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WHITE PAPER ON WATER RESOURCES

PURIFICATION TREATMENT, WASTE WATER, AND REUSE

By **Massimo Muscari**

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Edited by **Massimo Muscari**

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WE SERVE

As part of EXPO 2015 and the Lions Club motto of We Serve, we could not sidestep giving our attention to the problems of water supply and water quality for human, health and hygiene, and agricultural use. Water quality, both technically and legally, is a matter that affects the entire population of our planet and therefore, what better opportunity was there to approach the subject than Expo 2015. What supporter is more appropriate than The International Association of Lions Clubs, which is present in virtually all countries throughout the world with its acts of service.
I am honoured to represent District 108 Ib1 Italy.
The purpose of this white paper is to call attention to the problems concerning the management of water resources and to offer helpful suggestions to resolve them.
But, what specifically are these problems?
First, we cannot underestimate the increasing risk of depletion and pollution of our water reserves, a situation that can be controlled with adequate planning in the use of water sources.
Also, further issues arise in relation to treatment of water just retrieved from the sources as well as waste water. Different case studies have identified the recommended treatments. This white paper aims to suggest the best solutions for water purification, wastewater treatment and reuse, supply of water resources in emergency situations, or scarcity of natural sources.
This work is addressed to Directors in countries that are in the difficult situation of creating a cutting edge water management plan designed to distribute water sources according to different uses and to evaluate increasing water reuse. Water conservation should not be limited only to the careful management of sources, but must also consider alternatives such as the reuse of treated water in order to increase the amount of water available.

Preserve, save, and reuse: these are the basic points of an intelligent water plan that is beneficial to all users and the entire ecosystem.
The incontrovertible dependence of human life on water requires us to respect this element and to give new generations an environment that is suitable for future developments. We will be pleased if our work can be even just a small step in this direction.
I would like to thank everyone who collaborated in this document, in particular OD Lion Giovanni Benedetti of the Seregno Brianza Lions Club, responsible for the District 108 Ib1 Water for Life committee who promoted this white paper and Engineers Samuele Mariani and Massimo Muscari who synthesized and developed the theme of this white paper with valuable suggestions and advice regarding its content and who managed the publishing project along with Eleonora Benedetti, Stefania Bonacina, Giorgio Pizzi, and Nicola Cattaneo.
We also thank the sponsors: Idrodepurazione Srl, EMWG Srl and Swenco Sagl for the technical material they provided.

DG Lion Luigi Pozzi
District 108 Ib1 Italy

INTRODUCTION

Life cannot exist without water. And human life cannot exist without fresh water. In 1977 at Mar de Plata, Argentina, the United Nations Water Conference defined access to clean drinking water as a basic human right: "All peoples,whatever their stage of development and social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs."

Three decades later in September 2010 the United Nations further defined the right of access to clean drinking water aspart of international law and therefore legally binding on all countries of the world. The United Nations called upon its member States to develop appropriate tools and mechanisms to achieve progressively the full realization of human rights obligations related to access to safe drinking water and sanitation, including in currently unserved and underserved areas.

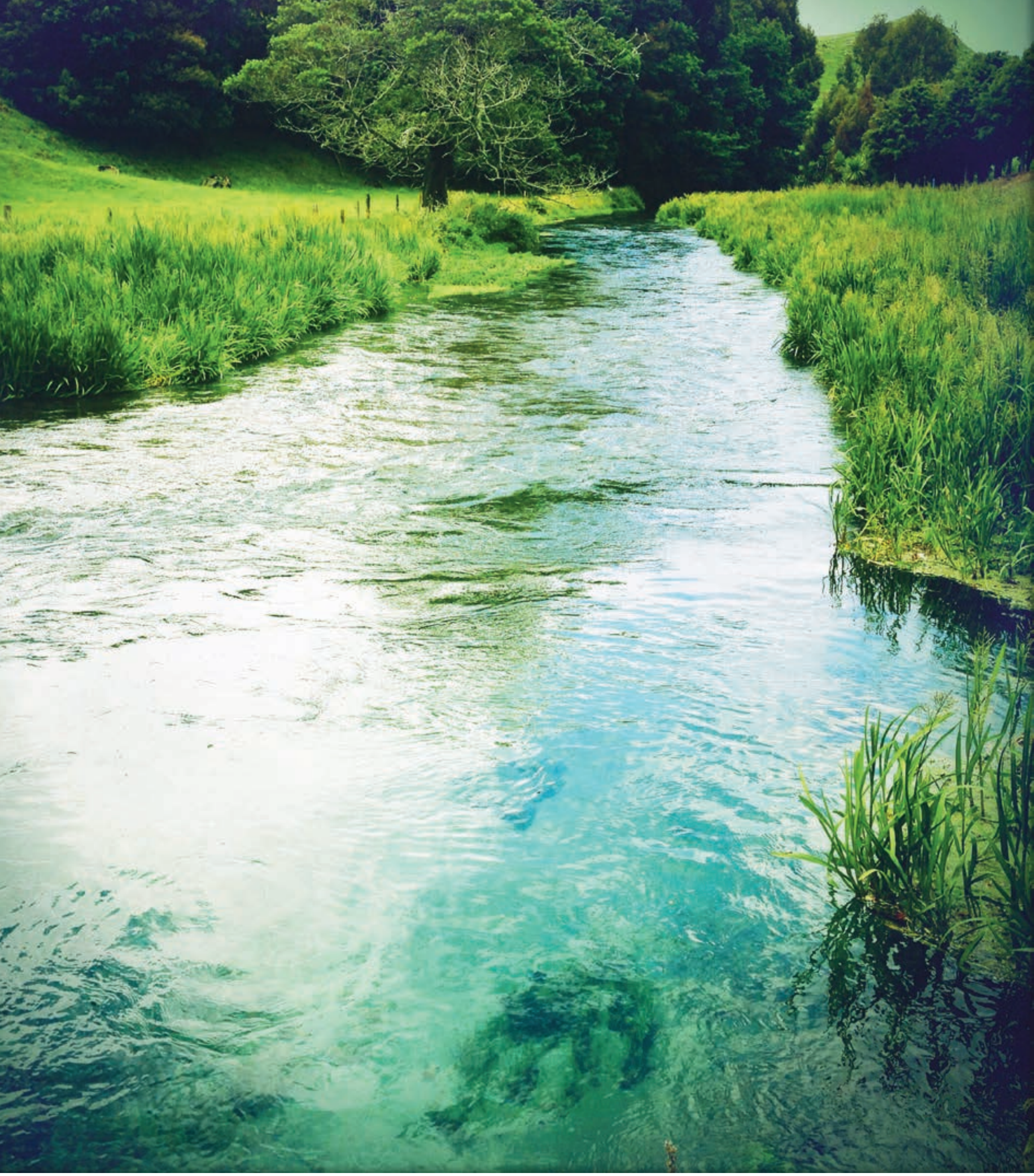
The exhortations of the United Nations could not be more urgent. Nearly 70% of the Earth's surface is covered by water, but less than 1% of the Earth's water can be used directly by human beings for drinking or agricultural use. It is estimated that water consumption doubles every twenty years, and that by 2025 demand for clean water will exceed supply by more than 50%, leaving 2.5 billion people in a state of water shortage, which is also known as water stress. Continued water stress could have devastating consequences on all people, not just from developing nations. The continued water shortage in the state of California in the United States is just one example of many of water stress.

As in any basic economics calculus, as demand exceeds supply prices will rise. The rise of water costs will also mean increases in food and energy prices and potential environmental, hydro-geological, and agricultural destabilization. Such destabilization in *the past has led to deteriorating social and economic conditions and ultimate geopolitical conflict. Management of water resources will be come more and more institutional, as access to water will constitute a measure of a nation's status, wealth, and possibly power.*

Yet in such uncertainty one may find opportunity, since necessity is the mother of invention and innovation, or Mater artiumnecessitas. The authors of this White Book have attempted to describe water's many uses and needs from drinking and agriculture to industrial and energy applications. They have identified the sources of potable water including the technologies and styles of water treatment plants that convert non-potable water to clean water fit for consumption and use. They further analyze the waste-water discharged by human civil use and industrial applications and describe many innovative ways that this water can be purified and reused.

The contents of this White Book should be considered a part of common human patrimony, and what better venue to unveil it than the Expo 2015 Feeding the Planet, Energy for Life, which focuses on food and beverage and therefore indirectly, or really directly, on water. Love and passion for food and beverage is a theme that can unite us all and bring us together to discuss water intelligently as a matter of basic human rights, a matter of economic and social prosperity, a matter of geopolitical and environmental strategy, and a matter of world peace.

The Honorable Richard Greco, Jr.
Former Assistant Secretary of the United States Navy
Knight of the Order of Merit, Republic of Italy



CHAPTER 1

WATER

1.A WATER, A PRECIOUS COMMODITY

Water is a fundamental resource for humans as it is essential to life.
The human body is made up of 50-65% water, therefore it is a fundamental commodity for survival, although this is not the only reason why it is important for human life. Water is necessary for the most basic hygiene practices, is a precious commodity for agricultural, industrial, and energy production and, last but not least, is important for the stability of the entire ecosystem.

As a renewable resource, it is supplied in large quantities by the very nature of our planet but unevenly distributed and not proportionate to the people who need it and use it. In recent years the availability of fresh water per capita (indispensable for human health) is significantly decreasing due to various factors such as population increase and the improper treatment of water by people themselves who contaminate and waste it.

This compromises the natural water cycle that allows its renewal through precipitation, which returns water that has evaporated from the surface of the Earth to the ground. Nevertheless, it does not decrease the total amount of water available; instead an increasingly consistent part is altered and made unusable because it is polluted by humans during the natural cycle.

For this reason,

Special attention should be given to this resource to protect its quality and increase distribution.
It is therefore desirable to be able to prevent water pollution and the depletion of the resource by planning in advance the correct management of the available water in each country, through the consideration of the uses of the water in relation to its various characteristics and the construction of plants to be able to treat water for purification, disposable, or possible reuse.
So by designing a connected process of the various water treatments, we can ensure water savings, especially in countries where it is scarce, and better quality, by limiting consumption as much as possible and investing in water reuse.

In this regard, the methods to achieve these goals are:

a) prevent and reduce pollution and implement the recovery of polluted water bodies;
b) achieve the improvement of water condition and adequate protection for water intended for particular uses;
c) pursue the sustainable and enduring use of water resources, with priority given to potable water;
d) maintain the natural ability of water bodies to self-purity, as well as the ability to support large and diversified animal and plant communities.

1.B WATER: CHARACTERISTICS AND RESOURCE MANAGEMENT

As much as 70% of the Earth is covered with water but all of it is not immediately available and does not have the same characteristics. Of this, 97% is made up of salt water (seas and oceans) while only the remaining 3% is fresh water, which is present in nature with a low concentration of salt and is considered suitable for extraction and treatment in order to produce potable water.
For a more in-depth look at the sources of fresh water and related treatments, refer to the subsequent chapters regarding purification. Here we state in advance, however, that it is fundamentally important to safeguard our reserves of fresh water as necessary to human health and subject to depletion. In fact, once used, its properties are altered and it must be treated again with specific procedures but it can no longer be made potable.

Within a territory, water resources appear under various aspects. Below is a preliminary classification of the sources that are generally available:

- **Surface waters**: this includes inland waters (except ground water), transitional waters and coastal waters. Inland waters refers to all of those within the territorial boundaries.

    - Rivers: flowing bodies of water on the surface (but there may be underground sections). They reach edge of the transition waters, which vary for each watercourse.
    - Lakes: bodies of water that are lentic, or still, and not temporary. Both natural and man-made bodies of water are considered lakes if they have a surface greater than 0.5 km². The definition of lakes also includes those with an effluent flow.
    - Coastal waters: surface waters located inland when compared to an imaginary line that is equidistant one nautical mile from the baseline that serves as a reference to define the limit of territorial waters; salty composition.
    - Transition waters: bodies of water on the surface near river mouths which are partly saline because of their proximity to coastal waters but are substantially influenced by freshwater flows.

- **Groundwater**: all waters found below the surface of the ground in the saturation area and in direct contact with the ground or subsurface.

Therefore, in order to create a good "management plan" for hydrogeographic basins and take into account all water sources the region offers, the following is necessary:

- assess the various bodies of water available, that is the surface or underground sources, and carry out a precise cartographic reporting by type of resource and perimeter extension, specifically indicating areas that are particularly at risk or protected areas;
- evaluate the existing quality and quantity of water bodies, through special analysis;
- make reference estimates that especially consider the level of human activity on the resource and the level of pollution present. It is also essential to prepare a cartographic support to report human activity in the area, identifying all the places of water extraction and draining;
- provide a monitoring network, with additional related cartography for areas that are monitored;
- plan a water management system aimed at water savings that includes the search for a balance between the extractions performed and the waters restored (consumption refers to the water that is completely absorbed and not returned to the environment). It should also allow the use of natural sources of fresh water for human consumption only when there are no viable alternatives available;
- aim at maintaining (or improving) the quality of the resource and its availability over time, still promoting the protection of potable water over others.

The evaluation of the quality of bodies of water present in the territory is useful for proper, preliminary water management planning because the entire management program must be calculated on the current conditions and must pursue (also for the future) specific "**quality objectives**":

a) **“environmental for significant bodies of water”**: that is, ensure for each body of water the ability to self-purify naturally and protect the quantity and quality of the resource over time, quantifying the impact of human use of the resource.

b) **“by specific destination”**: that aims to identify water bodies with characteristics suitable for human consumption and the maintenance of fish and shellfish.

Therefore, the primary purpose of this analysis is to determine the condition of water reserves and take action to improve or maintain good conditions, if they do not reach a standard specified by the technical parameters.
For the evaluation criteria and sampling procedure, refer to the technical tables given in the appendix.

1.C WATER USES

Having established, therefore, that water in nature does not always present the same chemical and physical qualities, specific uses have been defined for each type of water by virtue of its different properties.
For the classification of water uses, refer to the European guidelines created with the intent to find a good compromise between the needs of the Member States of the European Community.

Once the water quality (which has definite corresponding chemical, physical, and microbiological characteristics) of a water body has been verified, it can be directed to different uses on a general level which can be distinguished as follows:

1) **CIVIL USES**: water for this use must be potable, if aimed primarily at satisfying human thirst. All functions related to personal hygiene and other domestic practices related to food also fall under this category. For other kinds of uses (street washing, resources for fire-fighting systems, heating for buildings, watering green areas not open to the public) is not necessary to use potable water. Major sources of supply are natural fresh water, such as groundwater and surface water.
It is calculated that on a global level, the percentage of water intended for these purposes is an average of around 10%.

2) **IRRIGATION USES**: the percentage of water required by the agricultural sector is estimated at 70% worldwide, assuming however that it reaches 90% in countries affected by an arid climate where agriculture is hampered by the high temperatures and the high rate of evaporation.
Useful for irrigating agricultural land or in greenhouses and livestock, it is extracted from underground and surface sources and artificial bodies of water (that is, man-made), sources upon which the water quality itself depends.
Benchmarks used to authorize the use of water for irrigation are based on FAO indications, variously implemented by the Member States of the European Community. In recent years there has been increased attention to the monitoring of chemical elements that are harmful to humans
- in water used to produce food, especially those eaten raw, nitrates are particularly kept under control.

3) **INDUSTRIAL USES**: water reserved for the industrial sector (about 20%, again on a worldwide average) is generally extracted from wells or structures dug into the ground to allow extraction from the subsoil. It is used for machining processes in the industrial sector and for cooling equipment or heating buildings. Potable water is not required for these uses (and it would be better if the states used valid alternatives to it) so it is very convenient to use purification mechanisms to be able to reuse the same water. The only situations in which the use of potable water is required are in the production and conservation of foods meant for human

consumption.

4) **ENERGY USE**: water can be used to produce renewable energy through various procedures. In hydroelectric power plants, mechanical energy is derived from the movement triggered by large bodies of water, which are conveyed in the plant and poured over special machinery. This mechanical energy then becomes convertible into electricity. In thermoelectric power plants the process starts with the combustion of fossil fuels that heats the water and turns it into steam. In this state the water moves electric generators to create mechanical energy that can also be turned into electricity.

Significant amounts of water are needed for this and therefore it is prudent to not use natural fresh water for this type of use but rather to employ already used water or sea water, when possible.

Obviously, prudent planning of water use must take into account the need for adequate plants for the collection and disposal of wastewater, considering the impact that these can have on the territory.
Also, the possibility of employing wastewater for the uses listed above once it has been adequately treated is particularly advantageous because then it is possible to limit the consumption of natural sources and offer a valid alternative.
The use of only potable water is forbidden for this use, but refer to the chapter on wastewater and its residue for specific information on this topic.

