house is disinfected with 5% bleach solution or 3% solution of two-third-basic salt of Ca-hypochloride in quantity 0.5 liters per 1 m^3 of the log house. Water in the well is chlorinated with solutions of the same chlorine-containing preparations from the calculation of 100–150 mg of active chlorine per 1 liter of water.

Approximately for clear and colorless water, 6–8 g of bleach is required per 1 m^3 of water, for turbid and colored – 10–12 g/m^3, accordingly. A sample of dry disinfectant is dissolved in a bucket in a small amount of water until a liquid uniform suspension is obtained, thereafter it’s poured into the well, stirred with a vial for 15 minutes, then left for 6 hours.

Then, the presence of residual chlorine in water is determined by the smell. In the absence of the odor they add 1/4 or 1/3 of the initial amount of the reagent, contact time – 3–4 hours. If the water smells strongly of chlorine, it is necessary to scoop up some water, the incoming groundwater will reduce the concentration of chlorine, and the smell will disappear. After this, water samples are taken for bacteriological and physicochemical studies.

With intensive use of well water, chlorination is carried out 2–3 times per day. To permanently disinfect water in the wells, use ceramic cartridges filled with chlorine-containing reagents.

Practical part

1. Conduct experimental coagulation of water and choose the coagulant dose. When using aluminum sulfate as coagulant, small doses of it may not provide the proper cleaning effect, and too large doses give a secondary coagulation, that is, formation of flakes in the future and giving acidic taste to the water. In addition, aluminum compounds in concentrations exceeding MPC (0.5 mg/l) are toxic to the body. Taking this into account, the dose of the coagulant is established in each individual case experimentally, coagulation is carried out in 3 glasses (flasks) containing the same amount of water under study but different amount of coagulant.

Technique of the experiment. The water to be examined is poured into 3 flasks in amount of 200 ml, and thereafter into one flask there must be added 2 ml, into the other 3 and in the third – 4 ml of 1% solution of aluminum sulfate, respectively. Within 1–2 minutes the contents of the flasks are mixed with a glass rod and the appearance of flakes is observed for 10 minutes. The dose is taken by the smallest amount of coagulant that caused formation of flakes and consequent precipitation of them to the bottom.

Example of calculation. Suppose that the most pronounced coagulation occurred in the second flask, where 3 ml of 1% aluminum sulfate solution was added.

In terms of the dry coagulant, it is required for 200 ml of purified water 0.03 g, since the aluminum sulfate solution is 1%, therefore, 1 g of dry matter is contained in 100 ml of the solution, and 0.03 g in 3 ml. For 1 liter of water it will be required: 0.03 × 5 = 0.15 g of coagulant.

In soft water, the coagulation proceeds slowly, since such water requires little coagulant and the flocculation is usually inadequate. In such cases, soda or lime is added to the water to be purified, in order to increase the removable hardness in half of the chosen dose of coagulant.

2. Determine the content of active chlorine in the finished 1% solution of bleach.

Chlorine lime is a complex compound obtained by saturation of hydrated lime with gaseous chlorine:

$$2Ca(OH)_2 + 2Cl_2=[Ca(OCl)_2 \cdot CaCl_2 \cdot 2H_2O]$$

Chlorine lime is unstable substance. When stored in warm or light, with access to moisture, oxygen and carbon dioxide, it decomposes, losing the main active compound – chlorine. The losses of chlorine, depending on the storage conditions, range from 0.5 to 3% per month. Fresh bleach contains up to 35% of active chlorine. To disinfect water use chlorine lime with an active chlorine content of not less than 20%.

Method of determination. In a 100–200 ml flask pour 50 ml of distilled water, 5 ml of a ready 1% solution of bleach, 5 ml of 5% solution of potassium iodide, 1 ml of hydrochloric acid in 1:3 dilution. As a result of the reaction between chlorine, chlorine lime and potassium iodide, certain amount of iodine is released, equivalent to the content of chlorine, while the solution turns yellowish brown. Iodine is titrated with 0.01 N sodium hyposulphite solution until slightly yellow, after which 1 ml of a 1% starch solution is added and the contents of the flask are dyed blue, then the solution is titrated with sodium hyposulfite until the blue color disappears.

Example of calculation. For titration, 29.3 ml of 0.01 N sodium hyposulphite solution was used. When adjusted for a titer of 0.95, this corresponds to 29.3 × 0.95 = 27.84 ml. One ml of 0.01 N solution of sodium hyposulfite binds 1.269 mg of iodine, which corresponds to 0.355 mg of chlorine, then 5 ml of 1% solution of bleach contains active chlorine 27.84 × 0.355 = 9.88 mg. This amount of solution corresponds to 0.05 g or 50 mg of dry bleach.

