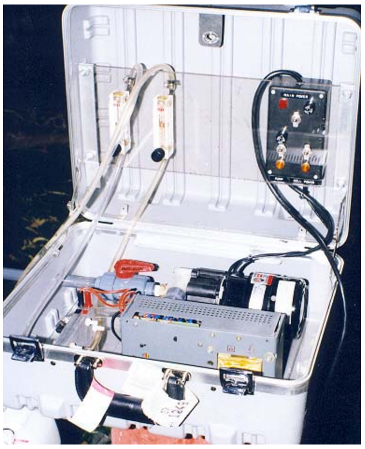
Chapter 9

ALTERNATIVE DISINFECTION METHODS



Introduction

If what is meant by disinfection is the elimination of pathogens that could harm human health, then from the viewpoint of disinfection possibilities alone, there are countless ways to kill off these small living organisms. There have been experiments over the years in which continuous and sharp changes in only the water's pH have been enough to disinfect contaminated water.

Temperature is another key element. Boiling is perhaps the oldest and best-known method of disinfection. It is not enough merely to bring water up to a temperature of 100 °C, however. An appropriate ratio between time and temperature must be reached so that disinfection is produced by "pasteurization," as we have seen in the chapter on solar disinfection. Other experiments have shown that sudden sharp changes from high to low temperature, without any need for permanence, are also effective in eliminating microorganisms.

At the end of nineteenth century, when the existence of bacteria and their relationship to disease was already known, work was done with pressures. Contaminated water was placed in hermetically sealed containers and submitted to pressure. After a few minutes' time, the pressure was suddenly brought down to normal and the result was pure, germ-free water.

Similar experiments using continuous and violent shaking over long periods of time apparently also resulted in disinfection. Certain ancient cultures placed their drinking water in silver jars. Without understanding why, they knew that after a period of contact with these containers, the water was safe to drink. The list is almost endless. Microorganisms can be eliminated in a variety of ways.

Obviously, however, only a few of these possibilities are viable. The power to annihilate is not sufficient, in itself. It must be accompanied by specific characteristics, such as simple equipment and ease of operation and maintenance. If chemicals are used, these must be easily available at the site of use. Disinfection must be accomplished rapidly and the inexpensiveness of the method is vital. The risks must not be excessive, nor must the water's characteristics be modified; it has already been discussed the problem of disinfection by-products in this connection.

These requirements limit the long list of possible disinfection methods. This manual has given a detailed description (up to this point) of only those methods that can be used for disinfection because of their special characteristics. There are others, however, that without being overly obtuse and without having been classified as the most suitable methods, fall somewhere in between. These are the methods that have been used in special situations (in emergencies and during disasters, for example) or that are under experimentation or are being developed, or that for only one or another specific reason (cost or the small size of the flow to be treated), are good, but are not among the top disinfection methods. These will be briefly described in this chapter to provide full information to the engineer or technician wanting to know all of the disinfection possibilities.

<u>Disinfection with bromine</u>

Description

As a member of the halogen family, bromine is very similar to chlorine and operates in the same way: once dissolved in water, it produces hypobromous acid (HOBr), a first cousin to hypochlorous acid (HOCl). The disinfecting power of HOBr is very high, although slightly less than that of hypochlorous acid.

The advantage of using bromine is that at normal temperature it is liquid, making it easier to handle and dose than chlorine. It should be stressed, however, that bromine is both corrosive and aggressive and must be handled very carefully. Furthermore, it is not easily found in just any country or city, unlike chlorine, which can be purchased off the shelf.

Effects of bromine on health and DBP production

Since bromine vaporizes very easily and its gas is highly aggressive, care must be taken to keep from inhaling it. It should be stressed that neither chlorine nor bromine appear to be carcinogenic per se or when dissolved in water. Chlorinated water and bromated water are not carcinogenic. But, like chlorine, bromine forms trihalomethanes, and if fulvic acids and ammonia are present in the raw water, it will produce bromoform. Therein lies the risk, because the latter compounds are carcinogenic and, like many other DBP, are reason for concern.