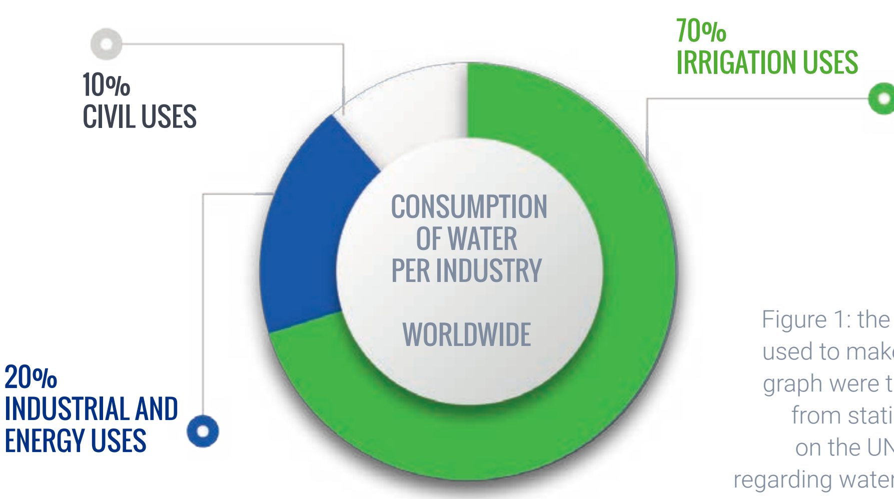


Figure 1: the data used to make the graph were taken from statistics on the UN site regarding water and are calculated on a global scale.

APPENDIX TO CHAPTER 1

I.I GENERAL ASSESSMENT OF THE QUALITY OF A WATER BODY

As previously observed, for proper management of a hydrographic basin, a preliminary analysis of the territory and the location of the resources is necessary. Subsequently, planning should be done according to the quality of the water sources available. The environmental condition, or the quality of a resource is analysed.
Based on the definitions assigned to the sources, a country should then improve the conditions of those resources that were negatively classified (working to improve their condition in as short a time as possible) and to maintain the others in good condition.
Below is a table that summarizes the general definitions of the **ecological conditions for rivers, lakes, coastal waters, and transition waters**.

HIGH	No alterations in the quality values of the chemical-physical and hydromorphological elements were detected for that type of water body subject to human impact or they are minimal compared to values normally associated with the same eco-type in undisturbed conditions. The biological quality will be characterized by a composition and abundance of species corresponding completely or almost completely with conditions normally associated with the same eco-type. The presence of synthetic and non-synthetic micro-pollutants is comparable to detectable background concentrations in bodies of water that are not affected by any human pressure.
GOOD	The values of the biological quality elements for that water body type show low levels of alteration resulting from human activity and only differ slightly from those normally

associated with the same eco-type in undisturbed conditions.

The presence of synthetic and non-synthetic micro-pollutants is in concentrations that do not create brief and long-term effects on biological communities associated to the reference water body.

SUFFICIENT

The values of the biological quality elements for that type of water body differ moderately from those normally associated with the same eco-type in undisturbed conditions. The values show signs of alterations due to human activity and are significantly more disturbed compared to those in the "Good" condition.

The presence of synthetic and non-synthetic micro-pollutants is in concentrations that do not create brief and long-term effects on biological communities associated to the reference water body.

POOR

There are major alterations from the values of the biological quality elements for the surface water body type and the relevant biological communities deviate substantially from those normally associated with the type of surface water body when unaffected.

The presence of synthetic and non-synthetic micro-pollutants is in concentrations that not create medium and long-term effects on biological communities associated to the reference water body.

BAD

The values of the biological quality elements for the type of surface water body changes present serious alterations and large portions of the biological communities normally associated with the type of surface water body when unaffected are missing.

The presence of synthetic and non-synthetic micro-pollutants is in concentrations with serious brief and long-term effects on biological communities associated to the reference water body.

Note that “unaffected eco-type” refers to a reference water body in that territory (or possibly also an abstract model) which presents exemplary physical, chemical, biological and hydromorphological characteristics, so as to be able to make a comparison with the remaining sources.

It is also possible to outline a definition of the environmental condition of **subterranean waters** as illustrated in a similar table:

HIGH	No or negligible human effect on the quality and quantity of the resource with the exception of what is expected in the special natural state.
GOOD	Reduced human impact on the quality and/or quantity of the resource.
SUFFICIENT	Reduced human impact on the quantity, with significant effects on the quality that require targeted actions to prevent worsening.
POOR	Significant human impact on the quality and/or quantity of the resource with a need for specific recovery actions.
SPECIAL NATURAL	Qualitative and/or quantitative characteristics that while not presenting a significant human impact, present limitations on the use of the resource due to the natural presence of particular chemical species and for the low quantitative potential.

These are the definitions that are conventionally used in a water management plan to evaluate the quality of a body of water. Once again, the primary goal of a country is the progressive improvement of the quality of its waters.

I.II ANALYSIS FOR THE DEFINITION OF A QUALITY CONDITION

The analysis to define the quality of a body of water is based on calculations that are differentiated based on the source of water to be analysed.
For surface waters, the environmental quality is determined by the crossed combination of the results investigating the following areas:

- **Chemical condition**: checks the proportion of pollutants present in a body of water, on an annual mean average. The primary pollutants to be monitored are given in the table with their recommended values:

INORGANIC POLLUTANTS µg/L	
Cadmium	≤ 5
Total Chromium	≤ 50
Mercury	≤ 1
Nichel	≤ 20
Lead	≤ 10
Copper	≤ 1000
Zinc	≤ 3000

ORGANIC POLLUTANTS µg/L	
Aldrin	≤ 0,1
Dieldrin	≤ 0,1
Endrin	≤ 0,1
Isodrin	≤ 0,1
DDT	≤ 0,1
hexachlorobenzene	≤ 0,1
Hexachlorocyclohexane	≤ 0,1
Hexachlorobutadiene	≤ 0,1
1,2 dichloroethane p	≤ 10
Trichloroethylene	≤ 10
trichlorobenzene	≤ 0,4
chloroform	≤ 12
Carbon tetrachloride	≤ 12
Perchlorethylene	≤ 10
Pentachlorophenol	≤ 0,4

- **Ecological status**: changes to the reference eco-type are monitored, investigating the aquatic eco-systems, the physical and chemical nature of the waters and sediments, the characteristics of the water flow and the physical structure. Biological indicators are used for the calculation, which provide parameters to verify the water condition based on changes in the plant and animal communities.

For subterranean waters, on the other hand, the chemical and quantitative state of each resource is monitored. Specifically speaking, this means:

- **Chemical condition**: here the percentage of pollutants in the water body is also evaluated. Parameters referring to the standard class are still provided, which define the quality of the chemical condition on a general level.

INORGANIC POLLUTANTS µg/L	
Aluminium	≤ 200
Antimony	≤ 5
Silver	≤ 10
Arsenic	≤ 10
Barium	≤ 2000
Berillium	≤ 4
Boron	≤ 1000
Cadmium	≤ 5
Cyanides	≤ 50
Chromium tot.	≤ 50
Chromium VI	≤ 5
Fluorides	≤ 1500
Mercury	≤ 1
Nichel	≤ 20
Nitrites	≤ 500
Lead	≤ 10
Copper	≤ 1000
Selenium	≤ 10
Zinc	≤ 3000

ORGANIC POLLUTANTS µg/L	
Halogenated aliphatic	
totals	10
of which: -1,2-dichloroethane	3
Total pesticides (of which)	0,5
- 1) aldrin	0,03
- 2) dieldrin	0,03
- 3) heptachlor	0,03
- 4) heptachlor epoxide	0,03
Other individual pesticides	0,1
Acrylamide	0,1
Benzene	1
Vinyl chloride	0,5
Total IPA	0,1
Benzo[a]pyrene	0,01

OTHER POLLUTANTS	
CHLORIDE	from ≤ 25 to ≤ 250 mg/L
MANGANESE	from ≤ 20 to ≤ 50 µg/L
IRON	from < 50 to < 200 µg/L
NITRATES	from ≤ 5 to ≤ 50 mg/L
SULPHATES	from ≤ 25 to ≤ 250 mg/L
AMMONIUM ION	from ≤ 0,05 to ≤ 0,5 mg/L

- **Quantitative status**: this seeks to calculate the availability of the resource by making long-term forecasts (for at least 10 years). Comparing it with a state of equilibrium postulated as a model, the comparison is calculated by comparing the extractions and alterations of the source recharge speed.

I.III MONITORING METHOD

For good resource management, it is necessary to monitor the quality of bodies of water. Even in this case, each type of body of water needs specific analyses but the valid indications for surface and underground water are reported here on a general level.

In fact, in both cases the monitoring process is divided into two steps:

- Initial survey phase: aims to classify the quality of each water body. Based on this, the measures needed to reach or maintain the environmental quality objective are defined within the protection plan.
- Operational phase: continues over time, aims instead to detect systematically any changes in the quality of a water resource. Whenever a “good” or “high” level of environmental quality is reached, monitoring may be simplified.

Analysis calls for sampling the **waters**, **sediments** (organic and inorganic material in contact with the liquid but within a very fine thickness of around 2 mm), and the **biota** (total range of animal and plant lie within the body of water). The sampling methods call for the creation of sampling stations in areas judged to be suitable based on the type of water body analysed. For a river, the stations should be located along the entire path (even in areas near urban settlements) and must be located at the end of the path. For lakes the location of the stations varies based on the surface. For coastal waters enough stations should be set up to ensure a precise mapping of the water condition in correspondence with every other type of tributary.

The sampling frequency varies greatly not only due to the type of water source but also its environmental condition, location, and the material analysed. Taking as a reference the analysis of a surface water course, the sampling frequency is generally as follows:

- During the monitoring phase, for 24 months, one sample of the waters must be taken monthly, one of the sediments must be taken yearly, and one of the biota must be taken every four months until the planned environmental quality level has been reached.
- During the regime phase, sampling must be done at the same rate until the preset quality objective has been reached, otherwise it can even be reduced (but no less than four times per year) and simplified, investigating only the essential parameters.

We have chosen to provide an illustrative example for a single type of body of water to show how the monitoring operation varies greatly and also relies on the discretion of the competent authorities.

CHAPTER 2

POTABLE WATER

2.A POTABLE WATER SUPPLY SOURCES

Of the 3% of fresh water available on the earth's surface, most of it (almost 70%) is in the solid state (polar ice caps and mountain glaciers), 30% of it runs underground (groundwater) and only 0.3% is found in surface waters (lakes, rivers).

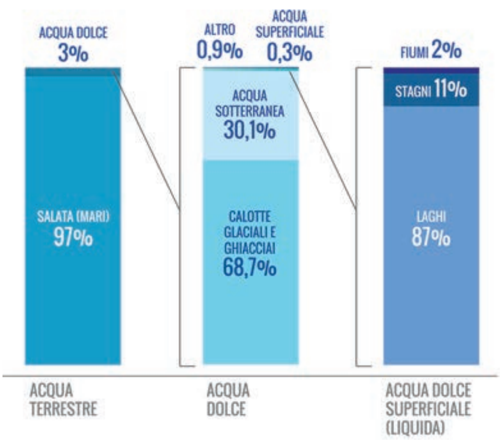


Figure 1: percentage of water composition on the surface of the earth

Therefore, fresh water not only makes up a small quantity of the total, it is not immediately usable by man in its entirety and often is lacking in dry tropical countries where there is a higher percentage of evaporation and precipitation is very rare. This combination of factors, put these regions continuously at risk of a water deficit.

We have already discussed

the importance of fresh water for human health (as the primary natural source of potable water based on its low salinity) and the potential risk of depletion if not protected from pollution and waste.

The primary natural sources of fresh water where extraction is generically authorized for the supply of potable water are both surface and underground waters but, on a practical level, the following requirements apply:

- the preferred source is aquifers since underground water is usually purer because it has less human impact. Extraction is usually through man-made wells for pumping water from the subsurface;
- from surface waters after suitable treatments based on the source location;
- from bodies of water that have been previously evaluated to have a sufficient flow to satisfy the needs of an adequate number of people and not subject to the risk of depletion.

It is possible, however, to also extract potable water from sources that are not suitable by nature, like salt water from both the sea and surface or subterranean brackish waters.

In each of these cases, however, the water cannot be simply intended for human consumption but must be subjected to specific analysis and treatments.

2.B QUALITY PARAMETERS FOR WATER INTENDED FOR HUMAN CONSUMPTION

Potable water (intended to satisfy thirst) falls under the classification of "water intended for human consumption", a category that also includes those used for food production and those useful for other types of domestic use. These types of water, all absolutely judged as being suitable for consumption, are supplied to houses through the distribution network (aqueducts) or in bottles or containers.

Potable waters must first be "wholesome" and "clean" in order to ensure the greatest possible safety to human health.
It must also meet special characteristics as follows:

- on the physical level it must be odourless, tasteless, and colourless with an extremely low level of turbidity;
- on the microbiological level it must not contain micro-organisms that are pathogenic and harmful to humans;
- on the chemical level, it must have components kept within the recommended standards.

To judge the suitability of the purification of the water, an initial evaluation of the water bodies must be performed in order to determine the necessary treatment procedures based on the chemical and physical composition of the samples (an evaluation that is basically the starting point of the management plan, as discussed in the previous chapter).
The sampling methods and parameters for judging the results of the analysis are defined in the appendix to this chapter.

From the analysis results, the waters can be divided into three **categories** in numerical order based on the quality. The lowest category (A3) can only be used if there are no other valid alternatives. For each of these, various treatment types are required that we will cover briefly.

1. For **fresh water** from the surface:
   - Category A1: simple physical treatment and disinfection;
   - Category A2: normal physical and chemical treatment and disinfection;
   - Category A3: extreme physical and chemical treatment, refining and disinfection.

2. For **underground waters** a similar classification is not necessary since they are better protected from pollutants being filtered by the ground. It is, however, recommended to perform analyses to prevent any damage to human health created by pollution due to the discharge of harmful substances, especially if found in industrialized areas.

2.C PURIFICATION TECHNIQUES

The primary water treatment techniques for purification can be classified in three specific methodologies:

- chemical methods: that use a chemical element as a reagent, with the ability to sterilize;
- physical methods: that use the action of natural elements;
- mechanical methods: that purify the water through passage through a filter.

The purpose of all of these methods is to eliminate pollutants and pathogens, that is, those bacteria harmful to human health. Potable water, however, is not completely without micro-organisms, which is typical of sterilized water.
To obtain potable water, the chemical method is usually combined with the physical one, performed in that order and followed by a disinfection treatment.

The following are the primary purification techniques in the order performed:

A) FILTRATION

This expressly mechanical method calls for water to be filtered through various materials, even in combination, at high pressure and speed. The pressure, type and quantity of filtering material

are determined by the material to be filtered, which calls for a diversified treatment based on the water to be treated.
Usually, the mechanism used by an automatic plant calls for the water to be purified of contaminating material by passing it through various layers of filter, leaving the residue on the filtering unit. This waste material that accumulates gradually is then eliminated during a backwashing operation in which water is allowed to run (in the other direction from the filtered water) to remove the waste material. Everything is regulated by internal valves and pipes programmed to automatically respond to these activities or manually activated.

Figure 2: automatic pressure filtration plant

The following are the primary types of plants:

- for the filtration of solids: a layer of 80/100 cm of gravel or quartz sand of various granulometry, with a possible layer of anthracite (particularly suitable for waste waters);
- for the elimination of iron and manganese: also a layer of gravel and sand, but mixed with manganese dioxide;
- for the elimination of chlorine and organic compounds: between 80 and 200 cm of active carbon, of vegetable or mineral origin, which has a good adsorption capacity under certain temperature and pressure conditions;
- for the neutralization of contaminated waters: layers of slaked dolomite (between 80 and 100 cm).

Also, right before starting the purification cycle, at the sampling site for surface waters, sand collecting filters can be used which perform a preliminary separation of the sands and solid elements form the water to protect the pipes from residues and incrustations.
For an even better elimination of solids, sand, and other external elements, the same type of sand collecting filters (although smaller in size) can be hooked up to the domestic lines. They can be semi-automatic or completely automatic (and so suitable to perform the filter backwashing independently) and are able to catch very fine residues since the filter has holes from 100 to 50 μm.

Figure 3: Sand collecting filters

B) DISINFECTION OR BACTERIAL REMOVAL

This technique is the most used also because it is required for all three categories (A1, A2, and A3) of surface waters to be used for potable. It is mainly performed using:

- chlorine (specifically sodium hypochlorite, as indicated in European standards), chemical method;
- ozone, chemical method;
- ultraviolet rays, physical method.

