TECHNIQUES TO IMPROVE THE QUALITY OF DRINKING WATER

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Abstract: *The natural / raw water captured from any source can't qualitatively meet all the requirements demanded by the areas in which it is used, so that a permanent need for a permanent monitoring of its parameters is required; when some of these parameters do not correspond to the area in which the water is used, it intervenes through the treatment plants, so that at the end of the process the water meets the qualitative standards in force. In this context, the present paper aims to analyze, on a comparative basis, several methods of drinking water treatment.*

Key words*: water treatment, chlorination, ozonation, UV*

1. Introduction

Water, an indispensable element of human life and activity, is an important indicator of the appreciation of the degree of civilization and the development opportunities that a community offers to its inhabitants.

In our days, waters as well as the entire environment are subject to an aggressive impact generated by the development of society on the basis of polluting technologies as well as of the entire human activity. That's why the protection of water quality has become today one of the major concerns, which influences the life on our planet.

Research has highlighted the fact that, along with the quantitative problems of localities water supply, there are also high quality (physical, chemical and bacteriological) deficiencies of drinking water with repercussions on the health of the population.

Some of the risk factors for drinking water contamination are:

- low efficiency of treatment processes;
- lack of sanitary protection of water sources;
- the lack of adequate qualification of the operational staff at the level of the water treatment plants.

As I mentioned, one of the risk factors for drinking water contamination is the low efficiency of treatment processes. This low efficiency is primarily due to the treatment of chlorine water that has its disadvantages and limits.

The scientific research reveals the adverse effects of chlorine in water to the detriment of public health and the environment. Chlorination also causes corrosion of metallic pipes and affects the smell and taste of water.

Another major problem would be that some pathogen agents have already acquired resistance to chlorination, which, of course, leads to poor quality drinking water.

2. Advanced methods of drinking water treatment

2.1. Generalities

Conventional water treatment methods are: sedimentation, coagulation, filtration (physical or biological), then disinfection. Optional methods could be: mineralization, demineralization, deferrization, etc.

Disinfection is usually done by chlorination (chlorine, chlorine dioxide, chloramines), but also by ozonation, iodination or bromination, or by silver, potassium permanganate, etc.

The main drinking water disinfection technologies currently used are:

- Disinfection with chlorine and its derivatives;
- Disinfection with chlorine dioxide;
- Disinfection with bromine compounds;
- Electro-physical disinfection procedures (Cu^{2+} and Ag^{+} ions)
- Disinfection procedures by membrane separation;
- Disinfection procedures with PHMB (*Polihexamethylenebiguanida*);
- Ultraviolet (UV) disinfection procedures;
- Ozone disinfection procedures

In order to analyze these technologies, you need to look at some basic parameters such as:

- the effectiveness of disinfection technology;
- ease of operation;
- environmental impact;
- the impact on the human user;
- the degree of occurrence of the by-products of the reaction;
- operating costs.

In most cases, we need to clean non-discriminatory classes of water components, not just the toxic ones, which also leads to removal of desired substances, especially at high costs, high reagent consumption, frequent filter change, etc.

In Romania, have been defined in HG 100/2002 for the approval of the NTPA 013 Water Quality Standard, the following three standard water treatment technologies for the conversion of

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surface water categories A1, A2 and A3 into potable water:

- Category A1: Simple physical treatment and disinfection (eg rapid filtration and disinfection);
- Category A2: Normal physical, chemical and disinfection treatment [egpreclorination, coagulation, flocculation, decantation, filtration, disinfection (final chlorination)];
- Category A3: Physical chemical treatment, advanced chemical treatment, perchloration and disinfection [eg intermediate chlorination, coagulation, flocculation, decantation, adsorption filtration (on activated carbon), disinfection (ozonisation, final chlorination)].

Among the chemical substances used in the treatment of water are: lime, aluminium sulphate, chlorine, calcium hydroxide, caustic soda, carbon dioxide, sodium carbonate, ferrous sulphate and ferric sulphate, active coal dust or granules, sodium, polyelectrolyte, ammonia, phosphates, copper sulphate, potassium permanganate, hypochlorite, sodium chloride, clays, etc.

Although the substances are very diverse, the active element and mechanism is common to several categories.

2.2. Procedures and stages of water treatment in order to be potable

Water treatment plants have quite different structures depending on size, complexity, used technologies, etc.

There are also mini-treatment stations or even individual devices. Still, the treatment steps are often the same and the same principles.