Disinfecting action of bromine

HOBr acts similarly to HOCl, as we have already mentioned –that is, by penetrating the membranes of microorganism cells. Once inside the cell, the very presence of HOBr appears to "disorganize" the cell structure; at the same time, it also attacks by reacting with sulfhydryl compounds to inactivate enzymes and stop the metabolic process, leading to the microorganism's death.

Equipment

Bromine, as a liquid, is dosed by means of a diaphragm or piston pump and both its operating requirements and safety measures are the same as those used and described for chlorine.

Monitoring

There is no specific test for bromine. The orthotolidine method used to determine the presence of chlorine is used for routine analyses of bromine, although it is subject to interference.

Costs

As already indicated, bromine acts similarly to chlorine in water and could have been as popular as the latter had it not been for the price difference. It has been estimated that, using the same dosing equipment, bromation is five times as expensive as chlorination. To that, we must add the difficulty of obtaining bromine.

Advantages and disadvantages of bromine disinfection

Disinfection with bromine offers almost all of the same advantages as chlorination. However, it has two major disadvantages that the latter method does not have: it is much more expensive and it is difficult to acquire in just any community, particularly small and remote communities in developing countries.

Disinfection with silver

Description

Most metals are "oligodynamic;" this means that "with only a small amount, they can produce an effect." Metals like silver, copper, mercury, manganese and iron, among others, are all potential water disinfectants. However, of all of these metals, only silver, for several reasons, has been used to some extent to disinfect water for human consumption, and this use dates back to ancient times.

Effects of silver on heath and DBP production

Silver is not particularly toxic to human beings and, on being ingested, the body absorbs only a very small fraction. Large doses of this metal used for certain medical treatments have been found to cause discoloration of the skin, hair and nails (argirosis), but no problem has been noted with the small concentrations needed to disinfect water. The WHO has not proposed any guideline value for silver in drinking water, precisely because of its relative safety. Treatment of drinking water with silver produces no abnormal taste, smell or color. Nor are any DBP generated.

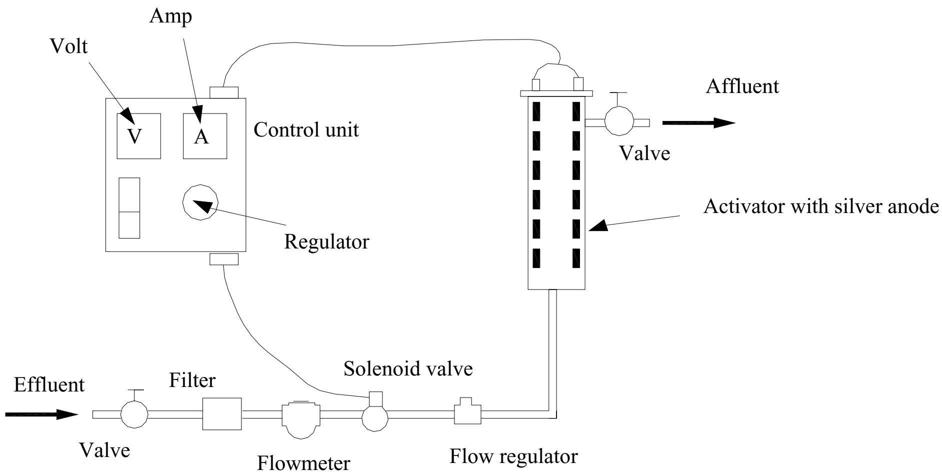
Disinfecting action of silver

Silver has disinfecting properties only in its colloidal state –when it is in the form of extremely small particles in suspension which, because of their size, are easily charged electrically. In this state, it is also known as silver protein, silver salts, weak silver protein and strong silver protein. The salts that are used are silver chloride and silver iodide.