Elements promoting the use of **chlorine (sodium hypochlorite)**, which is the most widespread method, are the low cost and relative ease of use as well as the wide applicability to various types of waters. The use of chlorine has disadvantages that significantly alter the taste of the water and during treatment lead to the creation of derivative compounds that are harmful to human health like trihalomethanes (THM) and halogenated acetic acids (HAA). For the dosage of sodium hypochlorite, systems with a storage tank and a metering pump are used, which are also possibly adjustable according to the flow of water present in the treatment. Also, for this type of chlorinator there is also a system that works in complete energy autonomy, **the gravity doser** that provides its own energy supply by exploiting the force of gravity acting on the water, which is channelled from a storage tank placed on a higher level to a dosing device placed at a lower level. The flow rate can be adjusted

using a capillary. For more information on this type of independent supply system, refer to the chapter on emergency systems.

As an alternative, **chlorine dioxide** can be used, which significantly reduces the formation of those compounds and is thus a more secure method for human health compared to sodium hypochlorite. The use method, however, offers various problems, because it is very unstable and difficult to handle before placing in water, so instant mixing is also necessary on site.

To check the amount of disinfectant chlorine in the water to be supplied to consumers, an effective check can be performed on the percentages present in purified water using equipment called residual chlorine meters by setting them before the water is fed into the distribution network. They are regulated based on the chlorine values that must not be exceeded, whenever they detect a quantity that is greater than planned, they can automatically block distribution in order to be able to correct it immediately. The use of these

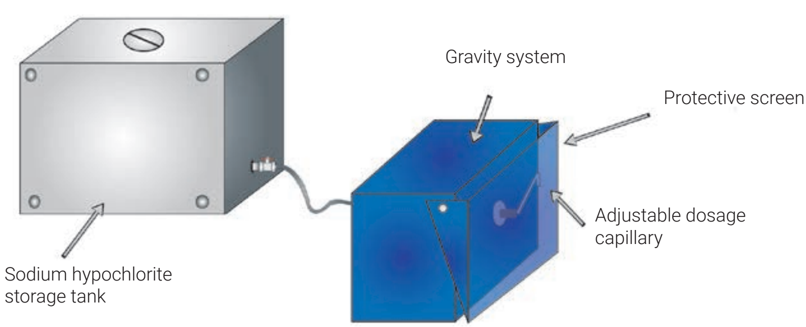


Figure 4: Gravity dosing system

affordable installations allows good water quality even if it comes from unsophisticated disinfection processes.

The use of **ozone**, on the other hand, allows the oxidation of various elements, especially those that are organic in nature, which are reduced to hydrates through the reaction and then eliminated using other techniques (also physical methods). Ozone has a high disinfectant power, even greater than chlorine, but it does not change the taste of the treated water. Plant management costs, however, are rather high since the raw material itself (ozone) has a high purchase or possibly production cost.

The use of **ultraviolet rays** is a particularly advantageous treatment because it does not require the addition of chemical products, does not alter the characteristics of the water and there is no risk of overdosing, all at a relatively low cost.
The method calls for the water to pass through tanks subjected to **ultraviolet radiation** (produced by a germicidal lamp), able to destroy the reproductive capacity of the bacterial elements present in the water itself. Of all the methods it is the safest and most preferable, though still less common.

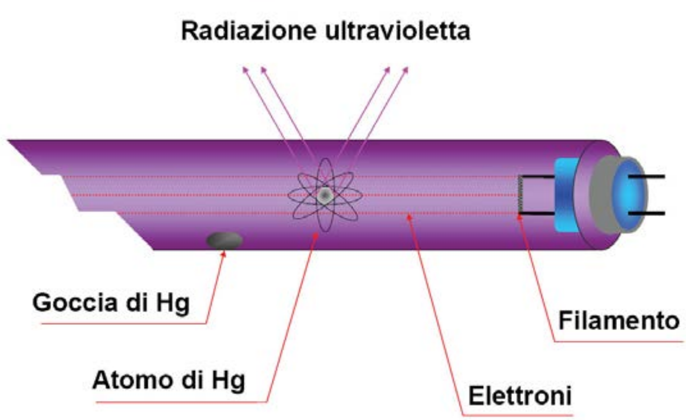


Figura 5: UV Sterilizer

C) CLARIFLOCCULATION

Such processing is a widely applied chemical-physical process because it allows the elimination of colloidal elements (i.e. not separable physically) through the use of coagulant chemical elements and the consequent and subsequent sedimentation. Such a technique is employed to facilitate the sedimentation of electrically stable elements.

In this manner, it is one of the main methods to remove the turbidity of the water.

The procedure calls for two phases:

- coagulation: coagulants (aluminium, iron, and calcium salts) are added to the water that based on their electrical charges destabilize the colloidal elements making the first compounds that are not yet large enough to be filtered;
- flocculation: through flocculants (to which electrolytes can be added) the coagulation of previously formed compounds and subsequent sedimentation are facilitated.

At the end of the procedure, the elimination of the residual elements occurs through filtration.

Figure 6: Clariflocculation plant with final filtration

D) MEMBRANE FILTRATION AND INVERSE OSMOSIS

When very small particles must be eliminated a special type of filtration is performed using a semi-permeable membrane, often of synthetic material. When talking of this type of purification we are talking about **microfiltration**.

This process is not purely mechanical like the previous ones but uses the porosity of polymeric membranes to only pass some elements beyond the filter while managing to retain others that are very small in size. Through microfiltration, in fact, we manage to retain particles of about 0.05 and 10 μm in diameter.

Ultrafiltration, on the other hand, is the filtration process that occurs through a porous membrane but that has even smaller holes capable of retaining elements between 0.05 and 0.01 μm. Ultrafiltration is used for both purification (and sterilization) of surface waters and for purifying wastewater and can be used to replace the clariflocculation-disinfection sequence, allowing significant energy and economic savings.
Compared to microfiltration, offers greater effectiveness in removing bacteria and viruses, while still retaining the necessary elements for human consumption.

Purification with **nanofiltration** is even more accurate.
The technique offers the ability to retain particles of a diameter between 0.01 and almost 0.001μm.

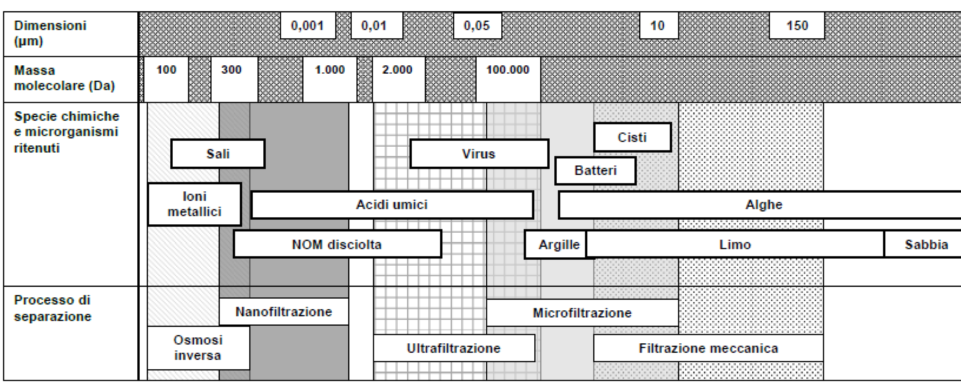
Reverse osmosis is a process that allows the removal of salts, microorganisms, and pollutants from the water through a semi-permeable membrane made of synthetic material.

The purification mechanism uses the osmotic procedure (passage of solvent between two communicating liquids, from the one with a lower concentration to those of greater concentration), but is defined as "reverse" because it goes in the other direction compared to the natural process. This is possible because a difference of pressure that is greater than and contrary to the natural one is applied to the liquid separation membrane.

The process of reverse osmosis is used to remove the salt from sea water and brackish water since it allows for the elimination of salt ions. Since the membrane holes are very small, this treatment cannot be used without having carried out a previous filtration step to remove residue of considerable size. For this reason in fact, reverse osmosis must be used on already treated water, in order not to jeopardize the condition of the membranes with blockages of solid parts and consistent substances.

Figure 7: Reverse osmosis plant

The following illustrative table of the membrane filtrations and mechanical filtration that were previously analysed summarizes the various degrees of filtration.



2.D APPLICATION OF PURIFICATION TECHNIQUES

The various purification techniques illustrated above can be combined together to obtain water that falls within the parameters of potability but in any case the process required depends on the characteristics of the water body from which it is extracted. In this regard, below is a classification of water sources with their treatments recommended in response to the most common problems.

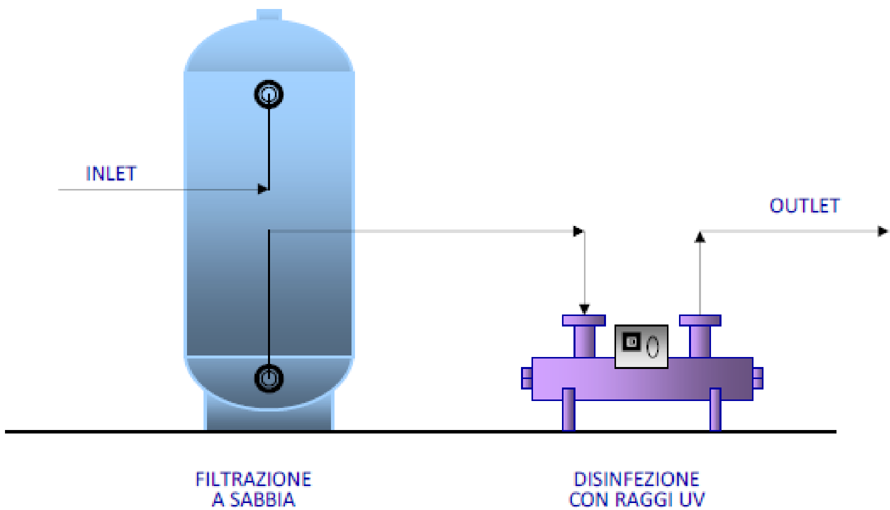
Starting from groundwater, which we said is preferable due to its greater degree of purity, we can identify:

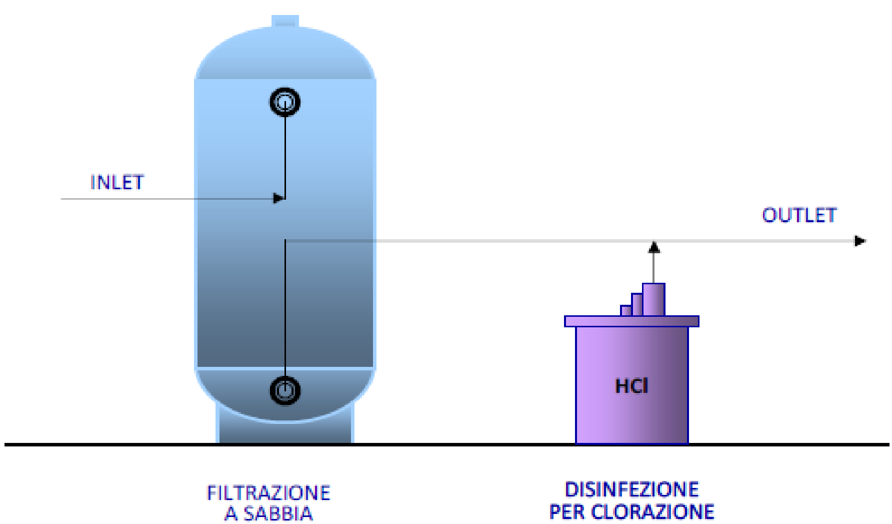
- **spring waters**: present in mountain areas and naturally springing from the ground, they are generally already pure by nature and possibly only require a disinfection treatment;
- **groundwater**: theoretically they should be as pure but frequently are seriously contaminated by industrial and agricultural waste, especially groundwater that is not very deep. After appropriate analysis, action is taken in relation to the concentration of certain elements (that may be damaging for man, regardless of whether they are natural or man-made). Special attention must be paid to bacterial pollution of faecal origin which leads to the presence of the Escherichia Coli bacteria and to chemical pollution of agricultural origin that has concentrations of nitrates.

In both cases a cycle of disinfection is performed whether it is considered sufficient for potability or if it is performed as a preliminary treatment to an entire purification process.

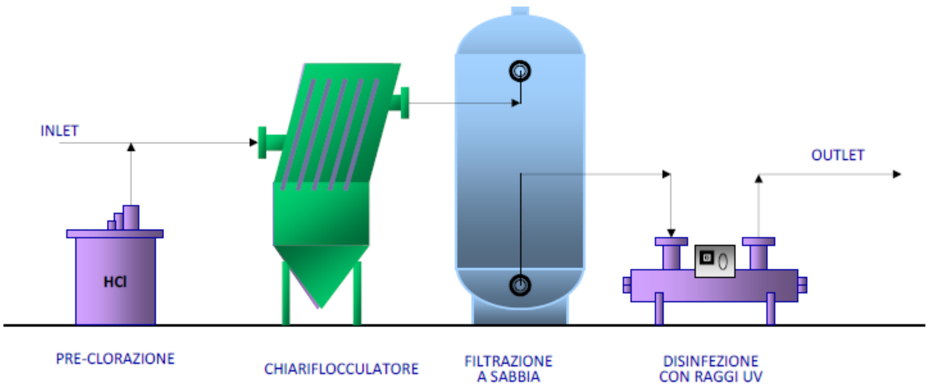
For surface water sources, the classifications of water are given based on the quality condition, also providing the specific treatments recommended in order of performance:

category A1 = filtration + disinfection;

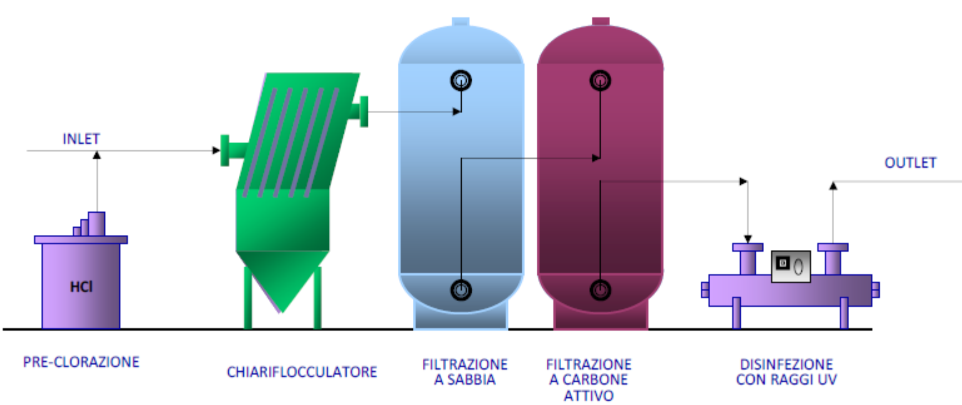




category A2 = pre-chloration + clariflocculation + filtration + disinfection.



category A3 = pre-chloration + clariflocculation + filtration + filtration with active carbons + disinfection.



In this case the purification process is much more articulated and complex because it depends on the various pollutants present in the water body from its origin.
Therefore, we provide the primary pollutants and related problems that are encountered in surface waters:

- natural pollutants (suspended solids, organic substances, sand) that cause high turbidity, due to week exchange of water (especially in lake water);
- bacterial pollutants;
- organic pollutants;
- finally, further pollutants due to the same purification process.

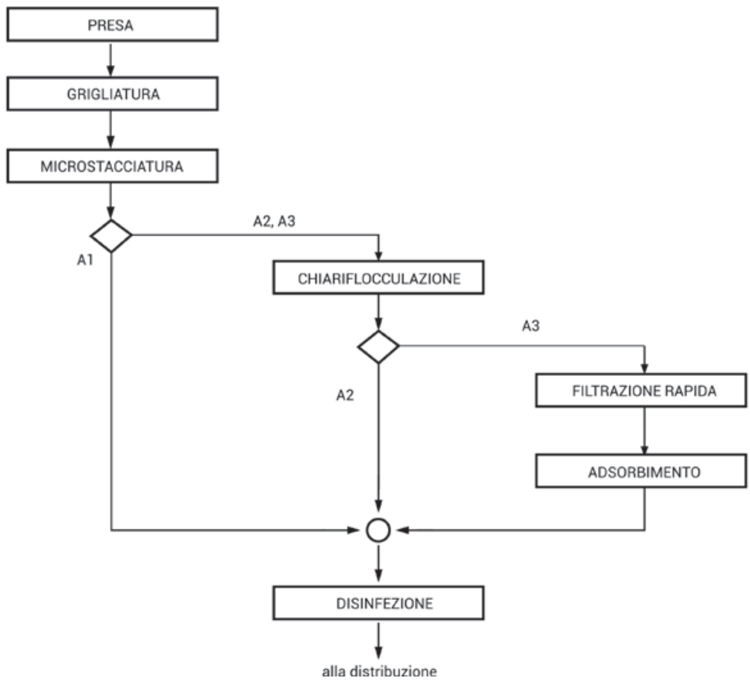
Based on these considerations and especially in compliance with the water quality categories, the purification treatment calls for an initial disinfection phase. Following this, we must proceed point by point to remove every class of pollutants.
Water turbidity comes from clay and muddy substances that, since they are in constant movement (due to their electrostatic charge), cannot aggregate and be easily removed. For this reason, it is necessary to use a chemical-physical treatment aimed at the destabilization of the particles of various types of clay through the use of coagulants, in order to create consistent, solid aggregates that are then filtered (clariflocculation).