Physical water treatment processes

Grates are used to remove coarse impurities (pieces of paper, twigs, chips, fabrics, plastic foils, etc.) from the water, which must be the first process applied in a treatment and purification plant.

Sedimentation or decantation of particles is a complex process, which depends to a large extent on the origin of waste water. This process takes place in the gravitational field, based on the differences that occur between the particle limit velocities, the basic characteristic that occurs when moving solid particles in a fluid medium (water or air).

In the case of waste water loaded with mineral suspensions, the fall limit velocity (which is a physical parameter due to environmental strengths) is a basic parameter according to all the other constructive and functional parameters of the sedimentation equipments (desanders, basins, decanters of different constructions).

Due to the complexity of the phenomena that occur during the gravitational separation of the solid particles, the calculus provision of their behavior is imprecise.

The most realistic information on the kinetics of decantation is obtained by laboratory tests which determine the sedimentation velocity of different types of solid suspensions.

These laboratory tests (or waste water cleaning tests) are usually carried out by adding to the waste water and different clarifying reagents that lead to a significant increase in sedimentation rate of solids suspensions in water.

Filtration is the process of water passage through a porous medium where retention by predominantly physical phenomena of some of the constituents of water, especially solid particles of material, occurs. [1]

Chemical water treatment processes

Neutralization

It is the process by which the pH of a water, with values outside the range favorable to the development of aquatic flora and fauna (about 6.5-8.5), is regulated by the addition of acids or bases, as the case may be.

Water neutralization also has the effect of reducing the corrosive properties of water that can cause degradation of the materials it comes into contact with (pipelines, construction and transport or purification facilities).

Oxidation and reduction

There are processes in which substances turn into others as a result of electron exchange.

About materials that turn electrons yielding are said to oxidize, and to those that accept electrons, they are reduced. The main oxidizing agents are: oxygen, ozone, chlorine, permanganate. Reduction can be done with divalent iron or sulphuric acid in an acidic environment. Other reducing agents commonly used in practice are divalent iron salts, sulphites, sulphurous acid and other combinations with sulphur at valences less than 6, metallic iron in acid medium.

Precipitation

It is the purification process based on the conversion of pollutants into water into insoluble products. Precipitation is usually the result of chemical reactions resulting in more insoluble substances, but it can also occur as a result of physical conditions such as over-precipitation of concentrated water, reduction of the solubility of some organic substances by increasing electrolyte concentration, etc.

Chemical precipitation is frequently applied to the removal of heavy metal ions from water, since they form hydroxides with low solubility at certain pH values.

Ion exchange

It is a purification process that is based on the properties of materials such as when they are in contact with mineralized water (containing ionized salts), they replace water ions with their own ions (present in the material itself). Different cation exchangers (cationites) and anion exchangers (anionites) are distinguished. The cations retain cations by releasing hydrogen ions and the anions retain the anions releasing OH^-.

Chlorination

Chlorination is the chemical method of disinfection that uses chlorine. It is a simple, economical and safe method and can be applied for large quantities of water.

Chlorine is a very active non-metal which can be found in three states of aggregation: solid, liquid and gaseous. For water disinfection, chlorine is delivered to water treatment plants, bottled in liquid form, at a pressure of 6-8 atm.

In the process of disinfection of water with chlorine, three main processes are distinguished:

- oxidation of organic and ammoniac compounds and inorganic chlorides;
- direct chlorination of organic substances;
- destruction of microbial germs.

Most of the chlorine is used in the process of oxidation of organic matter and ammoniac compounds. Chlorine consumed in this process is called absorbed chlorine.

Only after the oxidation has taken place, the rest of the chlorine acts on microbial germs, and the chlorine dose to be added to the water for effective disinfection is determined by the oxidation process.

The second process of direct chlorination of the organic substance leads to the formation of organochlorine compounds that make the water unpleasant taste. They can be removed from the water by an overdose of chlorine.

The third process, concerning the direct bactericidal action of chlorine, leads to alteration of the microbial cell membrane, to the penetration of chlorine inside the pathogen, leading to its death. [7].

Ozonation consists of treating water with ozone, a powerful oxidant that also has advantages and disadvantages. Ozone is found in small quantities in the atmosphere and near electrical equipment - TV tubes, xeroxes and sometimes air conditioners. Wherever there is a spark in the presence of oxygen, ozone is formed.

Ozone has strong oxidizing properties. It is an unstable gas, depending on temperature and air pressure. It decomposes rapidly in oxygen at temperatures above 35^o C.