In its colloidal form, silver does not eliminate viruses, but is considered highly effective in destroying different types of bacteria. Silver's disinfection mechanism acts by inactivating bacteria and mold cell enzymes that need oxygen for their metabolism; its causes their cellular disruption, although over periods that vary widely according to the water temperature. Very long periods are required at temperatures of 10 °C or less, making it difficult to determine silver's precise germicidal power. Colloidal silver can remain in the water for a long period of time, but is not considered to have good residual power because of the slowness of its reactions in eliminating organic matter. The recommended dose for high germicidal efficacy is in the range of 25 to 75 micrograms of silver per liter (0.025 – 0.075 mg/l).

Equipment

Three methods are used for disinfection with silver. The first or "contact" method requires the passage of the water through silver saturated devices, such as tanks with walls and screens coated with special silver-containing paint. The second method consists of dosing low concentration silver solutions in the same way used for chlorine solutions, with similar equipment and feeders. The third, electrolytic, method appears to be the most practical. A number of silver electrodes are connected to the positive pole (anode) of a low power electric source. An inert electrode is used as a negative pole, where hydrogen is produced and freed. Through electrolysis, the silver ions are freed by the electrodes inside the water current to be treated in proportion to the supply current. The method is appropriate, for the dose can be varied by changing the current.



Typical silver electrolyte equipment

The electrolytic method is used only for small water supply systems. From a practical and safety viewpoint, a certain degree of automation and complexity are needed in the control system, which should have sensors to check the properness of the disinfection. This simply cannot be done manually. A connection should be made to a solenoid valve that can cut off the water flow automatically at any moment if the system is unable to produce the proper dose.

Monitoring

There is no simple test for measuring the silver content of the water. The measurements taken with the existing test show a considerable degree of error. The most effective method is to dose the water with controllable amounts of silver –in other words, the control is carried out basically through the dosing and not analytically following it.

Costs

Silver paint is not very expensive, but this is the least appropriate method. The dosing of a silver solution for a small population requires the equipment already cited in the case of chlorination; a wide range of diaphragm metering pumps can be used and their cost is not high. The solutions, on the other hand, are extremely costly, especially compared with the equivalent chlorine solutions that provide the same bactericidal capacity.

The electrolytic devices are expensive for small systems and can cost anything from $1,000 on up. The final cost depends on the size of the flow to be disinfected and the ancillary equipment needed. Insofar as the operating cost of this equipment is concerned, not only must the cost of the silver solution be considered, but also that of the electric power. In the case of its maintenance, it is necessary to consider the cost of electrodes, which must be replaced frequently because they are the only source of the silver ions and they wear out fairly rapidly.

Advantages and disadvantages of disinfection with silver

Silver's apparent advantages for water treatment are that it does not produce any taste, odor or color in the treated water and that no by-products are formed as a result of its use.

The methodology is very simple and easy to handle in rural areas of the developing world. For that reason, it is appropriate for household water disinfection.

One of its disadvantages is the difficulty in controlling dosing for lack of a simple laboratory analysis. The second disadvantage -and this has proven to be an insurmountable barrier throughout history- is the high production cost. Both the electrolytic method, in which the electrodes that are needed to produce the silver ions wear out fairly rapidly, and the dosing of colloidal silver are expensive. Disinfection with silver has been estimated to cost between 200 and 300 times more than chlorination.

Disinfection with iodine

Description

Iodine belongs to the halogen family and is solid at normal temperature. Its has low solubility in water and is the least aggressive substance in the family (chlorine + bromine).

Effects of iodine on health and DBP production

Unlike chlorine and bromine, substances that per se do not cause any problems when consumed in the normal concentrations to be found in drinking water, iodine of itself can do so. Actually, concern over iodine use does not have to do so much with the DBP, as with the action of the chemical itself.

Although iodine is essential for the synthesis of thyroid hormones, it is not certain what will happen if it is oversupplied in drinking water. There have been reports of numerous cases of "iodism," which can be defined as an allergic reaction produced in people who are hypersensitive to the consumption of iodine in doses larger than their daily need. According to the WHO, "the consumption of iodized water does not appear to have caused adverse effects on human health, although some changes have been noted in the state of the thyroid gland." Furthermore, Volume 2 of the "WHO Guidelines for drinking water quality" states that "little relevant information is available about the effects of iodine," and goes on to add that "inasmuch as iodine is not recommended for water disinfection over long periods of time, exposure to iodine from its consumption in drinking water is quite unlikely."