The procedure is carried out in two phases:

- decantation in tanks, where the heavier particles to settle to the bottom;
- flocculation through coagulants that thicken the substances. At the end of this phase, the sediment material is filtered out. A further filtration phase can be carried out with active carbon to eliminate organic compounds or chlorine.

At the end of purification, a further disinfection phase is needed (using chlorine or ozone depending upon the considerations mentioned) to counteract the effect of possible proliferation of bacteria inside the filters.

For illustrative purposes, we have provided a graph that shows the succession of the treatments based on the categories.



In addition, we must keep in mind that a considerable presence of calcium and magnesium in the water (already suitable for human consumption) does not compromise potability but causes incrustations in the distribution pipes. To overcome this problem, we resort to water softeners (automatic), which replace the calcium salts and magnesium salts with soluble sodium salts, exploiting the passage of water through synthetic resins. In any case, to maintain a good balance of components (and therefore not the total elimination of calcium and magnesium), not all the water is treated this way but a smaller part (30%) of non-softened water is mixed with the water passed through the softener.

Figure 8: Water softening plant

While respecting the stages of purification according to the quality category, the selection of individual treatments depends significantly on the **quality of the source** from which it is extracted, but other variables should also be considered in the plan such as:

- plant startup and management costs;
- the preliminary and subsequent treatments needed for purification;
- the availability (in quantitative terms) of the chosen resource;
- the waste products obtained.

Therefore, in conclusion, we schematically list the primary methods of purification (covered in the previous paragraph) with related advantages and disadvantages as shown in the following table: Remember that the trends in recent years is toward a switch from chemical to mechanical methods or chemical methods that do not lead to a risk to human health.

TREATMENT	ADVANTAGES	DISADVANTAGES
Sand filtration	Ideal as the first step to remove solids of significant volume.	Purification degree not sufficiently accurate for purification.
Active carbon filtration	High power of adsorption, particularly suitable for the removal of organic elements and chlorine.	High management costs; continued need for controls to ensure the adsorbing capacity of the filters, which tends to be depleted in a short time.
Disinfection: sodium hypochlorite	Economical and easy to use, good disinfecting power. Performance further benefits if equipped with residual chlorine meters.	Flavour alteration, production of derivative compounds that are harmful to humans.
Disinfection: chlorine dioxide	Good disinfectant power, does not involve the production of derivative elements that are harmful to humans in significant quantities.	Difficult to use and manage due to the instability of the element. Overall costs are high.

Disinfection: ozone	Excellent disinfectant power, no alteration in water flavour, no contraindication for human health due to derivative products.	High cost of plant startup and management, high cost of disinfectant material (ozone is very expensive as a raw material and when produced directly). Need to produce disinfectant on site.
Disinfection: UV rays	Good disinfecting power that is effective on the total elimination of the reproductive capacity of the bacteria; no contraindication for flavour and human health. No type of chemical element is required.	Low costs, but the material quickly lose functionality (lamps). Preliminary water filtration is required. Does not protect from subsequent contamination.
Clariflocculation	Ideal for eliminating water turbidity, especially indicated for surface waters. Allows intervention on very fine elements in a short amount of time with subsequent economical savings.	Requires a further final disinfection treatment. Heavy use of chemical agents.
Microfiltration	Effective in the elimination of very fine material and bacteria and viruses.	A preliminary treatment is needed, not suitable for filtering large solids.
Ultrafiltration	Replaces clariflocculation-disinfection treatments, high purification power since it can eliminate bacteria and viruses as well as colloids.	A preliminary treatment is needed, not suitable for filtering large solids.
Reverse osmosis	Suitable for desalination, method without chemical agents.	Filtration pre-treatment needed. Requires a further disinfection treatment. A generalized use of the treatment to produce potable water requires a lot of energy (and is therefore expensive).

APPENDIX TO CHAPTER 2

II.I SUITABILITY PARAMETERS FOR POTABLE WATER

In order for a source to be judged suitable for the extraction of potable water, the waters of the resource must be able to meet certain recommended parameters. Specific analyses are performed based on the elements to be measured as shown in the following table, which groups the characteristics and various chemical elements into three categories:

GROUP I PARAMETERS	pH, colour, total materials in suspension, temperature, conductivity, odour, nitrates, chlorides, phosphates, COD, OD (dissolved oxygen), BOD5, ammonia.
GROUP II PARAMETERS	dissolved iron, manganese, copper, zinc, sulphates, surfactants, phenols, nitrogen, Kjeldahl, total coliforms and faecal coliforms
GROUP III PARAMETERS	fluorides, boron, arsenic, cadmium, total chromium, lead, selenium, mercury, barium, cyanide, dissolved or emulsified hydrocarbons, polycyclic aromatic hydrocarbons, total pesticides, substances extractable with chloroform, faecal streptococci, and Salmonella

In response to the values set for each of these parameters three categories are defined precisely (A1, A2, A3), which indicate that in general the necessary purification treatments (as already mentioned in chapter 2), are valid especially for surface water. For completeness we include the complete purification treatments according to the assigned category:

- *Category A1: simple physical treatment and disinfection;*
- *Category A2: normal physical and chemical treatment and disinfection;*
- *Category A3: extreme physical and chemical treatment, refinement and disinfection.*

We will now show the values for each chemical element and the corresponding limits assigned to each category. These values are the guidelines in force in the member countries in the European Union but we highlight that each member state can also have more restrictive values to determine water quality:

m.	PARAMETERS	Unit of measure	A1 G	A1 I	A2 G	A2 I	A3 G	A3 I
1	pH	pH unit	6,5-8,5	-	5,5-9,9	-	5,5-9,9	-
2	Colour (after simple filtration)	mg/L pt scale	10	20	50	100	50	200
3	Total material in suspension	mg/L MES	25	-	-	-	-	-
4	Temperature	°C	22	25	22	25	22	25
5	Conductivity	μS /cm at 20°	1000	-	1000	-	1000	-
6	Odour	Dilution factor at 25°C	3	-	10	-	20	-
7	Nitrates	mg/L NO3	25	50	-	50	-	50
8	Fluorides	mg/L F	0,7/1	1,5	0,7/1,7	-	0,7/1,7	-
9	Total extractable organic chlorine	mg/L C1	-	-	-	-	-	-
10	Dissolved iron	mg/L Fe	0,1	0,3	1	2	1	-
11	Manganese	mg/L Mn	0,05	-	0,1	-	1	-
12	Copper	mg/L Cu	0,02	0,05	0,05	-	1	-
13	Zinc	mg/L Zn	0,5	2	1	5	1	5
14	Boron	mg/L B	1	-	1	-	1	-
15	Berillium	mg/L Be	-	-	-	-	-	-
16	Cobalt	mg/L Co	-	-	-	-	-	-
17	Nickel	mg/L Ni	-	-	-	-	-	-
18	Vanadium	mg/L V	-	-	-	-	-	-
19	Arsenic	mg/L As	0,01	0,05	-	0,05	0,05	1
20	Cadmium	mg/L Cd	0,001	0,005	0,001	0,005	0,001	0,005
21	Total Chrome	mg/L Cd	-	0,05	-	0,05	-	0,05
22	Lead	mg/L Pb	-	0,05	-	0,05	-	0,05
23	Selenium	mg/L Se	-	0,01	-	0,01	-	0,01
24	Mercury	mg/L Hg	0,0005	0,001	0,0005	0,001	0,0005	0,001
25	Barium	mg/L Ba	-	0,1	-	1	-	1
26	Cyanide	mg/L CN	-	0,05	-	0,05	-	0,05

m.	PARAMETERS	Unit of measure	A1 G	A1 I	A2 G	A2 I	A3 G	A3 I
27	Sulphates	mg/L SO4	150	250	150	250	150	250
28	Chlorides	mg/L C1	200	-	200	-	200	-
29	Surfactants (reacting with methylene blue)	mg/L (lauryl sulphate)	0,2	-	0,2	-	0,5	-
30	Phosphates	mg/L P205	0,4	-	0,7	-	0,7	-
31	Phenols	mg/L C6H5OH	-	0,001	0,001	0,005	0,01	0,1
32	Dissolved or emulsified hydro-carbons (after extraction by petro-leum ether)	mg/L	-	0,05	-	0,2	0,5	1
33	Polycyclic aroma-tic hydrocarbons	mg/L	-	0,0002	-	0,0002	-	0,001
34	Total pesticides (parathion HCH, dieldrine)	mg/L	-	0,001	-	0,0025	-	0,005
35	Chemical oxygen demand (COD)	mg/L O2	-	-	-	-	30	-
36	Saturation rate of dissolved oxygen	% O2	>70	-	>50	-	>30	-
37	At 20°C without biochemical oxy-gen demand nitrifi-cation (BOD 5)	mg/L O2	<3	-	<5	-	<7	-
38	Kjeldahl nitrogen (except NO2 and NO3)	mg/L N	1	-	2	-	3	-
39	Ammonia	mg/L NH4	0,05	-	1	1,5	2	4
40	Chloroform ex-tractables	mg/L SEC	0,1	-	0,2	-	0,5	-
41	Total organic carbon	mg/L C	-	-	-	-	-	-
42	Residual organic carbon (after flocculation and filtration on 5µ membrane) TOC	mg/L C	-	-	-	-	-	-
43	Total coliforms	/100 mL	50	-	5000	-	50000	-
44	Faecal coliforms	/100 mL	20	-	2000	-	20000	-
45	Faecal streptococci	/100 mL	20	-	1000	-	10000	-

m.	PARAMETERS	Unit of measure	A1 G	A1 I	A2 G	A2 I	A3 G	A3 I
46	Salmonella	-	absence in 5000 mL	-	absence in 1000 mL	-	-	-

Legend:
Category A1 - Simple physical treatment and disinfection;
Category A2 - normal physical and chemical treatment and disinfection;
Category A3 - extreme physical and chemical treatment, refinement and disinfection.

I = Imperative value
G = guideline value

II.II REQUIREMENTS FOR THE DEFINITION OF POTABLE WATER

Once the quality of the source has been defined, the primary requirements for the definition of **potable water** are those shown in the following tables. To determine suitability, these value thresholds must not be exceeded:

- microbiological parameters:

PARAMETER	PARAMETER VALUE (number/100 ml)
ESCHERICHIA COLI	0
ENTEROCOCCHI	0

The parameters required for water offered for sale **in bottles or containers** are also included:

PARAMETER	PARAMETER VALUE
ESCHERICHIA COLI	0/250 ml
ENTEROCOCCHI	0/250 ml
PSEUDOMONAS AERUGINOSA	0/250 ml
COLONY COUNT AT 22°C	100/ml
COLONY COUNT AT 37°C	20/ml

– parametri chimici:

PARAMETER	PARAMETER VALUE	UNIT OF MEASURE
ACRYLAMIDE	0,10	µg/l
ANTIMONY	5,0	µg/l
ARSENIC	10	µg/l
BENZENE	1,0	µg/l
BENZO[A]PYRENE	0,010	µg/l
BORON	1,0	µg/l
BROMATE	10	µg/l
CADMIUM	5,0	µg/l
CHROME	50	µg/l
COPPER	10	mg/l
CYANIDE	50	µg/l
1.2 DICHLOROETHANE	3,0	µg/l
EPICHLOROHYDRIN	0,10	µg/l
FLUORIDE	1,50	mg/l
LEAD	10	µg/l
MERCURY	1,0	µg/l
NICKEL	20	µg/l
NITRATE (SUCH AS NO3)	50	mg/l
NITRITE (SUCH AS NO2)	0,50	mg/l
PESTICIDES	0,10	µg/l
PESTICIDES - TOTALS	0,50	µg/l
POLYCYCLIC AROMATIC HYDROCARBONS	0,10	µg/l
SELENIUM	10	µg/l
TETRACHLOROETHYLENE TRICHLORETHYLENE	10	µg/l
TRIHALOMETHANES - TOTAL	30	µg/l
VINYL CHLORIDE	0,5	µg/l
CHLORITE	200	µg/l
VANADIUM	50	µg/l

II.III FRESHWATER SAMPLING AND ANALYSIS METHODS

Samples are taken from lakes and fresh water courses (natural or artificial) through stations located in strategic points so that they can represent the overall condition of the water.

It is of the utmost importance to be particularly careful to avoid altering the samples during their procurement, storage and transport, as each small change can have a significant effect on the analysis.

Therefore:

- the containers must be absolutely sterile;
- the bottles for sampling must be sufficient for the analysis of all microbiological parameters;
- the analyses must be done within 24 hours of sampling;
- samples must be transported using refrigerated trucks to keep them at a low temperature between 4°C - 10°C and out of direct sunlight.

CHAPTER 3

WASTEWATER

Social, production, and recreational activities primarily in the urban area require and use a large amount of water.

The direct consequence of water use is the alteration of its properties and the inevitable production of discharges that, in order to be returned to the environment must be subjected to a purification treatment. The sea, rivers, and lakes are not able to receive an amount of pollutants greater than its self-purification capacity without compromising the quality of its waters and the normal balance of the eco-system.

It is obvious therefore that the need to purify wastewater through treatment systems that imitate the biological processes that occur naturally in bodies of water (though purification is quicker in plants than in water courses thanks to the technology and energy used). Wastewater treatment is therefore more extreme as more bodies of water (seas, rivers, lakes, etc.) are at risk of permanent pollution.

3.A CLASSIFICATION AND DERIVATION OF WASTEWATER

Wastewater is mainly classified according to its origin, which is the place and method in which they were used before their discharge. The primary origins are civil and industrial use.

Waters for civil use include:

- **domestic wastewater**: wastewater from residential communities and services and primarily from human metabolism and domestic activities;
- **wastewater treated as domestic**: wastewater with qualitative characteristics that are equal to domestic ones. These values are expressed in Table 1 in the Appendix.

Water for industrial use refers to wastewater from buildings or installations where a trade or production of goods is carried out and is qualitatively different from domestic wastewater and runoff.

The appendix also contains the definition of runoff water and urban wastewater that complete the picture on the classification of wastewater.

3.B POSSIBLE DISCHARGE POINTS

For the classification of wastewater reception bodies, we distinguish three primary discharge points:

- surface waters, or those present on the earth's surface such as road ditches, hollows and canals, streams, artificial water bodies, rivers, lakes, and the sea;
- the ground or the surface layers of the subsoil: that is, the surface of the earth that is uncultivated, agricultural or urban;
- sewer system: the sewage networks serving the conglomerations.

Special attention must be paid to discharges near areas that are defined as sensitive, where the quality of water from natural sources may be compromised. A water system that can be classified in one of the following groups is considered a sensitive area:

a) natural lakes and other fresh waters, estuaries, and waters which are eutrophic;

b) fresh surface waters intended for the production of potable water;

c) areas that, due to discharges, require additional treatment to the secondary treatment.

To identify which nutrient should be reduced through further treatment, the following elements should be considered:

a) in lakes and water courses that flow into lakes/basins/closed bays with limited water exchange and were accumulation of nutrient substances such as **nitrogen** and **phosphorous** can occur which gives rise to the production of algae and aquatic plants with a subsequent decrease in oxygen dissolved in the basin and introduces an anaerobic regime that leads to the destruction of every vital organism;

b) in estuaries, bays, and other coastal waters with poor water exchange or in which large quantities of nutrients flow if, on one hand, discharges from small urban conglomerates are generally of irrelevant importance, on the other hand those from larger conglomerates make elimination interventions necessary.

3.C EMISSION LIMITS

- **Discharges into surface water bodies**

All discharges into surface water bodies must be resolved on the basis of respect for the quality objectives of the receivers, therefore it is recommended to follow the emission limit values given in Table 2 in the Appendix.

If water is taken from surface water bodies, it must be returned with quality characteristics that are not worse than those taken.

- **Discharges on the soil and in the subsoil**

The values in Table 3 in the appendix indicate the limit parameters that it would be proper to follow in the event of discharges on the ground, only authorized in situations where it is impractical to discharge into a body of water.

Discharge of dangerous and pollutant substances into the soil and subsoil is prohibited (organophosphorus compounds, mercury and mercury compounds, cyanides, etc.).

- **Discharges in the sewer system**

The discharge into the sewer system is performed according to the type of treatment that is performed downstream of it, respecting the values reported in Table 2 in the Appendix.