Then we make the proportion: 50 mg – 100%.

9.88 mg – X%

X = (9.88 × 100) / 50 = 19.8%.

Conclusion. The chlorine content of the bleach is at the lower limit.

3. Selecting a dose of 1% bleach solution for chlorinating water.

In the course of the study, it is proposed to develop a procedure for chlorinating water with normal doses of chlorine, correct conducting of which ensures the necessary destruction of microbes and does not impair the organoleptic qualities of water.

The iodometric method of determining residual chlorine in water considered here as well as in the task 4, allows determining the total residual chlorine (that is, the sum of free and bound chlorine). Therefore, in accordance with the requirements of SanPiN 2.1.4.1074-01, an estimated criterion for the residual bound chlorine standard is 0.8–1.2 mg/l.

Method of determination. In 3 flasks pour 200 ml of water to be disinfected. Then 1% chlorine bleach solution is added to each flask by pipetting: in the first one – 2 drops, in the second – 4, in the third – 6, respectively. The water is stirred with glass sticks and left for 30 minutes. Then 5 ml of 5% solution of potassium iodide and 1 ml (20 drops) of a starch solution are added to each flask. If there is active residual chlorine in the water, then after the addition of starch, a blue color will appear. Water in the flasks where the staining took place is titrated dropwise with 0.01 N sodium hyposulfite solution until discoloration, mixing it after adding each drop. Calculation of the chlorine dose begins with the flask, where there was a discoloration due to 2 drops of sodium hyposulphite. If after experimental chlorination in all glasses there is not the required amount of residual chlorine, then the experiment is repeated with a large number of drops of 1% chloric lime solution.

Example of calculation. In the first flask, after the addition of starch, there was no blue staining. Consequently, no residual active chlorine is present in it, and a dose of 2 drops was definitively insufficient to disinfect the water. For titration of water in the second flask, 0.3 ml of sodium hyposulphite solution was spent, respectively, 0.3 × 5 = 1.5 ml per 1 liter. Since 1 ml of 0.01 N sodium hyposulfite solution corresponds to 0.355 mg of chlorine, 1.5 ml will correspond to 1.5 × 0.355 = 0.5 mg/l (insufficient content!).

For titration of water in the third flask, 0.5 ml of sodium hyposulfite was spent, which corresponds to residual chlorine content of 0.9 mg/l:
0.5 × 5 × 0.355 = 0.9, i.e., it corresponds to the range 0.8–1.2 mg/l.

4. Determination of residual chlorine concentration in drinking water.

The residual chlorine content is regulated in the water at the outlet from the water supply station, just after the clean water tank. The presence and sufficient content of residual chlorine in drinking water is an indirect, but sufficiently reliable criterion for its safety in the epidemic context. This indicator is slightly inferior to other indirect indicators of possible epidemically dangerous microbial contamination of water (total microbial count, total coliform and thermotolerant coliform bacteria count, oxidizability, etc.), but unlike them, it is cheap, simple and quick to determine. At any water station the residual chlorine content in the water is monitored hourly.

Method of determination. Within 3–5 minutes, drain the water through the tap (if the class is in the morning hours, more time is required to drain the water). In a conical flask with a capacity of 300–500 ml, pour 200 ml of tap water, then 5 ml of 5% solution of potassium iodide and 1 ml of 1% solution of starch are added to it. After stirring and appearance of a blue coloring, titrate dropwise, stirring the contents of the flask with 0.01 N sodium hyposulfite solution, until the solution is discolored. It is possible to titrate drop by drop from the burette followed by recalculation in ml (20 drops = 1 ml).

The calculation of the result is analogous to the experiment with the choice of the dose of chloric lime solution in the task 3.

Questions for self-control

1. The aim of conditioning of water taken from a water resource.
2. Classification of methods for water improvement.
3. Methods of water treatment in case of centralized water supply.
4. Chemicals used for water treatment.
5. The purpose of using of flocculants for water conditioning.
6. Chlorine-containing substances used for water disinfection.
7. Microorganisms resistant to chlorine.
8. How do mineral and organic compounds of natural water influence effectiveness of its disinfection?
9. Products of hydrolysis of chlorine-containing substances, which determine the bactericidal effect during the chlorination of water.
10. The concepts of "chlorine requirements of water", "chlorine absorption capacity of water", "residual free active chlorine", "residual bound active chlorine".
11. Methods of water disinfection using chlorine-containing reagents in centralized water supply.
12. Indications for chlorination of water with preammonization.