This substance, like other members of the family, generates DBP. However, because of its lower oxidizing potential and its lower reactivity, iodine produces less THM than the others.

Disinfecting action of iodine

Once dissolved in water, iodine, like chlorine and bromine, forms the corresponding hypo-acid (in this case, hypoiodous acid) HOI. Depending on the water's pH, however, a portion (which can be quite large) remains in the water as I_2. The table below gives an idea of the relative concentrations of each compound, depending on the pH and these have been compared with the relative concentrations of hypochlorous acid and hypochlorite ion.

Percentage of iodine and chlorine species according to the solution's pH

pH	I_2	HOI	OI-	Cl_2	HOCl	OCl-
5	99	1	0	0	99.5	0.5
6	90	10	0	0	96.5	3.5
7	52	48	0	0	72.5	27.5
8	12	88	0.005	0	21.5	78.5

It should be stressed that while the hypoiodite ion is not a good disinfectant, both I_2 and hypoiodous acid are; and they also possess highly desirable microbicidal characteristics. The two are good bactericides and destroy even spores, cysts and viruses.

When iodine is used as an emergency disinfectant and in small volumes, the doses employed are larger than those that would normally be used to disinfect drinking water systems. In such cases, solutions from 1 to 8 mg/l are commonly used, with contact periods of at least 30 minutes. When using iodine tincture, which is prepared with a 2% concentration, the recommended dose is two drops per liter of water to be disinfected.

Equipment

Iodine can be added to water by passing a steam current through a bed of iodine crystals and then dissolving the steam in water. The most recommendable method, however, is to prepare a saturated solution by passing a water current over the bed of iodine crystals and then dosing them with a conventional diaphragm pump.

Monitoring

There are two methods for determining the iodine content of water. The most widely used is amperometric titration, while the second is spectrophotometry, using N,N-dimethylaniline or leuco crystal violet (LCV) as a reagent. Although these methods are not complicated, the plant operators or chemists must be trained to perform the tests.

Costs

All operational parameters being equal (equipment, simplicity, ease in handling, etc.), iodine, like bromine, cannot compete with chlorine and its compounds for water disinfection purposes, because it costs 10 to 20 times as much and is difficult to find in remote areas of developing countries.

Advantages and disadvantages of disinfection with iodine

Iodine disinfection is as simple as chlorination. Its use over long periods of time for water disinfection has been questioned by many health organizations, particularly because of the physiological effects it can have on people who are sensitive to it. Although no decisive tests have been made and there is little confirmed data on the subject, when deciding whether or not to use iodization as a disinfection method, these considerations should bear more weight than its higher costs, which are also convincing reasons for deciding against it.

Its easy handling, on the other hand, makes it a good option for disinfection purposes in emergency situations.

Disinfection with sodium dichloroisocyanurate (NaDCC)

Description

Sodium dichloroisocyanurate, often called "sodium isocyanurate," and recognized by the abbreviation "NaDCC," is a compound that frees chlorine in very precise concentrations. It is easily handled and contains a high concentration of active chlorine (60%). Its use is highly practical and it does not leave the usual telltale odor and taste of other chlorine treatments. It is stable over long periods of time, making it appropriate for storage over much longer periods than any other chlorine compound. If conditions are optimum, it can be stored for over five years without losing its strength.

Effects of NaDCC on health and DBP generation

As it will be seen in the following section, on being dissolved in water, NaDCC produces a sodium cyanide molecule. It is not known how this compound -and in fact, how isocyanurate itself-affects human health and it is precisely this lack of information that has kept the method from being used indiscriminately despite all of its benefits.

The WHO has stated that "there is concern over the possible toxic potential of NaDCC, above all for long-term use in disinfecting water for human consumption" and goes on to add that "this concern stems from the insufficiency of health and toxicological evidence to make a final judgment on the subject."

This means that NaDCC is not condemned because it is harmful to health, but merely that its long-term use for water disinfection is not recommended because of a lack of information about its possible harmful effects on health, as well as its innocuousness.