The discharges must be made accessible for sampling to allow checks in the measurement point. The measurement of the discharge is intended to be carried out immediately upstream of the point of entry for all surface waters and groundwater, inland waters and marine waters, as well as in sewers, soil and subsoil.

3.D SEWER SYSTEMS

We can identify three types of sewer systems according to the type of discharge water collected:

- **mixed sewer systems:** systems intended for the collection and discharge into a final receiver of domestic and/or industrial wastewater in combination with water deriving from the weather;
- **black sewer systems:** systems intended for the collection and discharge into a final receiver of only domestic and/or industrial wastewater;
- **white sewer systems:** systems intended for the collection and discharge into a final receiver of only water deriving from the weather;

The planning, construction, and maintenance of sewer systems are performed by adopting the best techniques available and that involve economically allowable costs, taking into account, in particular:

- the average flow rate, annual volume and the characteristics of the urban wastewater;
- prevention of any resurgence phenomenon that involves the leaking of wastewater from the sewer sections;
- the pollution limitation of the receivers caused by overflows due to particular weather events.

Remember that the flow and average annual volume are calculated in relation to the population served therefore, for proper planning of a sewer system, distinctions must be made according to the various conglomeration situations, i.e. isolated settlement, small conglomeration, and consistent urban conglomeration.

3.E TREATMENT TECHNIQUES

For purification of municipal wastewater, treatment plants are chosen to be arranged in order to minimize effects on the receiving body.

The appropriate treatments should be identified with the objective being to:

- simplify maintenance and management;
- be able to adequately support great hourly variations of the water and organic load;
- minimize management costs.

Three types of treatment can be distinguished: primary, secondary, and tertiary, according to the technical solution adopted and purification results to be reached (see Appendix).

PRIMARY TREATMENT

Treatment of wastewater through a physical or chemical process that involves the sedimentation of suspended solids and, following which the BOD5 of the arriving wastewater is reduced by at least 20% before discharge and the total suspended solids in the arriving wastewater are reduced by at least 50%.

The primary treatments are:

- **screening;**
- **desanding;**
- **deoiling;**
- **primary sedimentation.**

a) SCREENING

Preliminary treatment separating of the more or less large solids from the slurry. The material captured by the grill must be periodically removed. Screening may also be modulated in two subsequent phases and, that is, in a large screening to capture larger bodies and fine screening to capture smaller parts. Large screening is usually performed with steel bars 4-6 cm apart while fine screening is performed with steel bars with free spaces of 0.2-0.5 cm up to a maximum of 1-2 cm.

Figure 1: Screening plant

b) DESANDING

Preliminary treatment that consists of the removal of sands and inert solids, normally heavier and coarser than organics, which would create problems such as wear of the mechanical parts or the accumulation of inerts in the subsequent sections of the plant.
The desanders can be of two classes: the first is made up of plants in which separation occurs only by gravity (channel desanders) and the second in which water is separated from the sand with the help of air blowers (aerated desanders).

c) DEOILING

Treatment of wastewater containing a high level of greasy and oily substances such as waste water from kitchens (both household and public) and other sources (sinks, bidets, showers), except for toilets.
The removal of these substances occurs through a calm-water tank equipped

with two semi-submerged separators that create three chambers: Grease chamber, where the removed grease is collected, the Separation Chamber where the water-oil separation occurs, and the Sludge chamber where the decanted substances are collected.

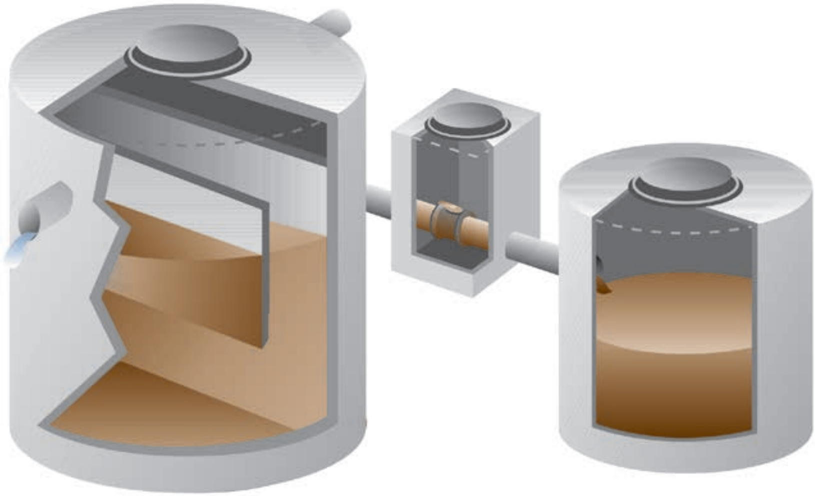


Figure 2: Deoiling plant with oil collection tank

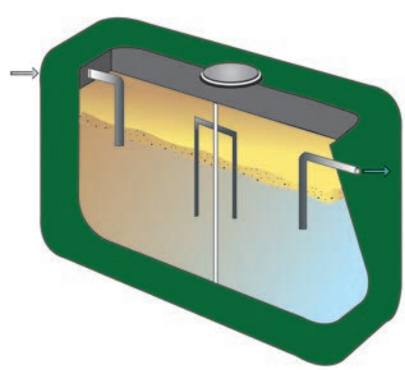
d) PRIMARY SEDIMENTATION

The treatment consists of the gravity separation of the suspended non colloidal solids from the slurry mass. In domestic slurry, 95% of the settleable substances decant in almost 2 hours and lead to a reduction of the pollutant load expressed as BOD5 of 30%.

- **Septic tanks**

  Make up the simplest they can type of primary sedimentation tank flow horizontal, be single chamber, dual chamber or triple chamber according to the number of compartments they can have.

Figure 3: Septic tank



• **Imhoff tanks**

These are tanks made up of two distinct compartments set one above the other. The first is for decantation and the second, lower one, is for sludge digestion. Through a connection, the overlapping compartments allow the decanted sludge to flow out of the sedimentation compartment and into the lower digestion compartment.

The raw slurry enters continuously and slowly flows through the sedimentation compartment towards the drain, allowing the light substances to float and the heavy ones to be deposited at the bottom of the sedimentation tank passing into the digestion chamber through the narrow opening at the base of the sedimentation chamber. The structure of the tanks means that the different processes do not interfere with each other.

Figure 4: Imhoff tank

SECONDARY TREATMENT

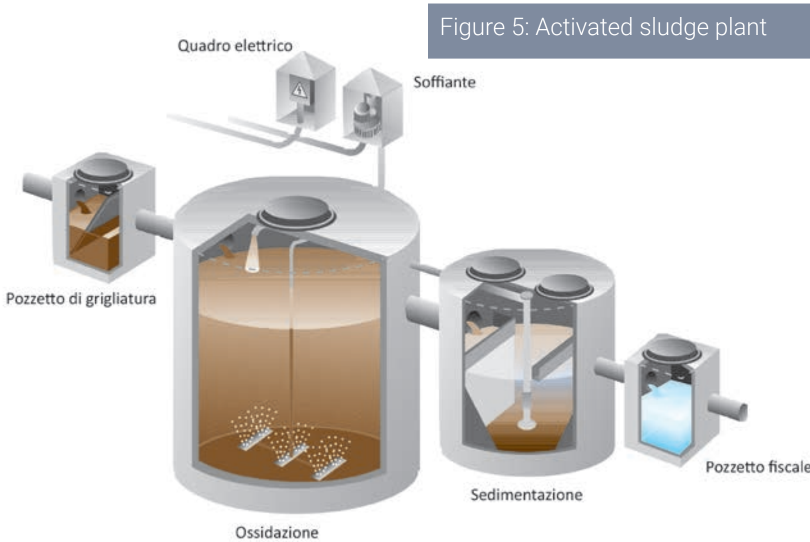
The secondary treatment consists essentially of putting the liquid mass in contact with a certain amount of oxygen to activate the biological process of decomposition of the pollutant organic substance. The emission of oxygen can take place naturally or by mechanical means so there are different types of systems:

- **activated sludge with air injection or surface or submersed aerators;**
- **bacterial bed filled with stone or plastic;**
- **biodiscs;**
- **phytotreatment.**

a) ACTIVATED SLUDGE PLANT

In this type of plant the biological agent is in the form of flake (activated sludge) in free suspension in the liquid mass. The air is injected artificially through blowers or aerators positions at the bottom of the tank. At the end of the oxidation process the sludge moves on to final sedimentation where the sludge flakes are separated from the sludge and in recycled parts upstream to take advantage of the biological activity on the newly arriving sludge. When the concentration of the sludge in the oxidation tank increases significantly part of the sludge is removed as surplus sludge.

Figure 5: Activated sludge plant



For small plants up to 100-400 equivalent inhabitants the **total oxidation** system is used which has the advantage of unifying in a single process and thus a single product, the treatment of the slurry and sludge. This system requires greater quantities of oxygen and longer exposure times to air and therefore with larger tanks and greater energy consumption.

Activated sludge plants, according to the values that are assigned to the characteristic parameters of the system (sludge load, volumetric load, oxygen request factor, aeration time) can be defined as follows:

- activated sludge plants with total oxidation with complete sludge stabilization
- activated sludge plants with weak load with partial sludge stabilization
- activated sludge plants with strong load with partial sludge stabilization

b) 1. AEROBIC BACTERIAL BED PLANT

In a bacterial bed, the conditions that regulate the natural phenomenon of self-purification of a water course are created artificially, accelerating them. This is determined by the development of aerobic microorganisms (that live in the presence of oxygen), that use the organic material present in water, transforming it progressively to create the final stable products.
In practice, the trickling filter bed consists of a cylindrical tank filled with inert material or plastic material of various sizes. Here the percolation of slurry takes place. It is clarified in the primary settler, from top to bottom while a current of air runs along the bed, counter-currently from the bottom upwards.

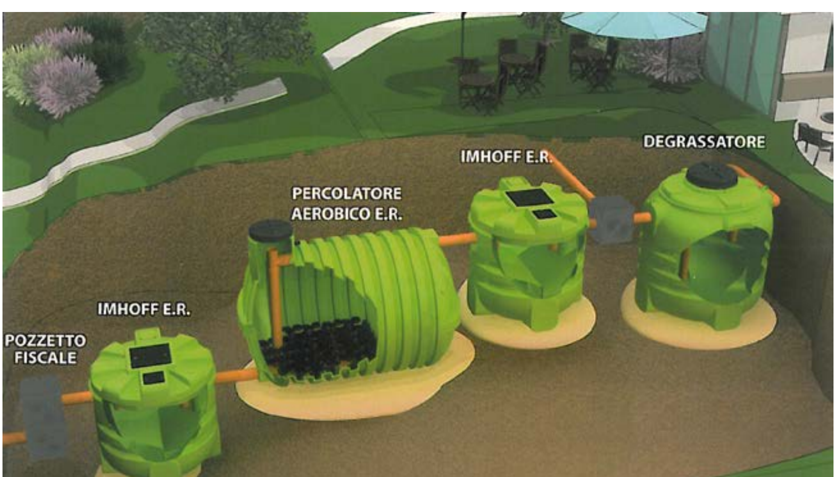


Figure 6: Aerobic bacterial bed plant

The organic substance is fixed on the filling elements and is attacked by the microorganisms, initially aerobic in nature, due to the presence of oxygen in the air, forming a biological film around the element. Thickening, this film loses oxygen and so an anaerobic phase, or the absence of air, takes over. The biological film is detached from the support and in the form of flakes, goes to the drain along with the slurry, where it is decanted in the final sedimentation tank.

b) 2. ANAEROBIC BACTERIAL BED PLANT

Unlike the aerobic bacterial filter, the slurry crosses the filter and is conveyed to the bottom of the filtering mass from where it moves slowly upward towards the overflow. In anoxia conditions, an anaerobic type bacterial flora develops that leads to the deterioration of the organic substance.

Over time the sludge produced settles to the bottom and in the interstices of the filter, inactivating it. It is necessary to remove the filter element and provide for the backwash at least once per year.

Figure 7: Anaerobic bacterial bed plant

c) BIODISC PLANTS

Treatment system made up of a semi-circular transversal basin where the biological disks made up of plastic material are immersed about 40% and located facing each other and pivoted on a horizontal drum set in slow rotation by an electric motor. The slurry coming from the Imhoff tank flows into the basin where the discs are immersed, after the start-up phase on the surface of the disks a biological membrane develops.

The biological film continues to develop until it detaches from the surface of the disk, made easier by the “cutting” action induced by the resistance to advancement of the disk itself in the liquid mixture. The treatment is normally adopted in several successive stages made up of individual groups in parallel, each in a tank portion separated from the next portion by a divider. The purification efficiency increases with the number of stages.

d) PHYTOTREATMENT PLANT

The phytotreatment plants are made up of damp areas artificially reproduced in waterproofed basins crossed with different flows from the properly collected wastewater. These systems are characterized by the presence of typical plant species from damp areas, rooted to a growth substrate or floating on the surface of the water.

In the incoming slurry, the particulate substances and larger parts must be removed as much as possible to avoid clogging (by, for example, an Imhoff tank or degreaser).

The substrate is chosen based on the porosity and hydraulic conductivity that affects the residence time. Uncrushed gravel, washed sand, or other equivalent materials may be used.

A type of vegetation that acts as an “oxygen pump” between the roots must be used as it is very important in submerged flows.

The plants are divided as follows: surface flow plants (SF) and horizontal submersed flow (HF) or vertical submersed flow (VF) plants. The individual types can be used individually or in modules connected in series or in parallel as needed.

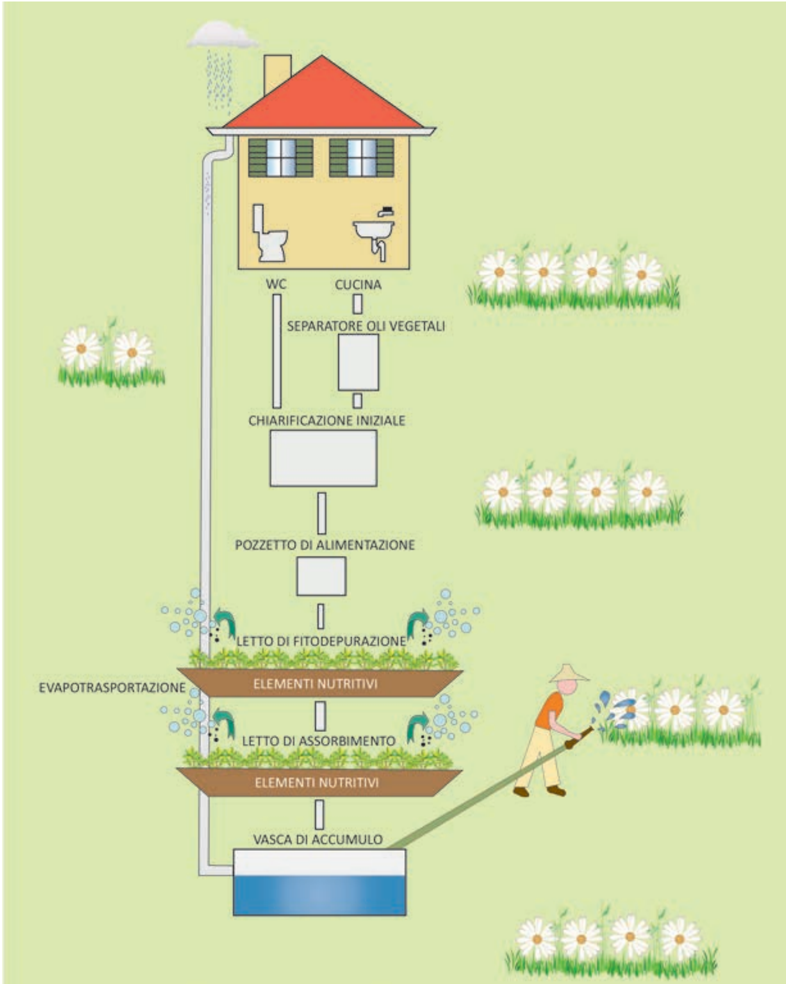


Figure 8: Phytotreatment bed diagram

TERTIARY OR CHEMICAL-PHYSICAL TREATMENT

Tertiary treatments tend to eliminate the non-biodegradable pollutant substances dissolved in the wastewater to reduce the organic load before the discharge is drained into the receiving water body or to eliminate any excessive quantities of phosphates or residual nitrogenous substances from the waters even though the wastewaters were subjected to biological treatment. Finally, they are often used to allow the use of wastewater for non-potable purposes.

