Luciano Coccagna

CHEMICALS FOR WATER DISINFECTION

fondazione AMGA

FrancoAngeli

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CHEMICALS FOR WATER DISINFECTION

**contributi di
Claudia Lasagna
e Giorgio Temporelli**

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PREFACE

Fondazione AMGA promotes and carries out research in the scientific and economic sectors, aimed at safeguarding nature and environment and identifying the most appropriate models for utility management. With the purpose of sharing research outcomes, disseminating water culture and providing knowledge tools to water sector operators, the Foundation promotes publication of scientific and economic volumes.

In this context an agreement has been finalized with FrancoAngeli for a publisher's collection including monographs, technical notebooks and conference proceedings.

The present book is a manual concluding the technical "trilogy" initiated by the book "*I materiali filtranti granulari*" ("*Filtering granular media*") and continued with "*Coagulanti e flocculanti nei trattamenti di potabilizzazione*" ("*Coagulants and flocculants in drinking water treatments*"). The volume, written in English to be understood also by non-Italian water industry operators, provides information on disinfection mechanisms as well as the characteristics and technical specifications indicated for the different chemicals by European standards, approved and used for water purification.

We wish "*Chemicals for water disinfection*" could provide a contribution for disseminating knowledge in this important area of water treatment.

Osvaldo Conio
Fondazione AMGA Vice President

INTRODUCTION

According to the WHO statistics the world population was approximately 7,000 millions in 2011 (50% rural and 50% urban population). Only 5,300 millions had access to water suitable for drinking purpose but only 54% of them had the household connection, i.e. only 2,800 millions (less than 50%) out of the total world population can account on water at home.

However it does not necessarily mean that such water is safe, for drinking but also for contact and inhalation.

Over 3 million people per year die due to the water home diseases originated by unsafe quality and the primary concern is the microbial hazard both in developed and developing countries.

In developed countries casualties are mostly related to *Legionella* but also gastrointestinal diseases are frequently recorded.

Therefore, as continuously reaffirmed by WHO, water disinfection is by far the most important goal in water treatment and distribution.

In particular, during the last decades, due to the presence of the so-called DBPs (Disinfection By-Products), the disinfection practice was heavily affected, frequently driving to insufficient water treatments protection.

Therefore, even in the last edition of the WHO "Guidelines for Drinking Water Quality" (IV Edition, Geneva 2011) it is firmly stated that «Disinfection should not be compromised in attempting to control disinfection by products (DBPs)».

The present manual is not a disinfection handbook but it is rather intended to describe the characteristics and specifications of the disinfectants.

For this reason it is extremely important to prevent the reader about the believing that disinfection can be attained with the use of a selected chemical, possibly with dosage variations.

On the contrary disinfection is an integrated implementation of different technologies whose individual efficiency contributes to the final goal, i.e. the “multiple-barrier approach”.

1. DISINFECTION MECHANISMS

1.1 Looking for a definition

By reviewing the available literature looking for a suitable definition of the term disinfection, mostly through some of the main institutions worldwide, the following were found:

1. **WHO** - *World Health Organization* - The Drinking Water Dictionary: «The process of destroying or inactivating pathogenic organisms (bacteria, viruses, fungi and protozoa) by either chemical or physical means (Symons et al., 2000)».
2. **IWA** - *International Water Association* - Dictionary of Water and Waste Management: «Destruction of pathogens that cause disease. It is not sterilization which is the destruction of the all microscopic life (Smith et al., 2002)». (The definition is completed with explanations and requirements).
3. **EPA** - *U.S. Environmental Protection Agency* - Drinking Water Glossary - A dictionary of Technical and Legal Terms related to Drinking Water: «The process designed to kill most micro-organisms in water including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with Chlorine being the most frequently used in water treatment (EPA, 2011)».
4. **WQA** - *Water Quality Association* USA - Glossary of terms: «The treatment of water to inactivate, destroy and/or remove pathogenic (disease-producing) bacteria, viruses, cysts and other microorganisms (but not eliminating all microorganisms) for the purpose of making the water microbiologically safe for human consumption. A disinfection operation should reduce the total viable microorganism population by 99.9999 percent (i.e. 6 log reduction).

> Disinfection may involve the use of disinfecting chemicals such as Chlorine, Iodine, Ozone or Hydrogen Peroxide; or it may involve physical processes such as distillation, microfiltration, ultrafiltration, boiling, or ultraviolet radiation (Harrison et al., 1997)».

In spite of the importance of this process, the large number of different definitions are, if not discrepant, at least incomplete in many parts.

Such “confusion” becomes even larger if, through Internet, a deeper investigation is performed, depending on the different activities where disinfection plays an important role (e.g. from surface cleaning to animals slaughtering).

From our modest point of view, disinfection simply is a «process intended to prevent pathogenic micro-organisms from harming to human health».