It has a specific smell and can be felt by most people at an extremely low concentration (0.02 ppm / volume). It is relatively water soluble; the solubility depends on the temperature of the water, and the types of liquefaction processes. The ozone molecule is a strong oxidizing agent capable of forming strong chemical reactions that contribute to additional oxidation reactions.

The development of ozonation as a current practice in drinking water treatment has mainly developed due to harmful products resulting from chlorination (formation of halogenated compounds).

The time required to obtain 99% disinfection against bacillus coli is seven times shorter if ozone is used than if chlorine is used. The rate of destruction of bacillus megatherium cereus spores is 300 times higher. Although the sporicidal effect of ozone is considerable, large amounts of ozone are needed to destroy them.

According to other researchers, a 60,000 coli/l emulsion is destroyed by chlorine at a concentration of 0.1 mg / l for 4 hours, while the ozone has the same effect in 5 minutes at 22 ° C and 0.5 seconds at 37°C.

Plankton, algae, protozoa, larvae and worms are also destroyed in short time; for example, protozoa, including histological entamoeba, are destroyed in 3 minutes at a dose of 15 mg / l ozone.

Under the same conditions, ozone reacts faster on bacillus coli, spores and various algae, and this action is particularly evident in chlorine-resistant organisms.

Ozone works effectively against viruses and bacteriophages at very low concentrations, tens of mg/l. Under similar disinfection conditions, the polio virus is destroyed by chlorination with 0.5-1 mg/l of residual chlorine in 1.5-2 hours, while by ozonation with 0.05-0.45 mg/l of residual ozone, is destroyed in 2 minutes.

The observations made by a number of water treatment plants using ozone as a disinfectant have shown that in 1 mg/l for 1 minute, the bactericidal effect obtained is satisfactory. In current practice, 0.5-2 mg / l ozone is used for water disinfection. The bactericidal effect is less influenced by pH and temperature than with chlorine. [2]

The criterion for a good disinfection process is the presence of residual ozone within the range of 0.05-0.1 mg/l. Therefore, in the practice of water ozone, it is necessary to introduce ozone quantities to cover the ozone requirement of water, so that the required amount of free ozone remains after the first contact.

For residual ozone levels of 0.013 mg/l, the bactericidal effect was 14.2%; at 0.05 mg/l the bactericidal effect increased to 48.8% and reached 99.7% when the amount of ozone was 0.135 mg/l. [8], [9], [11].

The residual ozone concentration to be ensured depends on the quality of the water. If water is polluted, a residual ozone concentration of 0.1-0.2 mg/l and even 0.4-0.5 mg/l is required in the case of highly polluted waters with organic substances to obtain a bactericidal effect.

Higher contents of organic matter in water require higher ozone consumptions. If the water contains great quantities of organic substances, they consume quickly large amounts of ozone, so that it remains too small to destroy the germs; In addition, the water also has an unpleasant taste due to the partial oxidation of organic substances.

In any case, the residual ozone concentration should not exceed 5 mg/l, because exceeding this limit would impart the characteristic odour and taste to the water. Others, however, consider that excess ozone spontaneously disappears from the water, with no inconvenience to water quality.

Ozone precipitates iron and manganese salts, being used as a method of removing them from water; it also oxidizes the nitrites it turns into nitrates.

Ozone is a dangerous substance for humans, even in small concerts. The maximum ozone concentration permitted in breathable air is 0.1 ppm. Recent water research shows that water disinfection by ozonation has capital costs, running costs, high maintenance costs, and high hazards, and that ozone-depleted water promotes cancer.

Advantages of potable water treatment with ozone:

-requires less reaction time (10 minutes versus 30 minutes for chlorine);

-bactericidal activity is 20 times stronger;

-is not influenced by the pH of the water;

-does not persist in the water and does not produce any residual products (oxygen is released);

-does not produce chlorophenols and does not otherwise affect the taste.

Disadvantages:

-it has no lasting, remanent effect on the network;

-efficiency is affected in the presence of organic substances that "compete" with the bacteria they should attack;

-produces toxic compounds such as ozonides, hard to dose.

2.3. Other methods of potable water treatment

Ultraviolet radiations are a disinfection method applicable to very clean water because it depends on the transparency of the water. It should be applied in thin layer and relatively long time, which makes the method applicable only for relatively small volumes of water. Certain amounts of ozone also form, which in turn gives toxic derivatives, so UV treatment is not perfectly "clean".