The primary tertiary treatments are:

- **disinfection;**
- **elimination of special nutrient salts (phosphorus);**
- **neutralization;**
- **filtration.**

a) DISINFECTION

Process through which the microbial load is reduced inside the slurry, generally through chemical agents (chlorine, chlorine derivatives, ozone, peracetic acid) and physical agents (UV and gamma rays).

b) 1. DEPHOSPHATIZATION

Process for the elimination of phosphorous in the slurry through chemical precipitation. Phosphorous is one of the primary nutrient substances that contribute to the eutrophication of lakes and natural waters. Its presence causes many water quality problems including increased purification costs, the decline in the value of recreation and preservation of the body of water, and a possible lethal effect of algal toxins on potable water.

b) 2. NITRIFICATION - DENITRIFICATION

If the concentration of nitrogen in the discharge is more than the recommended limits, it can be further reduced through a biological nitrification-denitrification process in which nitrogen abatement occurs by a biological route, using a denitrifying bacterial flora. Nitrification, together with the denitrification, allows good overall yields of the removal of nitrogenous compounds (nitrogen and phosphorus, as already mentioned, are nutrients that, in excessive quantities, can create shortages of oxygen in surface water bodies, leading to so-called eutrophication).

c) NEUTRALIZATION

Process of neutralization of the hydrogen ion concentration (pH) that in certain types of strongly acidic or basic slurry, inhibit the oxidative phase.
Through the addition of acids or bases, the neutralization process allows the correction of the pH of the water. The controlled parameter is therefore the pH. The neutralization is conducted by adding alkaline substances (e.g., milk of lime, sodium hydroxide solutions, sodium carbonate solutions, etc.) or acid substances (e.g., sulphuric acid solutions , hydrochloric acid solutions, etc.) as needed to the effluent to be treated.

d) FILTRATION

Filtration consists of a refinement of the water that was previously clarified by sedimentation in order to bring the quality of treated water to levels such that make its reuse safe and reliable. The water coming out of the filter is usually characterized by a turbidity similar to that of potable water. Typically, the sand filters under pressure ensure a 70-80% efficiency of the abatement of particulate material in suspension.
Filtration allows the interception of the solid particles in suspension in the water by a porous material with pores of a suitable size. The most commonly used filters are the granular filtering bed of sand or anthracite type and can operate by gravity or under pressure. The former are made up of an open air tank, the bottom of which has a suitable drainage system. The filtering material is made up of overlapping layers of material of different granulometry and specific weight. After a certain period of operation, the filter is washed to remove the particulate material retained in it. This is done by injecting washing water below the filtration layer through the drainage system (backwashing). Pressurized filters are similar to the gravity type, but the filter bed is built inside a closed container to allow pressure to be maintained on the water above the filtering layer. The result is greater filtering speed.

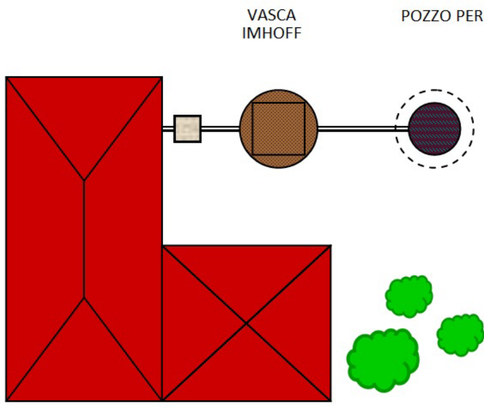
3.F GROUND DISPERSION SYSTEMS

Discharge into the ground should only be used in the presence of small settlements or when it is not economically sustainable to do otherwise. In order for the dispersion methods to be effective, the layers of earth involved must have high permeability characteristics, with K coefficients on average higher than 10-3 cm/sec. The K coefficient has the speed dimensions and depends on the porous material or the fluid. For the water the values range from 10-1 for the gravel to 10-10 for the clay.
There are essentially two dispersion systems:

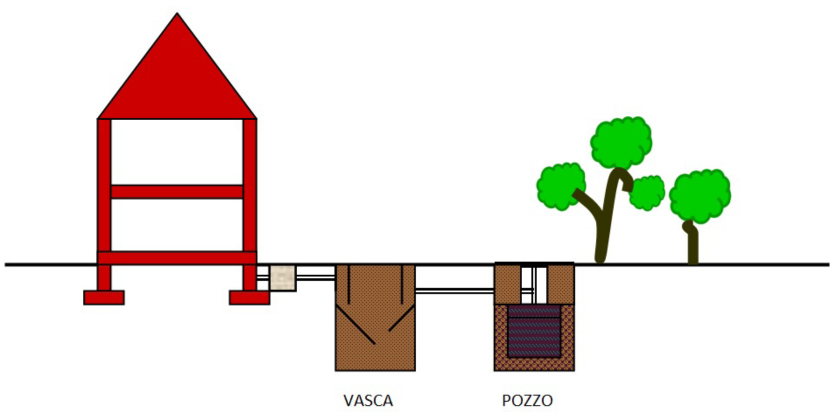
- **Cesspits**
- **Subirrigation**

a) CESSPITS
Cesspits are a widespread dispersion method, especially for the simplicity of production and the possibility of using easily available and low cost building elements.
They are made of masonry or concrete tanks, usually circular in shape, with perforated walls and an open bottom. They are often used for the disposal of clarified sewage.
It is important to make sure that the level of the water table is at least 2÷3 metres below the bottom of the well otherwise the dispersing capacity of the well will be greatly compromised.

Remember that no cesspit must be located within the minimum distance from the collection wells for potable water, i.e. within a radius of 200 meters from the withdrawal elements.
Aeration pipes must be arranged around the cesspits that penetrate from the ground level to a metre within the gravel layer.



DISPERSIONE SUL TERRENO MEDIANTE POZZI PERDENTI



DISPERSIONE SUL TERRENO MEDIANTE POZZI PERDENTI

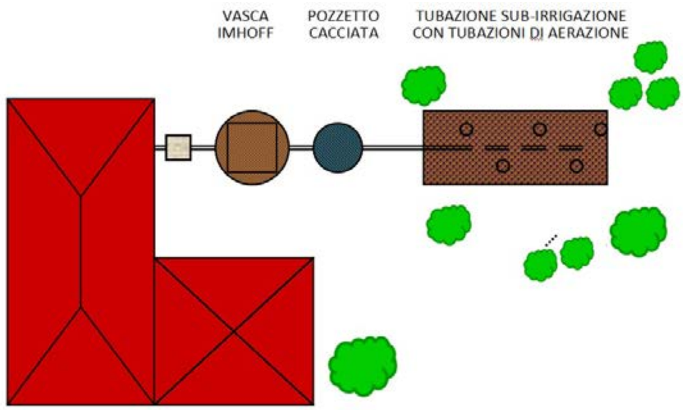
b) **SUBIRRIGATION**

This system of clarified domestic wastewater disposal allows controlled dispersion of the slurry (sub-irrigation) into the surface layers of the ground through their inflow directly below the surface of the ground through appropriate pipes. Pipe laying diagrams can differ greatly based on the available space and the shape of the ground, with serpentine, star, parallel strips, circle, or other layouts.

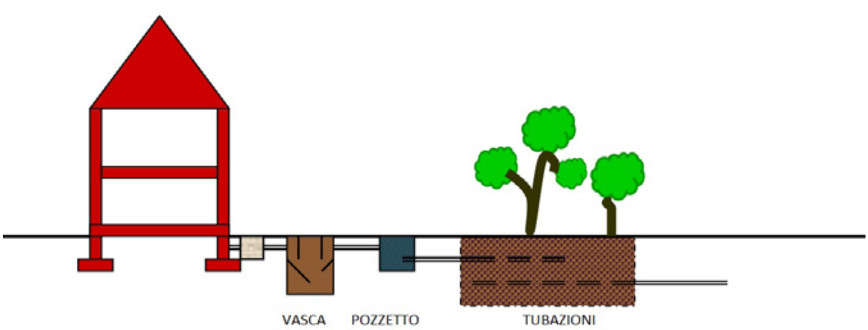
Making use of the purifying capacity of the soil, the wastewater undergoes a series of physical and biological transformation processes that reduce its polluting load, both from the chemical and bacteriological point of view.

Further drainage may be provided in a filter bed, in the case of impermeable soils (sub-irrigation with drainage).

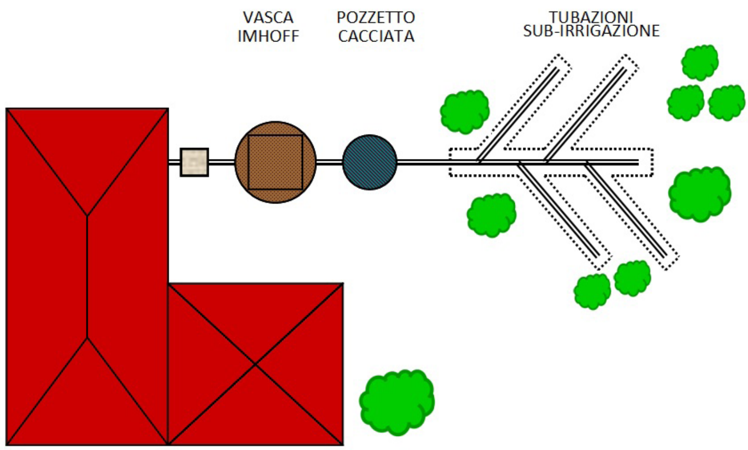
Dispersion through subirrigation, while making use of relatively large areas, allows good re-use of the ground as long as deep-rooted plants and the installation of heavy products are avoided.



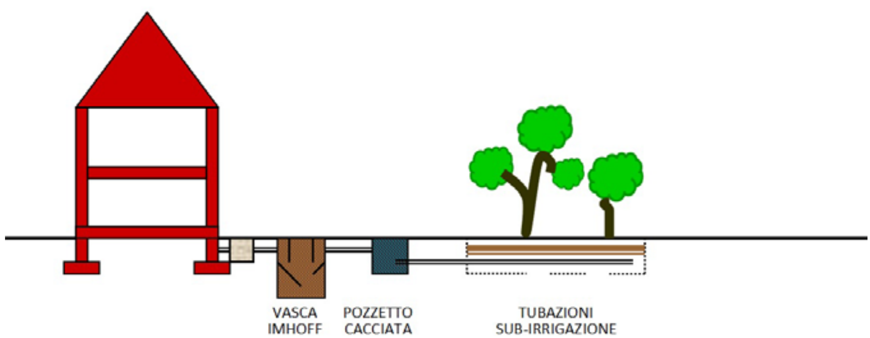
DISPERSIONE SUL TERRENO MEDIANTE SUB-IRRIGAZIONE DRENATA



DISPERSIONE SUL TERRENO MEDIANTE SUB-IRRIGAZIONE DRENATA



DISPERSIONE SUL TERRENO MEDIANTE SUB-IRRIGAZIONE



DISPERSIONE SUL TERRENO MEDIANTE SUB-IRRIGAZIONE

3.G APPROPRIATE TREATMENTS FOR URBAN WASTEWATER

In order to satisfy quality objectives, different treatments can be performed which are classified based on the **catchment basin**, meaning the amount of wastewater to be discharged in relation to the population.

The catchment areas of wastewater of civil use include:

- wastewater from residential housing;
- wastewater from manufacturing, industry, crafts (retail food sales and other retail sales, even with production workshops intended exclusively for sales);
- wastewater from services (hotels and restaurants, hair salons, barbers, and beauty institutions, closed cycle dry cleaning and ironing where the activities are aimed directly and exclusively at residential customers, toilets, kitchens, and/or canteens).

Depending on the amount of inhabitants in a building or in a conglomeration and the final discharge point, we recommend different types of intervention.

Settlements serving a population of less than 50PE.
If environmental conditions allow, the discharge is recommended in the surface layers of the subsoil, which must be preceded by a clarification treatment obtained using an Imhoff tank or septic tank managed to ensure values of 0.5ml/l for the settleable solids.
If higher purification values are desired, phytotreatment may be used.

Settlements serving a population of 50 to 400PE.
If environmental conditions allow, an extensive, or biological, treatment is recommended, preceded by an Imhoff tank or septic tank.

Conglomerates with a population of less than 2000PE.
An extensive, or biological, discharge system is recommended in surface waters, with treatment for the removal of nitrogenous compounds.

Conglomerates with a population equal to or greater than 2000PE.
A discharge system in surface waters is recommended, activating a biological treatment of the wastewater, also with the application of tertiary treatments.

For each type of user, compliance with the limits set forth in the Tables in the Appendix is recommended according to the wastewater discharge points.

	< 50 P.E.	50 / 100 P.E	100 / 400 P.E.	400 / 2000P.E.	> 2000 P.E.
DEGREASER	x	x	x	x	x
IMHOFF TANK	x	x	x		
BIOLOGICAL DISC			x	x	x
ANAEROBIC FILTER			x		
AEROBIC FILTER			x	x	
ACTIVE SLUDGE			x	x	x
NITRIFICATION/ DENITRIFICATION				x	x
TERTIARY TREATMENT					x
PHYTOTREATMENT	x	x			
SUBIRRIGATION	x	x			

THE FUTURE

One objective: re-use

Apart from the need for purification processes in terms of environmental impact, proper management of the water cycle involves the application of existing technological knowledge for the achievement of socially and economically useful objectives, such as the protection of surface water bodies and underground and proper management of water resources.
Re-use of purified wastewater can be considered an innovative and alternative expedient within a more rational use of the water resource. The economic advantage gained by re-use is in providing the community with water procurement, at least for certain uses that do not require high quality water, at lower costs, because recycling costs less than disposal.

The re-use of domestic, municipal, and industrial wastewater through proper regulation of the intended use and the related quality requirements to protect the quality and quantity of the water resources can lead to the decrease of the withdrawal of surface and underground waters, reducing the impact of the discharges in receiving water bodies and promoting water savings through the multiple use of wastewater.

Advantages and future prospects that can offer recycling of used water include new technologies that seek to obtain efficient processes guaranteeing procurement of purified water at low cost, with a certain degree of quality, especially health and hygiene. Conventional treatments are almost never enough and therefore technology is aimed towards the fine tuning of new tertiary and disinfection treatment alternatives aimed at high water quality through the abatement of the microbial load, nutrients, and toxic substances (membrane plants, ozone, ultrafiltration, etc.).

APPENDIX TO CHAPTER 3

III.I DEFINITIONS

Population equivalent: the biodegradable organic load having a biochemical oxygen demand of 5 days (BOD5), equal to 60 grams of oxygen per day.

Wash water: waters, however procured, attained, or recovered, that are used for washing draining surfaces such as streets, courtyards, and squares, loading and unloading areas and any similar exposed surface, to which the provisions and any other water not resulting from weather, that involves those surfaces either directly or indirectly.

Stormwater runoff: that part of atmospheric precipitation that is not absorbed or evaporated and runs over the draining surfaces.

First flush: water during the first part of a storm that equals a precipitation of 5 mm, uniformly distributed over the entire draining surface served by the drainage network, coming from drainage surfaces attributable to the settlements mentioned in the current regulations.

Black water: all wastewater from a discharge.

Rainwater after the first flush: lwater from precipitation that comes after the first flush.

Wastewater treated as domestic: wastewater with qualitative characteristics that are equal to domestic ones.

Domestic wastewater: wastewater from residential communities and services and primarily from human metabolism and domestic activities.

Industrial wastewater: wastewater from buildings or installations where a trade or production of goods is carried out and is qualitatively different from domestic wastewater and runoff.

Municipal wastewater: domestic wastewater or the mix of domestic wastewater industrial wastewater or precipitation conveyed in sewer system, even if separate, and coming from a conglomeration.

Conglomeration: area in which the population or economic activities are sufficiently concentrated to make possible, or technically and economically possible in relationship to the environmental benefits, the collection and conveyance of municipal wastewater to a municipal wastewater treatment system or to a final discharge point.

BOD5: the amount of O2 that is used in 5 days by aerobic microorganisms to decompose (oxidize) in darkness and at a temperature of 20°C, the organic substances present in a litre or water or a water solution.

Receiving water body: body of water that receives the treated wastewater.

Ecosystem: Dynamic complex that includes all organisms (plants, animals and microorganisms) that live in the same area and interact with the physical environment.
The ecosystem consists of components (living and non-living) which, while maintaining their independence, regularly interact with each other.

Eutrophication: the enrichment of water by nutrients, in particular nitrogen or phosphorus compounds, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and the quality of the waters concerned.

Sludge: the residual treated or untreated sludge coming from municipal wastewater treatment plants.

Purification plant: group of "structures" (in-ground, masonry, or metal tanks, with or without a mechanical and electromechanical equipment of greater or lesser sophistication) in which, in sufficiently reduced spaced, water purification is implemented. The purposes generally proposed, subjecting the wastewater to treatment with a purification plant are two-fold: 1) Separate the pollutants from the liquid, concentrating them into sludge; 2) Perform a treatment of the sludge, including "stabilization" in order to allow proper disposal.