In addition to the above definition, the following statements (more or less shared) could help to deepen how to perform the process:

a) disinfection, in principle, is intended to act against pathogenic micro-organisms only, while sterilization is aimed at acting against any kind of micro-organisms. Of course it should be considered that the harm to human health depends on many other factors, i.e. the type and number of micro-organisms, the tipe population vulnerability (age, health condition, etc.). In other words the border between pathogenic and non-pathogenic is not that sharp;
b) both disinfection and sterilization are not achievable at a 100% level. Therefore practical disinfection (as well as practical sterilization) is conventionally related to given micro-organisms and to given percent removal efficiency;
c) killing and inactivation are the most popular terms for indicating the disinfection mechanisms. However, today even more than in the past, removal is a tremendous tool for achieving disinfection, particularly in water treatment;
d) “to prevent pathogenic micro-organisms from harming to human health” has a broad meaning. In fact not only the micro-organisms should be considered but also their metabolic and catabolic products and substances which may be produced during their life or decay of dead bodies (e.g. various kinds of toxins produced by algae, like cyanotoxins of *Oscillatoria*, by bacteria, etc.);

e) the above considerations emphasize the need of considering disinfection as an integrated system which, in water treatment, should:
  - be performed with multiple barriers not only because very hardly one step only can guarantee the wished achievement but also because with multiple barriers it is always possible to achieve partial but helpful results in case one step fails;
  - take care of the consequence of disinfection not only in terms of DBPs but also of the possible formation of off-odours, off-tastes and other drawbacks (including toxin production) due to molecules released by killed microorganisms and/or to their chemical reactions with the disinfectants. For example, as far as algae are concerned, this approach emphasizes the preference given to removal instead of killing technologies.

In any case the planning and the design of a disinfection system should always follow the *Risk Assessment Analysis* as recommended by the WHO Water Safety Plan (WSP).

1.2 Removal

Even though the scope of this manual is to present the chemicals used for disinfection, nonetheless it is important to spend some lines about other technological solutions for water disinfection in order to complete the frame of disinfection matter.

The separation technology has improved quite a lot during the last decades and, not less important, also their cost (namely for membrane separation) has decreased significantly.

By limiting the review of technologies to those available in developed countries, two types of separation are commonly used in the waterworks:

- ✓ conventional systems basically aimed at removing micro-organisms with the capture mechanism, i.e. to aggregate them with coagulants and flocculants in order to form “flocs” which should be as large, heavy and strong as possible;
- ✓ barrier screen (usually membranes) where the separation goal is achieved by narrowing the screen meshes and opening.

1.2.1 Conventional systems

1.2.1.1 With sedimentation step

Historically a water treatment plant is made up with a sequence of steps each of them intended to partially contribute to the final goal or for making the following steps easier and/or more protected.

Typically it may be composed of:

1. catchment reservoir (natural or artificial, open air or underground) intended for smoothing sudden variations of the raw water quality (e.g. turbidity) or for hydraulic reasons (e.g. continuous availability of adequate flow);
2. depending on a number of reasons, the catchment may be protected with pre-treatments (e.g. copper salt for preventing algae growth, ozonation or pre-disinfection, etc.);
3. pumping station (if necessary);
4. straining (microstraining) mostly intended to remove algae.

   In principle the microstrainer is a barrier tool as the separation efficiency depends on the steric interaction between the opening size of the strainer and the size of the algae.

   However the selection of the most suitable strainer is quite often done through pilot plant testing. In fact, algae exist in many diverse forms and their tissues are quite elastic, so it is almost impossible to tell in advance whether a particular mesh will eliminate the algae bigger than that mesh.

   What counts, then, is the kind of algal film that forms on the mesh' surface, a film which is itself a winding arrangement of small algae. Overall performance depends on this film more than on the size of the clean mesh.

Figure 1-1: Microstrainer installation - Vallo della Lucania (SA) (courtesy of Culligan Italiana SpA)

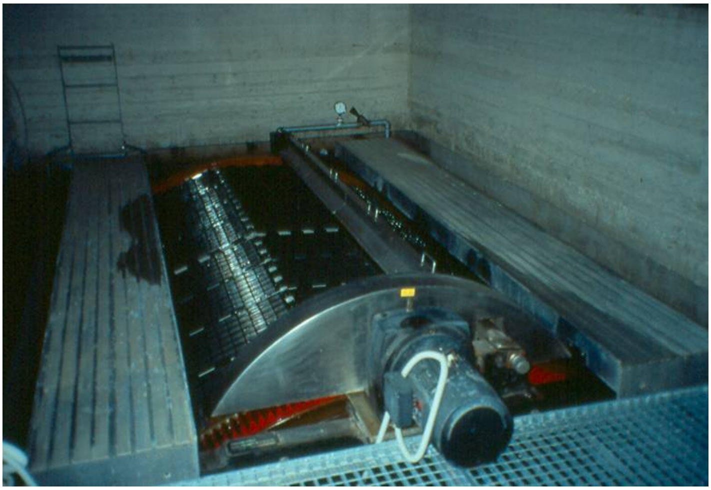

Figure 1-2: Microstrainer drum details - Vallo della Lucania (SA) (courtesy of Culligan Italiana SpA)

The following istograms (figures 1-3; 1-4; 1-5) show that the mesh size (15, 23, 30 and 35 micron) is not especially influential, since removal capacity is quite different for two algae of similar size (5-30 micron) but different shape: the elongated *Melosira* and the round-like *Chlorella Oocysts*.