This situation may possibly change as the results of studies come in and the information begins to be evaluated worldwide; for the moment, however, the use of this compound is recommended in some countries only for emergency disinfection purposes, in which case it is tacitly assumed that its use would be for short periods of time only.

The situation is the same in regard to the formation of DBP. Not only is nothing known about the problems stemming from the possible generation of DBP by cyanurates, but there are also the classical DBP of hypochlorus acid to be considered, among them THM, which have been mentioned frequently throughout this manual.

Everything that has been studied about sodium isocyanurate points to the following suggestion: Use for systematic disinfection, no. For emergency disinfection, yes.

Disinfecting action of NaDCC

Sodium dichloroisocyanurate is an organic compound deriving from isocyanurate, which, when dissolved in water, frees hypochlorus acid through the following reaction:

$$NaCl_2C_3N_3O_3 + 2\,H_2O = NaH_2C_3N_3O_3 + 2\,HOCl$$

Sodium dichloroisocyanurate   Sodium cyanurate   Hypochlorous acid

It is the hypochlorous acid, whose qualities were described in chapter 3, that is responsible for its disinfecting potential.

Equipment

Any of the dosing devices mentioned in the chapter on chlorine can be used, inasmuch as NaDCC dissolves in water to form a typical solution.

Monitoring

What is monitored is the residual chlorine, and for that reason both the DPD and the orthotolidine methods can be used.

Costs

The costs are slightly higher than those of using traditional chlorine compounds, like sodium or calcium hypochlorite.

Advantages and disadvantages of disinfection with NaDCC

Its simplicity, stability and ease in handling are among the most important advantages of this method. It does not produce the characteristic odors and tastes of other chlorine compounds. It also leaves a disinfectant residual.

Its main disadvantage is the lack of evidence of its innocuousness when consumed over long periods of time.

Disinfection using mixed oxidant gases

Description

Although Faraday laid the groundwork for electrolysis and worked extensively to produce chlorine from sodium chloride in the mid-nineteenth century, that technique has remained almost unchanged at the service of heavy industry until today. Sanitary engineering drew on its use to massively incorporate chlorine as a drinking water disinfectant.

In the 1970s, perhaps influenced by the new concepts of the appropriate technology, which emerged as a remedy for the lack of realistic technology acceptable to the rural communities of developing countries, the perception of Faraday's electrolysis underwent a change. It was no longer viewed as a technique only for operating large factories, but also as a simple method to enable small communities and even individual users to prepare their own chlorine on-site, in their own homes, using only electricity and table salt (sodium chloride).

Researchers then began to concentrate on reducing the scale of electrolysis use from the large factory to the rural workshop, to the water treatment plant of a small village, to the home. A whole series of electrolysis devices emerged, which can be broken down into two main groups: electrolysis with and without a membrane. Membrane systems reproduce the industrial chlorine production technique, while those without a membrane produce low-concentration hypochlorite solutions.

There was an interesting development in the research carried out on these systems. In an effort to escape the numerous patent restrictions placed on sodium chloride electrolysis, researchers played around with the placement of the electrodes, particularly with the dimensionally stable anodes (DS anodes) and produced equipment that generates not only chlorine, but also, as a result of the electrode arrangements, other high oxidizing species, including radicals of different types: ozone, nascent oxygen, atomic oxygen and others. PAHO generically calls this mixture of oxidant gases MOGGOD (mixed oxidant gases generated on-site for disinfection purposes). Because of their production in an electrolytic cell divided into separate and independent chambers, these gases constitute a highly concentrated and oxidant mix.

The cathode chamber produces hydrogen and the anode chamber, the oxidant gases. The two chambers, or semicells, are separated by a special membrane that is permeable only to certain ions.

This unique feature -the membrane- was responsible for the initial success and the subsequent failure of this method, for the membrane required delicate operation and a maintenance that, although simple, was also essential to keep the equipment operating at its best. Many systems of this kind were installed in small communities in the 1980s, but few were able to survive, given the operating and maintenance needs that rural areas of developing countries were unable to meet. As a result, very few of these systems continue to operate today.