Sewer system: the system of pipes for collecting and conveying municipal wastewater;

Discharge: Any direct inflow through pipes of liquid and semi-liquid wastewater and that can be conveyed in the surface water, on the ground, underground, and in the sewer system, regardless of the pollutant nature and even subject to prior purification treatment.

Primary treatment: Treatment of wastewater through a physical or chemical process that involves the sedimentation of suspended solids and, following which the BOD5 of the arriving wastewater is reduced by at least 20% before discharge and the total suspended solids in the arriving wastewater are reduced by at least 50%.

Secondary treatment: Treatment of wastewater through a process that generally involves biological treatment with secondary sedimentation.

Tertiary treatment: Subsequent treatment that the effluent of a plant undergoes after secondary oxidative treatment and sedimentation. This also includes nutrient (nitrogen and phosphorous) abatement treatments.

Emission limit value: acceptability limit of a pollutant substance contained in a discharged, measured in concentration, or in weight per product or raw material processed or in weight per unit of time.

III.II TRANSFORMATION COEFFICIENTS FOR CALCULATING THE P.E. NUMBER

SETTLEMENT	REFERENCE UNIT	COEFFICIENT	POPULATION EQUIVALENT
RESIDENCES	rooms (a)	1	a x 1 = P.E.
CAMPSITES	max presence per day (a)	0,5	a x 0.5 = P.E.
RESTAURANTS	seats per meal (a)	0,35	a x 0.35 = P.E.
HOTELS	beds (a) service workers (b) seats per meal (e)	1,5 1 0,35	(a x 1.5) + (b x 1) + (e x 0.35) = Total P.E.
SCHOOLS	students (a) teachers and employees (b) canteen seats (e)	0,3 0,3 0,35	(a x 0.3) + (b x 0.3) + (e x 0.35) = Total P.E.
OFFICES	employees (a) canteen seats (b)	0,35 0,30	(a x 0.35) + (b x 0.30) = Total P.E.
INDUSTRIES	employees (a) first shift workers (b) second shift workers (e) third shift workers (d) canteen seats (e)	0,35 0,5 0,5 0,5 0,35	(a x 0.35) + (b x 0.5) + (e x 0.5) + (d x 0.5) + (e x 0.35) = Total P.E.
HOSPITALS	beds (a) first shift employees (b) second shift employees (e) third shift employees (d) employee canteen seats (e)	2,50 1 1 1 0,35	(a x 2.5) + (b x 1) + (C X 1) + (d x 1) + (e x 0.35) = Total P.E.
REST HOMES	beds (a) employees (b)	2 1	(a x 2) + (b x 1) = Total P.E.

III.III SPECIFIC ORGANIC AND HYDRAULIC LOADS FOR VARIOUS TYPES OF USERS

	SPECIFIC HYDRAULIC LOAD [l/dì]	SPECIFIC ORGANIC LOAD [g BOD5/dì]
DOMESTIC DRAINS (per inhabitant)		
LUXURY RESIDENCES IN	300 – 400	60
HIGH LEVEL DISTRICTS	250 - 350	60
MIDDLE LEVEL DISTRICTS	200 - 300	60
POPULAR DISTRICTS, RURAL COMMUNITIES,	150 - 250	60
SUMMER VILLAS	150 – 200	60
SEA AND MOUNTAIN TOURIST CENTRES		
FOR ESTABLISHED GUESTS	150 - 200	60 - 70
FOR DAILY TOURISTS	15 - 40	7,5 - 25
SCHOOLS (students; teachers; service staff)		
ELEMENTARY	35 - 45	11 - 18
SCHOOLS MIDDLE	35 - 65	15 - 20
FOR SHOWERS FOR EACH TYPE OF SCHOOL	+20 l	+5 g
FOR KITCHENS FOR EACH TYPE OF SCHOOL	+20 l	+10 g
BOARDING SCHOOLS	**180 - 380 5**	**5 - 75**
OFFICES (for employee)	**50 - 75**	**15 - 25**
FACTORIES (employee, worker)	**50 - 130**	**20 - 35**
FOR SHOWERS	+20 l	+5 g
FOR KITCHENS	+20 l	+9 g
HOSPITALS (for bed)	**500 - 1100**	**100 - 160**
HOSPICES, REST HOMES (for bed)	**200 – 350**	**60 - 90**
HOTELS (guest, excluding restaurant and bar)	**150 – 400**	**55 - 75**
CAMPSITES AND HOLIDAY VILLAGES (for guest)	**100 - 200**	**40 - 70**
RESTAURANTS		
(for employee)	35 - 60	20 - 25
(for served seat)	10 - 12	10 - 15
CAFÈ, BAR		
(for employee)	50 – 60	20 - 25
(for customer)	8	5
CINEMA E THEATRES (for seat)	**15 - 20**	**8 - 10**
POOLS (for swimmer)	**20 - 40**	**10 - 15**
AIRPORTS		
(for employee)	50 - 60	22 - 25
(for passenger)	15 - 20	8
CONSTRUCTION SITES	**200**	**55 - 70**
DISCOTEQUES	**15**	**7**
LARGE STORES, SHOPPING CENTRES	**3 - 10 l/m2**	**1 - 2 l/m2**
LAUNDRIES (for machine)	**1000 - 3000**	**300**

III.IV REFERENCE TABLES

Table 1 – Emission limits that wastewater must comply with, upstream of any purification treatment, to be assimilated in domestic wastewater.

PARAMETERS	UNITS OF MEASURE	LIMIT VALUE
PH		6,5÷8,5
TEMPERATURE	°C	30
COLOUR	-	Not perceptible on a thickness of 10 cm after dilution 1: 40
ODOUR	[mg/l]	It should not cause inconvenience and trouble of any kind
TOTAL SUSPENDED SOLIDS		350
BOD5	[mg/l]	250
COD	[mg/l]	500
CHLORIDES (AS CL)	[mg/l]	The concentration detected in procured waters +40mg/l
TOTAL PHOSPHOROUS (AS P)	[mg/l]	6
AMMONIUM (AS NH4)	[mg/l]	40
NITROUS NITROGEN (AS N)	[mg/l]	0,6
TOTAL NITROGEN (AS N)	[mg/l]	50
GREASES AND ANIMAL/VEGETABLE OILS	[mg/l]	60
SURFACTANTS	[mg/l]	10

Table 2 – Emission limits in surface waters and sewer

	PARAMETERS	Unit of measure	Discharge in surface water	Discharge in the sewer system
1	pH		5,5-9,5	5,5-9,5
2	Temperature	°C		
3	colour		not perceptible with 1:20 dilution	not perceptible with 1:40 dilution
4	odour		It should not cause trouble	It should not cause trouble
5	large materials		absent	absent
6	Total special solids	mg/L	≤80	≤200
7	BOD5 (as O2)	mg/L	≤40	≤250
8	COD (as O2)	mg/L	≤160	≤500
9	Aluminium	mg/L	≤1	≤2
10	Arsenic	mg/L	≤0,5	≤0,5
11	Barium	mg/L	≤20	-
12	Boron	mg/L	≤2	≤4
13	Cadmium	mg/L	≤0,02	≤0,02
14	Total Chrome	mg/L	≤2	≤4
15	Chromium VI	mg/L	≤0,2	≤0,2
16	Iron	mg/L	≤2	≤4
17	Manganese	mg/L	≤2	≤4
18	Mercury	mg/L	≤0,005	≤0,005
19	Nickel	mg/L	≤2	≤4
20	Lead	mg/L	≤0,2	≤0,3
21	Copper	mg/L	≤0,1	≤0,4
22	Selenium	mg/L	≤0,03	≤0,03
23	Tin	mg/L	≤10	
24	Zinc	mg/L	≤0,5	≤1
25	Total Cyanide (as CN)	mg/L	≤0,5	≤1
26	Free active chlorine	mg/L	≤0,2	≤0,3
27	Sulphide (as H2S)	mg/L	≤1	≤2
28	Sulphites (as S03)	mg/L	≤1	≤2

	PARAMETERS	Unit of measure	Discharge in surface water	Discharge in the sewer system
29	Sulphates (as S04)	mg/L	≤1000	≤1000
30	Chlorides	mg/L	≤1200	≤1200
31	Fluorides	mg/L	≤6	≤12
32	Total phosphorous (as P)	mg/L	≤10	≤10
33	Ammonium (as NH4)	mg/L	≤15	≤30
34	Nitrous nitrogen (as N)	mg/L	≤0,6	≤0,6
35	Nitric nitrogen (as N)	mg/L	≤20	≤30
36	Greases and animal/ vegetable oils	mg/L	≤20	≤40
37	Total hydrocarbons	mg/L	≤5	≤10
38	Phenols	mg/L	≤0,5	≤1
39	Aldehydes	mg/L	≤1	≤2
40	Aromatic organic solvents	mg/L	≤0,2	≤0,4
41	Nitrogenous organic solvents	mg/L	≤0,1	≤0,2
42	Total surfactants	mg/L	≤2	≤4
43	Phosphorus pesticides	mg/L	≤0,1	≤0,1
44	Total pesticides (excluding phosphorous ones) where:	mg/L	≤0,05	≤0,05
45	- aldrin	mg/L	≤0,01	≤0,01
46	- dieldrin	mg/L	≤0,01	≤0,01
47	- endrin	mg/L	≤0,002	≤0,002
48	- isodrin	mg/L	≤0,002	≤0,002
49	Chlorinated solvents	mg/L	≤1	≤2
50	Escherichia coli	UFC/100 mL	nota	
51	Acute toxicity test		The sample is not acceptable when after 24 hours the number of immobile organisms is equal or greater than 50% of the total.	The sample is not acceptable when after 24 hours the number of immobile organisms is equal or greater than 80% of the total.

Table 3 – Emission limits for municipal and industrial wastewater that discharge on the ground.

		Unit of measure	(THE CONCENTRATION MUST BE LESS THAN OR EQUAL TO THE ONE INDICATED)
1	pH		6-8
2	SAR		10
3	Large materials	-	absent
4	Total suspended solids	mg/L	25
5	BOD5	mg/L O2/L	20
6	COD	mg/L O2/L	100
7	Total nitrogen	mg N/L	15
8	Total Phosphorous	mg P/L	2
9	Total surfactants	mg/L	0,5
10	Aluminium	mg/L	1
11	Berillium	mg/L	0,1
12	Arsenic	mg/L	0,05
13	Barium	mg/L	10
14	Boron	mg/L	0,5
15	Total Chromium	mg/L	1
16	Iron	mg/L	2
17	Manganese	mg/L	0,2
18	Nickel	mg/L	0,2
19	Lead	mg/L	0,1
20	Copper	mg/L	0,1
21	Selenium	mg/L	0,002
22	Tin	mg/L	3
23	Vanadium	mg/L	0,1
24	Zinc	mg/L	0,5
25	Sulphides	mg H2S/L	0,5
26	Sulphites	mgSO 3/L	0,5
27	Sulphates	mgSO 4/L	500
28	Active chlorine	mg/L	0,2
29	Chlorides	mg Cl/L	200
30	Fluorides	mg F/L	1

		Unit of measure	(THE CONCENTRATION MUST BE LESS THAN OR EQUAL TO THE ONE INDICATED)
31	Total Phenols	mg/L	0,1
32	Total aldehydes	mg/L	0,5
33	Total aromatic organic solvents	mg/L	0,01
34	Total nitrogenous organic solvents	mg/L	0,01
35	Toxicity test on Daphnia magna	LC50 24h	The sample is not acceptable when after 24 hours the number of immobile organisms is equal or greater than 50% of the total.
36	Escherichia coli	UFC/100	

Table 4 – Emission limits for plants, greater than 2000 P.E., of municipal wastewater that discharges in surface bodies of water.

Plant potential in P.E. (population equivalent)	2.000-10.000		> 10.000	
Parameters (average daily)	Concentration	% Reduction	Concentration	% Reduction
BOD5 (without nitrification) mg/L	≤ 25	70-90	≤ 25	80
COD mg/L	≤ 125	75	≤ 125	75
Suspended solids mg/L	≤ 35	90	≤ 35	90

Table 5 – Emission limits for plants, greater than 10000 P.E., of municipal wastewater that discharges in sensitive areas.

Plant potential in P.E. (population equivalent)	Plant potential in P.E.			
	10.000-100.000		> 100.000	
	Concentration	% Reduction	Concentration	% Reduction
Total phosphorous (P mg/L)	≤ 2	80	≤ 1	80
Total nitrogen (N mg/L)	≤ 15	70-80	≤ 10	70-80

CHAPTER 4

REUSE OF WASTEWATER AND RAINWATER

To ensure protection of the quality and quantity of water resources it is hoped to limit the collection of surface water and groundwater, reducing the impact of the discharges on the receiving water bodies and favouring water savings through the recovery and reuse of wastewater.

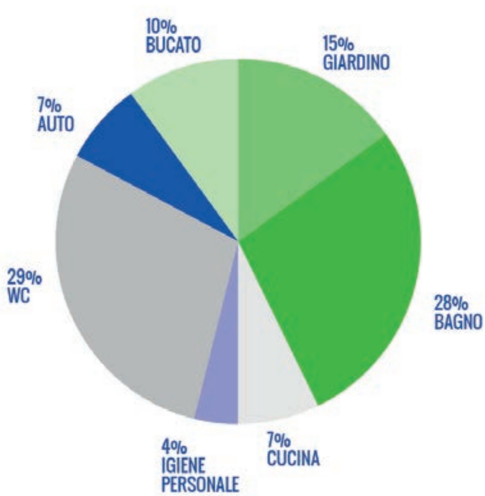
In a generic user, in order to satisfy water needs, potable water having high quality characteristics is collected and used without distinction for potable or non potable purposes. This is called double waste, because it uses high quality water for non potable purposes, discharging it immediately after. As already stated, potability conditions cannot be restored after use.

Just by considering the use of potable water in houses it is evident that its use is not always appropriate. Only a small percentage is used for drinking and preparing food while the remaining part is consumed for other uses.

Sustainable management of the water cycle is based instead on leveraging less noble water and using high quality water only where potability characteristics are truly required..

A correct practice calls for the insertion of these principles in the regulations governing the matter.

Re-use must occur in environmentally safe conditions, avoiding changes to the eco-systems, soil and crops, as well as health and hygiene risks for the exposed population.
The term recover refers to the requalification of wastewater through adequate purification treatment in order to make it suitable for distribution for specific reuses.
Re-use calls for the use of recovered wastewater of a certain quality for a specific use through a distribution network, in partial or total replacement of surface or underground water.

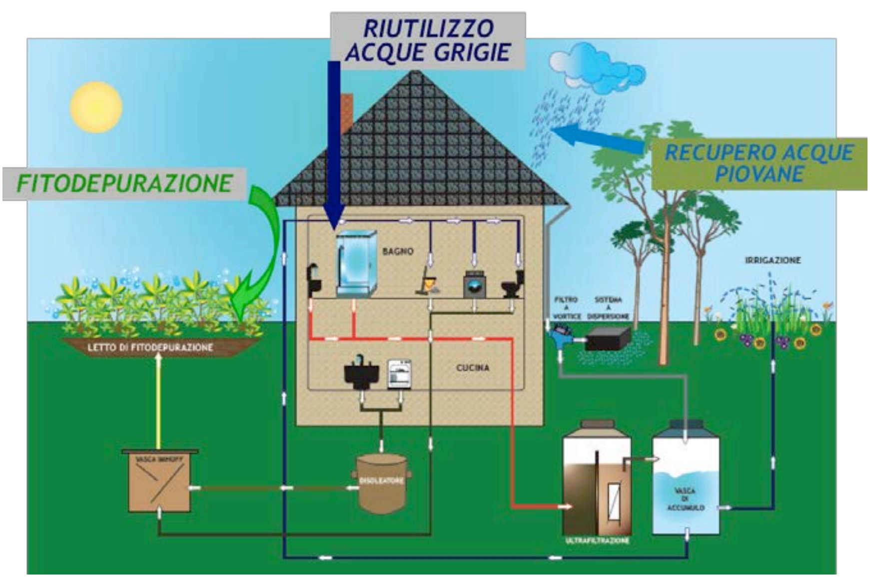


4.A POSSIBLE WAYS TO REUSE WASTEWATER AND RAINWATER

The allowable uses of recovered wastewater are as follows:

- irrigation: irrigation of crops for the production of food for human and animal consumption, for non-food uses as well as for irrigation of green areas or for leisure or sporting activities;
- civil: for the washing of the streets in urban centres; for the power supply for heating or cooling systems; for feeding dual adduction networks separate from those for potable water, with the exclusion of the direct use of such water in buildings for civil use, with the exception of discharge systems in sanitary facilities;
- industrial: as water for fire extinguishing, process, washing and thermal cycles of industrial processes, with the exclusion of uses that require contact between the recovered wastewater and foods or pharmaceutical and cosmetic products.