13. Method for eliminating an excess of active chlorine from the water after its hyperchlorination.

14. Minimum concentration of active chlorine in bleach, suitable for water disinfection.

15. Norm of residual bound chlorine in tap water.

16. Periodicity of control of residual chlorine content at a water station.

Test tasks

Choose one correct answer

1. Basic method of drinking water conditioning:
   1) Softening
   2) Desalination
   3) Deodorization
   4) Disinfection
2. In chlorinated water, the most powerful bactericidal action is provided by:
   1) Hydrochloric acid
   2) Hypochlorous acid
   3) Molecular chlorine
   4) Chloroform
3. Most widely used water disinfection method for centralized water supply:
   1) Double chlorination
   2) Hyperchlorination
   3) Chlorination by chlorine requirement
4. Minimum duration of chlorine contact with the water if chlorination is done in the warm period of the year (min):
   1) 10
   2) 30
   3) 60
5. Water treatment method:
   1) aeration
   2) dilution
   3) freezing
   4) boiling
6. Chemical method of water treating:
   1) Chlorination
   2) Ozonation

3) Use of silver ions
4) Coagulation

7. Special method of water conditioning used to reduce the odor:
1) Deodorization
2) Degassing
3) Deratization
4) Decontamination

8. Content of active chlorine in the chlorous lime, sufficient for water disinfection (at least, %):
1) 0.1
2) 1.0
3) 10
4) 20

9. Periodicity of residual chloride control in the water at a water station:
1) 1 time per hour
2) 1 time per day
3) 1 time per month

10. Purpose of flocculants usage for water improvement:
1) Water softening
2) Deodorization
3) Acceleration of coagulation

11. Chlorination of water with preammonization is used for:
1) Disinfection of water with reduced transparency
2) Reducing the dose of disinfectants
3) Elimination of chlorophenol odor
4) Acceleration of water disinfection

12. The most active flocculant is:
1) Polyacrylamide
2) Acid sulphate
3) Ferric chloride
4) Ferrous sulphate

13. The most powerful disinfectant used for water disinfection is:
1) Chlorine
2) Fluorine
3) Ozone
4) Silver

14. Chemical method of water disinfection:
1) Ozonation
2) Fluorination

3) Coagulation
4) Ultraviolet irradiation

Situational problems

Problem 1

During coagulation experiment, most quickly the water was purified in the flask (200 ml), where 5 ml of a 1% solution of aluminum sulfate was added.

1. Calculate the required amount of dry coagulant in mg per 1 liter of water.

Problem 2

During water chlorination experiment, after addition of 2 drops of 1% chloric lime solution to 200 ml of water, 4 drops of sodium thiosulfate were consumed for titration, 1 ml of 0.01 N solution of which corresponds to 0.355 mg of free active chlorine.

1. Determine the content of residual chlorine in the water.
2. Evaluate the result.

Problem 3

During coagulation experiment, most quickly the water was purified in the flask (200 ml), to which there was added 3 ml of a 1% solution of aluminum sulfate.

1. Calculate the required amount of dry coagulant (g/l).

ANSWERS TO THE TEST TASKS

Water as a factor of health. Hygienic requirements to the quality of drinking water						
Test number	№ 1	№ 2	№ 3	№ 4	№ 5	№ 6
Answer	4	3	3	2	3	3
Test number	№ 7	№ 8	№ 9	№ 10	№ 11	№ 12
Answer	2	1	1	3	1	3

Methods of water quality improvement							
Test number	№ 1	№ 2	№ 3	№ 4	№ 5	№ 6	№ 7
Answer	4	2	3	2	1	4	1
Test number	№ 8	№ 9	№ 10	№ 11	№ 12	№ 13	№ 14
Answer	4	1	3	3	1	3	1

ANSWERS TO SITUATIONAL PROBLEMS

Water as a factor of health. Hygienic requirements to quality of drinking water

Problem 1

The organoleptic properties of drinking water correspond to the norms.

Problem 2

All the indicators reviewed, except nitrates, correspond to the hygienic requirements for decentralized water supply. The presence of nitrates in the water in the absence of ammonia and nitrites indicates the completion of mineralization of organic compounds. A slight excess of nitrates in water is possible due to the salts contained in the soil.

Problem 3

According to the analysis drinking water corresponds to SanPiN norms "Hygienic requirements for water quality of centralized water supply systems".

Methods for water quality improvement

Problem 1

Solution: For 200 ml of water, 5 ml of 1% coagulant solution is consumed. In 5 ml of 1% solution of coagulant there is 0.05 g of the substance. Thus for 1 liter of water, 0.25 g of coagulant is needed.

Answer: for the coagulation of 1 liter of water, 0.25 g of aluminum sulphate is required.

Problem 2

Solution: for titration of 200 ml of water, 4 drops of sodium hypo-sulfite was required; whereas for 1000 ml – 20 drops, accordingly, i.e. 1 ml.