The other technique, electrolysis without a membrane, is much simpler. It is merely a matter of letting chlorine production in the basic medium continue its accustomed chemical reactions to produce, without much intervention or risk, a solution that, while very weak (generally, it is a 0.6% active chlorine solution), is easy to use and handle. This is obviously not the means used to produce oxidant gases, but is included here because of its common origin. Hypochlorite is produced by the following reaction:

$$2Na+ \; + \; 2Cl- \; + \; H_2O \quad = \quad Cl_2 \; + \; H_2 \; + 2\,HONa$$

$$Cl_2 \; + \; 2\,HONa \quad = \quad 2\,NaOCl \; + \; H_2$$

Although the MOGGOD system had a promising start, because of its operational and maintenance needs, only the systems that produce hypochlorite were successful.

Effects of the mixture of oxidant gases on health and DBP generation

Since these systems are basically chlorine producers, all of the considerations regarding the effects of chlorine on health and on production, management and DBP risks mentioned in chapter 3 are valid here.

Disinfecting action of the mixture of oxidant gases

The same considerations discussed with regard to chlorine are applicable here. However, it should be stressed that in the case of the MOGGOD, some components of the mixture cause an action that is so strong and so synergic (as can be seen further ahead in this chapter) that it was thought that no microorganism or organic compound could resist its oxidating power.

Equipment

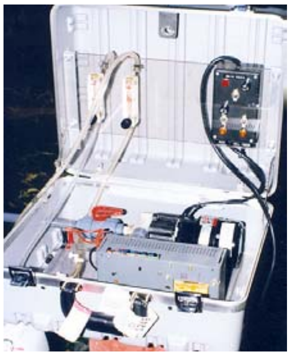
The costs of on-site hypochlorite generators was reviewed in chapter 3 “Chlorine.”

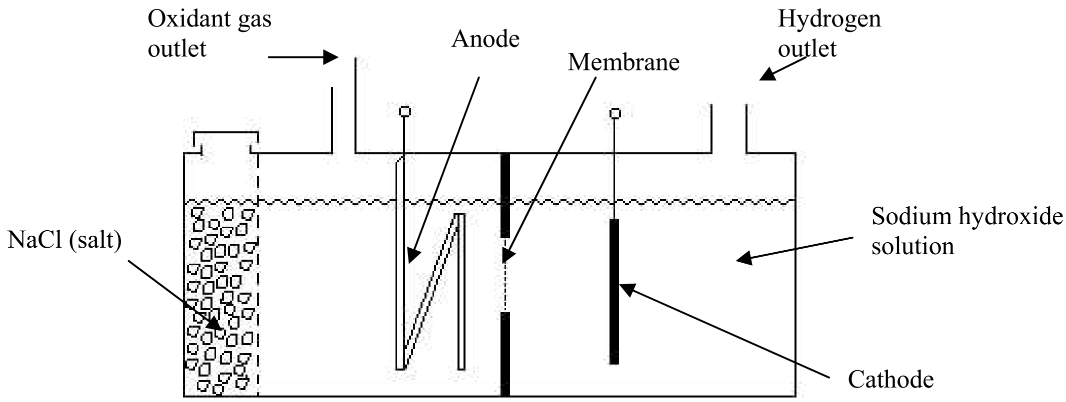
A few systems were designed in the United States for on-site hypochlorite generation, but inside a water current. Some 200 of them are in operation in national parks and small communities in that country.

The following figure demonstrates the components of a MOGGOD system.

The oxidant gases that emerge from the device are injected into piping equipped with a Venturi.

Equipment for generating hypochlorite in a water current





MOOGOD System

Monitoring

The oxidant gases are monitored in exactly the same way as residual chlorine, using the same techniques: orthotolidine and DPD.

Costs

With a very few exceptions, MOGGOD equipment are small. Their prices range from \$ 500 to \$ 4,000. The operating costs are very low because table salt (the main input) has always been and still is very inexpensive. Since the equipment uses low amperage, the cost of the electricity is not very high, either.