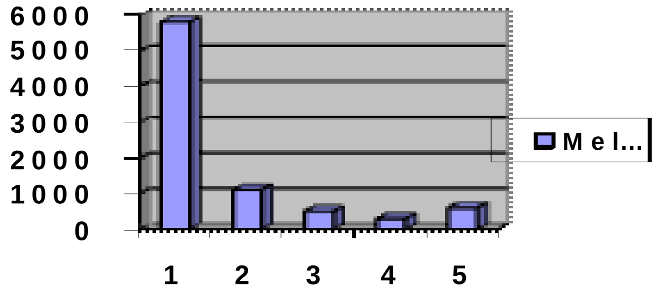

Figure 1-3: Melosira removal (cells/mL)

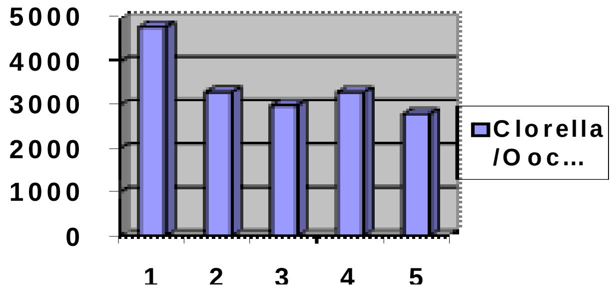

Figure 1-4: Chorella Oocysts removal (cells/mL)

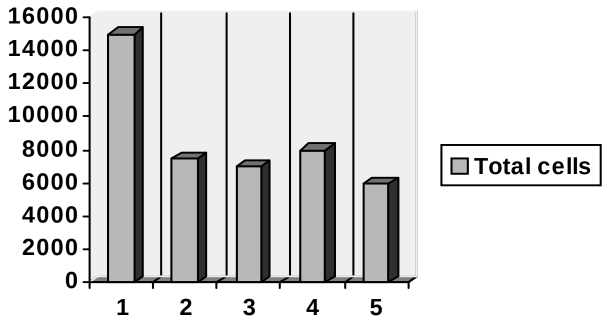

Figure 1-5: Total algae removal (cells/mL)

Where:

1. Raw water
2. Microstrainer 30 µm
3. Microstrainer 35 µm
4. Microstrainer 23 µm
5. Microstrainer 15 µm

Even though in this example the overall removal efficiency is not very high, nonetheless it might be sufficient for getting a notable decrease of the pressure loss in the following filtration. The scope of the microstrainer is not the complete removal of algae but rather of those species likely to create troubles during the following steps, for instance those algae which, when killed upon disinfection, release objectionable molecules or other very motile algae which may not remain entrapped into a floc or other very voluminous and light algae prone to clog the media filter.

Some manuals (i.e. Palmer, 1980) provide identification keys just intended for water suppliers and operators.

Generally speaking a removal capacity over 90% could hardly be expected from microfiltration.

- Coagulation and flocculation section.

  If sedimentation and sand filtration are used, coagulation and flocculation play an important role for the entire efficiency of the treatment plant. In literature many examples are recorded about huge improvements attained only by upgrading the coagulation and flocculation steps possibly with the use of suitable instruments (zed potential measurements, etc.) and specific mixing technologies.

  Quite often the coagulation and the flocculation steps (but also the pre-disinfection, if performed) fail due to the poor mixing. In fact the homogenous incorporation of the reagents in the body of water is an essential pre-requisite for making coagulation, flocculation and even disinfection effective and for reducing some drawbacks like coagulants leakage and increased DBPs formation.

- Sedimentation.

  Sedimentation is almost always intended to reduce the bulk of suspended solids to a level suitable for the following filtration step. The management of a sedimentation tank is not that easy because redundancy may create troubles even larger than the undersizing. Because the retention time of the water in the tank is rather long (in the order of hours), the most frequent drawbacks in the summertime and with low turbidity are, for example, raise of the sludge from the bottom and sludge floating, algae growth, flocs weakening, etc..

  In the case of low turbidity, it might be necessary to dose micro-particles of sand for increasing turbidity and/or the flocs weight.