Ultraviolet water disinfection has been successfully practiced for many years, with no negative consequences, while many new and available areas are still in place for application.

Of all the current methods of water disinfection, ultraviolet radiation is considered to be one of the most efficient, economical and non-pollution methods and is considered the fastest and safest method of disinfection. [3]

The benefits of using UV disinfection can be summarized briefly: the chemical and physical properties of treated water remain unchanged; no toxic compounds or precursor elements are introduced; after installation the device/plant only needs routine checks.

Owing to the fact that maintenance is minimal and no dangerous chemical substances are involved, there is no need for specialized or highly trained operating staff.

Advantages of UV disinfection:

- high efficiency
- capital and running costs
- it does not harm the environment
- has no effect on the taste and smell of water
- immediate disinfection during the technological flow
- overdose is not possible.

To meet increasingly stringent requirements for water quality, the UV equipment is equipped with high-intensity UV lamps for high flow rates and is equipped with specially designed control and regulation systems. High flow rates do not limit application of UV treatment to obtain complete bacterial control.

For many years, chemical disinfection techniques have been used to obtain pure microbiological water. Most chemical treatment methods involve the handling of hazardous materials, reactions that produce by-products/toxic derivatives, and alternation of fluid chemistry. UV provides a non-chemical alternative that has been successfully practiced, with no negative consequences. [10]

Silver treatment: Requires very clean water and contact with water for several hours with silver plates. It is a good disinfectant but can be used rather to keep sterile water after it has already been disinfected.

Oligodynamic method: It is based on the bactericidal property of heavy metal ions (silver, copper, etc.) at a very low concentration of 10 to 25 mg / m3 in disinfecting water. In ancient times, people knew the silver sterilizing effect, they kept and carried the drinking water in silver pots or in ordinary pots in which they placed a silver object.

Features: silver ions completely destroy bacteria and viruses; silver action is weak on spores and non-existent on mushrooms.

The water to be treated with Ag ions must meet the following conditions:
- be clear,
- low content of organic matter
- containing not more than 100 mg / dm3 of chlorides.
- the number of bacteria must not be too high because it has to increase the dose of Ag and therefore the cost of disinfection.
- reaction time 4 to 6 hours.

The gamma rays are electromagnetic, ionized radiation. They are used less frequently for disinfection.

Ultrasounds are high frequency mechanical vibrations that can kill microorganisms. They are rarely used.

Each of the technologies analyzed has been extensively addressed, including theoretical aspects, technical and practical aspects. As a result of the analysis I consider that, in the concrete case of drinking water treatment plants of public interest, an efficient disinfection technology has to meet the following criteria:
- high efficiency;
- handling and storing as small as possible of chemicals,
- the basic disinfectant is produced as far as possible at the application site;
- avoiding the formation of harmful side-effects on users;
- the disinfection technology is the stage complementary to the filtration and recirculation step;
- allow for a high degree of process automation.

As a result of this comparative study, it appears that the most appropriate drinking water disinfection technologies seem to be those technologies that minimize the risk of contamination by sub-reaction products, provide a powerful disinfection of water and eliminate the discomfort of users.

In table 1, I present comparatively the techniques of water disinfection by chlorination, ozonation and ultraviolet with their advantages and disadvantages.

Table 1. *Comparison of disinfection techniques*

	ULTRAVIOLET	CHLORINE	OZONE
Capital costs	small	smallest	high
Operating costs	smallest	small	high
Easy installation	excellent	good	weak
Easy maintenance	excellent	good	weak
The cost of maintenance	smallest	medium	high
Frequency of maintenance	without frequency	frequent	continue
Control system	excellent	weak	good
Disinfection performance	excellent	leaves some pathogens	excellent
Hazards	small	high	high
Effect on water	no one	organic compounds with chlorine, taste, change of Ph	unknown
Contact time	0,5-5 seconds	30-60 minutes	10-20 minutes

3. Conclusions

In our country, as everywhere in the world, specialists' efforts are directed towards finding solutions that help to increase the safety of water, taking into account the direct relationship between water quality and health.

Another major problem of the element indispensable to life, namely water, deals with the quality conditions imposed by Law 458/2002 amended and supplemented by Law 311/2004. With Romania's accession to the EU, these quality conditions are much more rigorous and must be strictly respected, so treatment methods, distribution network, etc. need to be improved.

By comparing disinfection techniques through the cost of operation, installation, maintenance, control system, disinfection performance, hazards, water effects, we find that the ozone treatment method is expensive but also efficient.

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