Advantages and disadvantages of disinfection using a mixture of oxidant gases

On-site hypochlorite generating equipment has had good results. Once the hypochlorite solution is generated, there are several possibilities: 1) dosing it in drinking water systems 2) using it to disinfect water, not at the community level, but at the single family level, and 3) conducting programs to distribute bottles of hypochlorite for household disinfection purposes. Although advances have been made in all three areas, the centralized production of hypochlorite (in a hospital, school or community center) and its distribution to a given number of families has been the most successful course of action.

Disinfection by radiation

Description

Chapter 4 addressed ultraviolet disinfection, which consists merely of placing a substance (in this case, water) where it can be radiated with a certain wavelength.

There are two other types of radiation that have only been used experimentally, but that could potentially be employed in the future with a good capacity for disinfection. These are "gamma" and "X"-rays.

Effects of radiation on health and DBP generation

As in the case of ultraviolet radiation, these create no health or DBP problems.

Disinfecting action of radiation

Any type of radiation is characterized by a particular wavelength, which is inversely proportional to the wave frequency. This means that the shorter the wavelength, the higher the frequency; and, quite obviously, a higher frequency means more force or energy. Inasmuch as gamma and X-rays have a higher frequency than ultraviolet rays, they have more energy and, therefore, a stronger bactericidal capacity.

Two mechanisms for disinfection by radiation have been recognized: one in which the radiation power damages the microorganism's DNA and the other where the collision of the radiation with some oxygen atoms that are components of the cell or cells generate ozone and other radicals that disturb it to the point of destruction.

Equipment

No specific equipment exists for water treatment with gamma or X-rays. The equipment that can be found is based on cobalt radioisotope emissions; it is quite complex and its operation, although not difficult, does require especially trained personnel.

Costs

No reliable data is available on the cost of this type of water treatment. Inasmuch as it is highly unlikely that this technique will come into wide use, no comparative studies have been made of the differences between disinfecting food products and water. If this technique were to be implemented today, it would doubtlessly cost a great deal more than the usual and widely used disinfection methods.

Synergic disinfection methods

Description

According to the dictionary, the term *"synergy"* means "the interaction and combined activity of two or more biological beings, substances or components to produce something that is qualitatively and quantitatively different from the sum of their individual capacities." In other words, the formula for a synergy is: $1 + 1 \neq 2$ and the result can be, for example: 0.7 or 3.

In the specific case of the substances used as disinfectants, if, by adding together the individual capacities of each of them, we were to obtain a capacity larger than the sum of the two (in the case of the example, if by adding 1 + 1 we were to obtain 3), this would mean the discovery of a new, much more powerful substance with better qualities than either of the two individual substances and even than the combined qualities of the two. That is precisely what happens in certain special cases and what is called "disinfection synergy."

Not many of these synergies exist, but those that are mentioned below are promising and suggestive of a new field that will be broadened and enriched by new research, experiences and discoveries.

The synergic cases that have been most studied are the following:

- Silver/hydrogen peroxide
- Silver/copper
- Silver/copper/chlorine
- Iodine/chlorine
- Ozone/hydrogen peroxide
- Ozone/UV.

Effects of synergic disinfection methods on health and DBP generation

Information can be found about each of the separate disinfectant substances, but, as already stated, if the resulting substance does not have the same qualities as the individual components, then it is to be assumed that their effects on health and DBP formation will not necessarily be as expected. There may be in store for some surprises and thorough studies will be needed before it can be certain of their innocuousness or can determine the level of risk associated with each synergic product.

Disinfecting action of synergic methods

In all of the cases, the disinfecting action is much greater than the sum of the actions of each component of the synergic product. While it is not certain about all of the mechanisms involved, most have already been mentioned (oxidation, enzyme destruction, disturbances of the cell living and reproduction mechanisms, etc.), and obviously all of them are broadened and enhanced in the case of synergic substances.

Equipment

The equipment is no different from that used for each individual technique. In the case of the iodine/chlorine method, the doses of each substance or the mixture of the two are administered by the same diaphragm dosing pumps.