Answer: 1 ml of 0.01 N solution of sodium hypo-sulphite corresponds to 0.355 mg of free active chlorine. Consequently, the content of residual chlorine in water is 0.355 mg/l, which does not correspond (below) to the norm (0.8–1.2 mg/l).

Problem 3

Solution: 1000 ml of water requires 15 ml of aluminum sulfate solution, 1% of which contains 1 g of dry matter in 100 ml of water, whereas 15 ml, respectively, contains 0.15 g of coagulant.

Answer: The required amount of coagulant is 0.15 g/l.

RECOMMENDED READING

1. Shashina, E.A. Educational and Methodological textbook for practical classes on hygiene : tutorial / E.A. Shashina, V.V. Makarova. – Moscow : GEOTAR-Media, 2021. – 208 p. – ISBN 978-5-9704-5875-4. – Text : electronic // Online library «Student Consultant» : [website]. – URL:http://ezproxy.ssmu.ru:2048/login?url=http://www.studentlibrary.ru/book/ISBN9785970458754.html (date of access: 04.09.2021). – Access mode: by subscription.

2. Hygiene : textbook / ed. P.I. Melnichenko. – Moscow : GEOTAR-Media, 2021. – 512 p. – ISBN 978-5-9704-5919-5. – Text : electronic // Online library “Student Consultant” : [website]. – URL:http://ezproxy.ssmu.ru:2048/login?url=http://www.studentlibrary.ru/book/ISBN9785970459195.html (date of access: 04.09.2021). – Access mode: by subscription.

3. Hygiene with the basics of human ecology: a textbook / ed. P.I. Melnichenko. – Moscow : GEOTAR-Media, 2013. – 752 p. – ISBN 978-5-9704-2642-5. – Text : electronic // Online library “Student Consultant” : [website]. – URL: http://ezproxy.ssmu.ru:2048/login?url=http://www.studentlibrary.ru/book/ISBN9785970426425.html (date of access: 04.09.2021). – Access mode: by subscription.

4. Hygiene: a textbook for students of medical faculties of medical universities / ed. G.I. Rumyantsev. – 2nd ed., reviewed and suppl. – Moscow : GEOTAR-Media, 2009. – 608 p. – ISBN 978-5-9704-1169-8 – Text : electronic // Online library “Student Consultant” : [website]. – URL: http://ezproxy.ssmu.ru:2048/login?url=http://www.studentlibrary.ru/book/ISBN9785970411698.html (date of access: 04.09.2021). – Access mode: by subscription.

5. Volkotrub, L.P. Hygiene Practice Guide: Study Guide. Two parts. P. 1 / L.P. Volkotrub, T.V. Andropova, O.V. Safronova. – Tomsk : Siberian State Medical University, 2013. – 285 p. Text : electronic // Online library “SSMU Online Library” : [website]. – URL:http://irbis64.medlib.tomsk.ru/cgi-bin/irbis64r_14/cgiirbis_64.exe?LNG=&C21COM=2&I21DBN=BOOK&P21DBN=BOOK&Z21ID=111562028544968188633&Image_file_name=ft830.pdf (date of access: 04.09.2021). – Access mode: for registered users.

6. Collection of test tasks and situational tasks in hygiene: a textbook for students / T.V. Andropova, M.V. Gudina, I.Yu. Yakimovich et al. – Tomsk : SSMU, 2017. – 168 p. – Text : electornic // Online library “SSMU Online Library” : [website]. – URL: http://irbis64.medlib.tomsk.ru/cgibin/irbis64r_14/cgiirbis_64.exe?LNG=&C21COM=2&I21DBN=BOOK&P21DBN=BOOK&Z21ID=151764028544968138730&Image_file_name=ft1405.pdf&IMAGE_FILE_DOWNLOAD=1 (date of access: 04.09.2021). – Access mode: for registered users.

CONTENTS

Educational edition

Authors:

Kaveshnikov V.S., Andropova T.V., Serebryakova V.N., Gudina M.V., Yakimovich I.Yu.

WATER SUPPLY SANITATION AND HYGIENE IN POPULATED AREAS

Tutorial

Editorial and publishing department Siberian State Medical University
107 Lenin Street, Tomsk 634050
tel. 8 (3822) 901-101 доб. 1760
E-mail: otd.redaktor@ssmu.ru

Signed in print 06.06.2022 г.
Format 60x84 $1/16$. Offset paper.
Print the risograph. Headset «Times». Printed paper 2.6
Edition 40. Order № 12

Printed in the laboratory of operative polygraphy of SSMU
634050,Tomsk, Moskovsky trakt, 2