Monitoring

Little information is available about this monitoring, but it is understood to involve the normal chemical detection techniques that are in use today.

Costs

The information about the costs is not very clear, but obviously the costs will be higher than those corresponding to each individual substance.

Advantages and disadvantages of synergic disinfection methods

The advantage is a large disinfecting power that in some cases eliminates the risks and dangers associated with the use of the individual substances. A typical case in point is the reduction of DBP.

<u>Household filters</u>

Description

While small household filters do not have the necessary capacity to treat large water volumes, we have included them in this manual because, properly handled and accompanied by community information and education programs, they represent an important means for bettering drinking water quality in rural areas.

The subject is somewhat controversial, since the market is filled with filters; there are a whole range of processes (techniques) and a variety of forms and capacities. This makes their classification and rating extremely difficult. It should be stressed here that many of these filters have been made commercially without any scientific backing. They have been manufactured to make money and are not necessarily what they claim to be.

Lastly, it is important to stress the need for the user to be scrupulous in keeping the elements of the system clean and in changing the cartridges. Otherwise, these filters can become a greater problem than the one they are intended to solve.

Household filters are used to: 1) eliminate turbidity, 2) remove odors and tastes and some organic substances, among them DBP, and 3) disinfect. Some devices cover only one of these functions, while others accomplish two or the three purposes mentioned. Obviously, in order to have safe water, it is necessary to use a filter that disinfects it.

Household filters disinfect water through filtration or a physical or chemical action. In the former case, the water passes through ceramic candles with very tiny pores with diameters of less than 0.4 microns that retain even bacteria.

In the latter case, the most common disinfecting filters use UV or silver-coated sand.

There are no special observations to be made here, for we have already commented on UV radiation and silver disinfection. These filters cannot possibly generate DBP (with one clarification to be made under the following point).

<u>CEPIS System</u>
Filter with candles imbedded in fine sand and a geotextile covering to reduce candle clogging. The filtered water is collected on the bottom and is kept there, protected, until it is consumed.

Disinfecting action of household filters

As in the case of their effects on health, the disinfecting action of these filters was already commented under UV radiation. In the case of ceramic candles, the effect is merely mechanical. The filter pores, because of their smaller diameter, retain the microorganism. It is precisely with regard to this point that a comment should be made.

The bacterial load of a household filter effluent has frequently been found to be heavier than that of the raw water entering it. The explanation for this is that the microorganisms that are retained are dead organic matter that slowly builds up and becomes food for the new microorganisms that appear. The passage of some microorganisms through the pores (perfectly possible in this context of enormous profusion and saturation) creates colonies "on the other side of the filter" and slowly the entire filter (on both sides of the ceramic candle) turns into a mass of microbes. In the jargon of chemistry and sanitary engineering, many of these filters are called "nesting boxes," for they offer ideal conditions for bacteria multiplication.

This does not mean, however, that household filters are bad or risky. What is risky is the behavior of the users, for the problem of nesting boxes appears only when the filter's capacity has been oversaturated -when the raw waters are excessively turbid and contaminated and when the user fails to clean the filter or does not change the cartridges with the frequency recommended by the manufacturer. It is for that reason that follow-up actions and on-going motivation and educational campaigns are recommended to ensure that people operate these elements properly.

Equipment

There are a large number of household disinfection systems. A system can be put together, and can most likely be found in the market, using a paper or thick cellulose cone or cartridge to eliminate heavy turbidity, a candle filter or an element with a UV lamp to eliminate microorganisms and an activated coal cartridge to eliminate unpleasant odors and tastes.

The water flow volumes also vary, the devices range from those that treat several cubic meters a day to small ones that are attached to a faucet to filter a few liters of water a day.

Monitoring

There are no easy ways to monitor these systems. They can only be monitored through bacteriological analyses, which are not always possible in the medium where these filters are used.

Costs

The costs vary widely, ranging from fifty or sixty dollars to a thousand dollars for a highly sophisticated and complete system.

Information sources

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