Purified wastewater is forbidden for use as potable water or when in direct contact with raw edible products.



4.B LIMITS TO FOLLOW DEPENDING UPON THE REUSE

It is recommended those recovered wastewaters intended for irrigation or civil reuse possesses chemical-physical and microbiological qualities upon output from the recovery plant that are at least equal to those shown in table 1 in the appendix. For industrial re-use, refer to Table 2.

4.C RAINWATER RECOVERY

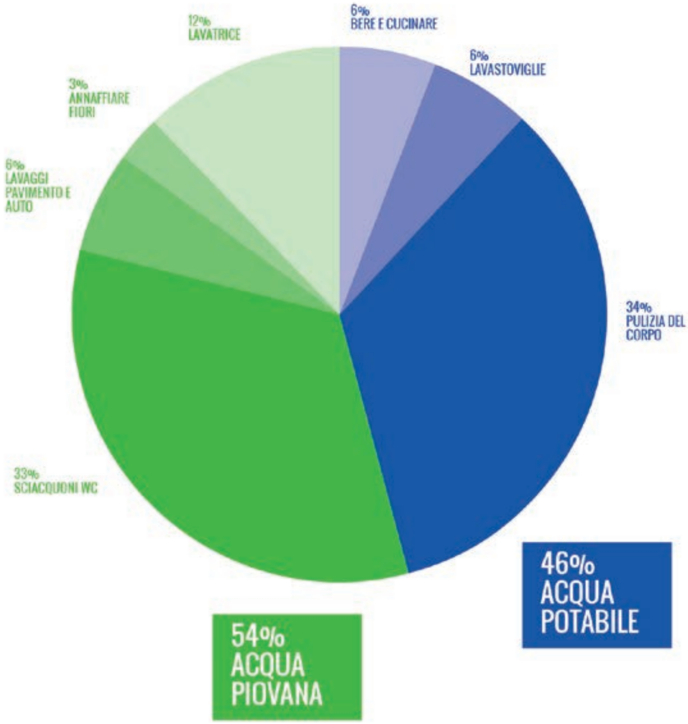
Plants intended for wastewater recovery allow the re-use of rainwater, storing it in a reserve tank.
These plants allow the creation of the possibility to recover rainwater that, rather than being dispersed, can be used for external and internal uses.

External uses:

- watering of public or condominium green areas;
- washing paved areas;
- car washes, meaning businesses;
- technological uses and supplying fire extinguishing systems.

Internal uses:

- filling toilet flush tanks;
- filling washers (if prepared);
- water distribution for basements and car washing;
- various technological uses such as, for example, passive/active air conditioning systems.



Recovery plants

The plant for optimizing rainwater recovery is made up of a filtering and storage part and an actual re-use part.

The plant usually has four intervention phases:
1) Water is collected from the gutters and conveyed to a filter that separates the water from larger suspended material.
2) Water is channelled inside the tank through a pipe so no turbulence is created.
3) Subsequent intake of the water in the tank occurs a few centimetres below the water level in order to collect cleaner water.
4) An electronic control unit controls a feed pump and the entire system.

The characteristic components of a rainwater recovery plant are:

- **Diverter/Filter**

  The diverter separates the first flush (generally having more pollutants) from the water intended for storage.

  The filter keeps any foreign bodies in the rainwater from entering the tank.

- **Tank**

  The tank is the heart of the entire rainwater recovery system.

  The ideal conditions for water conservation are: oxygenated environment and the absence of light.

  The choice of the type to be adopted depends on various factors.

  a) Position. The position influences the distribution system (with or without pump) and its uses, the installation and maintenance costs, the form (compact for inside, resistant for being buried) and the materials used. The tank can be placed above ground (it generally contains water intended for irrigating or washing and the like), inside the building (in premises at ground level or underground) and buried (the most expensive due to the excavation necessary, but it has the advantage of keeping the shape of the tank out of view and allows the installation of large capacity items).

  b) Capacity: to size these plants and to then determine the volume to assign to the accumulation tank, both the environmental characteristics (local rainfall, size and type of the collection surfaces, etc.) and the performance required (in relation to the number of inhabitants) must be evaluated.

  c) Material: The tanks are made of materials that are compatible with the standards. They are generally made of fibreglass, polyethylene, or are made of concrete poured on site.

- **Drain pipe**

  The drain pipe, shaped like a siphon, prevents the backflow of unpleasant odours from the disposal system. It is at a height equal to or lower than the input.

- **Check valve**

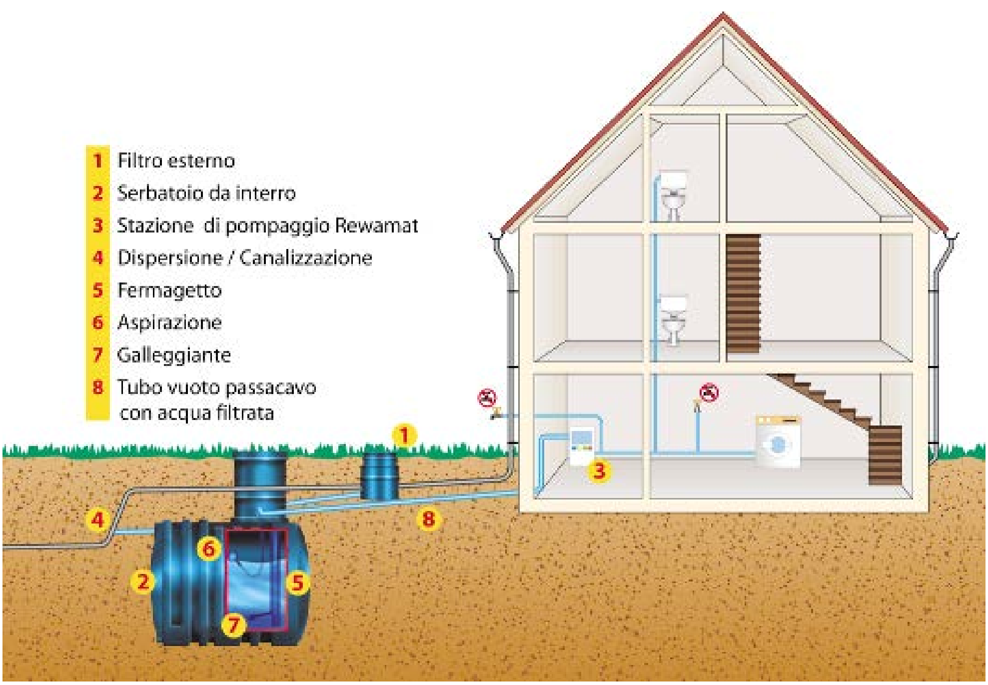
  The check valve prevents the contamination of the water stored in the tank, inhibiting backflow of waters from the disposal system.

  It is normally equipped with a grating filter that blocks access to the tank and other components upstream and animals and insects that could enter from the drain.

- **Delivery pump**

  The delivery pump, controlled by an electronic control panel, picks up the water stored in the tanks and distributes it to the equipment that reuses it.

  To prevent contamination, pipes and terminals on the recycling plant must be clearly marked and separate from those for potable water.



Refinement treatments for recovered water

After primary filtration of the large material, recovered rainwater can only be reused for irrigation with a subirrigation system.
For all of the other non-potable uses, a refinement phase is usually required to improve the quality characteristics of the water, especially regarding SS, BOD5, and bacteria.

Four systems are recommended as refinement treatments:
- disinfection (hypochlorite, UV, dioxide, etc.);
- filtration (sand and carbon);
- membrane filtration;
- phytotreatment.

For the description of the techniques listed, refer to the previous chapters regarding potable water and wastewater.

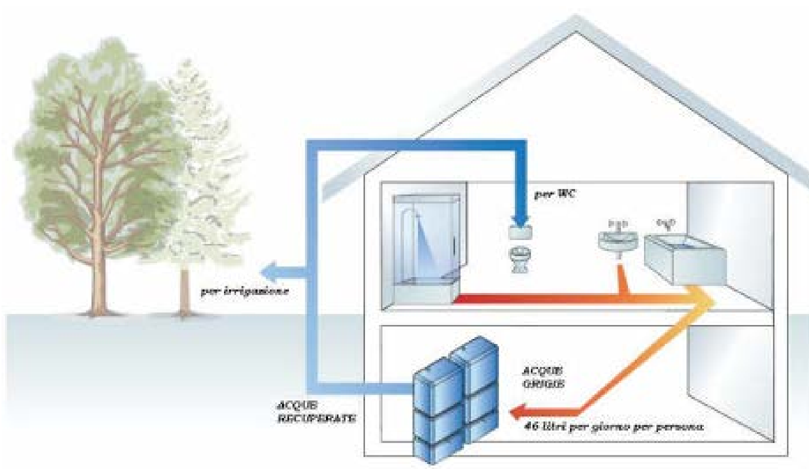
The advantages from the installation of rainwater collection plants for individual use can reflect positively on both the **private level:**
- water savings;
- economic savings considering that the re-used water is free;
- absence of limescale deposits in pipes and on heating elements in machines (washer, dishwasher) and subsequent savings on electrical consumption;
- detergent savings (up to 50%) due to lower water hardness.

and the **public level:**
- they prevent the recurrence of overloading of sewer and disposal systems during heavy precipitation;
- they increase the efficiency of the purifiers (where the white and black sewer systems are not separate) subtracting large amounts of liquid from the outflow that, diluting the amount of slurry to be treated, will reduce the effectiveness of the biological purification phase;
- they retain and/or disperse the excess rainwater on site (for example during heavy storms) that is not absorbed by the ground on the municipal level due to the progressive impermeabilization of the soil, making upgrades to the public collection systems useless.

4.D GREY WATER RECOVERY

Grey water refers to water from sinks, showers, and bath tubs (except for the toilet, bidet, and the entire kitchen) and that, due to their degree of contamination, can be collected, treated, and disinfected to then be returned for domestic use (inside rinse tanks) or reused for irrigation.

Grey water makes up about 70% of domestic consumption and purifying black water is easier due to greater speed of deterioration of the pollutants.



Operations regarding "grey water" are fundamentally comprised of:

- separation of the discharge networks of black water (containing toilet discharge) and grey water (all other discharged water);
- creation of distinct water distribution networks (potable water and non-potable water);
- treatment and re-use of purified grey water for non-potable uses such as irrigation of green areas, filling toilet flush tanks, and washing external areas.

Grey water recovery and re-use systems can reduce the consumption of potable water with particular efficiency in medium-large buildings or complexes that produce a consistent quantity of wastewater each day.

These buildings can be: hotels, guest houses, tourist facilities, retirement homes, housing complexes, apartment buildings, campsites, fitness centres, sports halls, swimming pools, hair salons, office buildings, motorway services, and companies which use showers.

Storage of grey waters is through underground tanks or tanks installed inside the building.
Grey water can be treated with a biological oxidation system or with an ultrafiltration system.

4.E WASTEWATER RECOVERY

Water demand has grown in recent decades and is likely to expand further, due to social and cultural factors and the development of urban conglomerations and production companies. UN estimates predict a strong growth in the world population that, in 2025, will be about 9 billion people, 50% of which will be concentrated in the larger towns.
It is therefore necessary to intervene in order to ensure a water supply for the future, limiting the exploitation of water resources and protecting the receiving bodies.

The re-use of domestic, urban, and industrial wastewater purified with tertiary type innovative systems (membrane plants, ozone, ultra filtration, etc.) is one of the most effective methods for meeting the objectives listed above.

Purified water must meet a certain degree of quality, especially at the health and hygiene level. There is a long list of illnesses (dysentery, gastroenteritis, allergies, etc.) that can be contracted through wastewater and it is more than evident that there is a need for water disinfection for its re-use.
On the disinfection level, three primary objectives must be established: reduction of the microbial load, control of the chemical elements present, and limitation of possible contact between people and the wastewater.

It is important to diversify the complexity of the treatments and the re-use environments depending on the origin of the wastewater. Treatment plants can be set up to treat water from city drains (municipal wastewater) or industrial drains (industrial wastewater).
Based on the type of re-use, a more or less intense treatment will be performed. The complexity of the process used to treat the wastewater call for increasingly elevated quality levels depending upon whether it will be for agricultural, industrial, or potable re-use.

Possible uses.

- **Reuse for agriculture** is one of the most adopted solutions, in various areas. These are mainly:
    - direct use (in which the wastewater, which is more or less refined, is directly re-used for irrigation);
    - indirect use (where the wastewater is put into a water body destined for irrigation use).

- Even **industrial re-use** has two possible solutions:reimpieghi per servizi generali (essenzialmente circuiti di raffreddamento e caldaie);
    - reuse for general services (essential heating and cooling circuits);
    - specific re-uses in various technological cycles (textiles, tanning, paper mills, steel mills, etc.).

- Re-use for potable use which calls for compliance with high quality standards (to prevent contamination with harmful and damaging substances), is divided into two types:
    - a "direct" (closed cycle) re-use that calls for direct inflow of the treated wastewater in the water distribution system;
    - "indirect" re-use that calls for intermediate storage of the wastewater in an artificial or natural basin before distribution in the network.

- Another category for re-use is for civil, non potable uses such as: irrigation of parks, green areas, and sports fields; domestic use in hygiene services (not in contact with people); commercial uses (e.g.: car washes); ornamental uses (e.g., fountains) that can be supplied by the so-called "dual systems" of distribution (with a network that transports "potable" water and another that contains re-use water for "non potable" use).

APPENDIX TO CHAPTER 4

IV.I REFERENCE TABLES

Table 1 – Quality requirements for irrigation or civil re-use.

CHEMICAL AND PHYSICAL PARAMETERS		
Parameter	**Unit of measure**	**Limit Value**
pH		6-9,5
SAR		10
Large materials		Absent
Total suspended solids	mg/L	10
BOD_5	mg O_2/L	20
COD	mg O_2/L	100
Total phosphorous	mg P/L	2
Total nitrogen	mg N/L	15
Ammonium	mg NH4/L	2
Electrical conductivity	µS/cm	3000
Aluminium	mg/L	1
Arsenic	mg/L	0,02
Barium	mg/L	10
Berillium	mg/L	0,1
Boron	mg/L	1,0
Cadmium	mg/L	0,005
Cobalt	mg/L	0,05
Total Chromium	mg/L	0,1
Chromium VI	mg/L	0,005
Iron	mg/L	2
Manganese	mg/L	0,2
Mercury	mg/L	0,001
Nickel	mg/L	0,2
Lead	mg/L	0,1
Copper	mg/L	1
Selenium	mg/L	0,01
Tin	mg/L	3
Thallium	mg/L	0,001
Vanadium	mg/L	0,1
Zinc	mg/L	0,5
Total Cyanide (as CN)	mg/L	0,05
Sulphides	mgH_2S/L	0,5
Sulphites	mgSO_3/L	0,5
Sulphates	mgSO_4/L	500
Active Chlorine	mg/l	0,2
Chlorides	mg Cl/L	250
Fluorid	mg F/L	1,5
Greases and animal/vegetable oils	mg/L	10
Mineral oils	mg/L	0,05
Note 1		
Total phenols	mg/L	0,1
Pentachlorophenol	mg/L	0,003

Total Aldehydes	mg/L	0,5
Tetrachloroethylene, trichloroethylene (sum of the concentrations of the specific parameters)	mg/L	0,01
Total chlorinated solvents	mg/L	0,04
Trihalomethanes (sum of the concentrations)	mg/L	0,03
Organic solvents aromatic totals	mg/L	0,01
Benzene	mg/L	0,001
Benzo[a]pyrene	mg/L	0,00001
Nitrogenous organic solvents total	mg/L	0,01
Total surfactants	mg/L	0,5
Chlorinated pesticides (each) Note 2	mg/L	0,0001
Phosphorus pesticides (each)	mg/L	0,0001
Total other pesticides	mg/L	0,05 10 (80% of samples)

MICROBIOLOGICAL PARAMETERS		
Escherichia coli	UFC/100mL	100 point value
Note 3		max
Salmonella		Absent

Table 2 – Quality requirements for industrial re-use

	PARAMETERS	Unit of measure	Discharge in surface water	Discharge in the sewer system
1	pH		5,5-9,5	5,5-9,5
2	Temperature	°C		
3	colour		not perceptible with 1:20 dilution	not perceptible with 1:40 dilution
4	odour		It should not cause trouble	It should not cause trouble
5	large materials		absent	absent
6	Total special solids	mg/L	≤80	≤200
7	BOD5 (as O2)	mg/L	≤40	≤250
8	COD (as O2)	mg/L	≤160	≤500
9	Aluminium	mg/L	≤1	≤2
10	Arsenic	mg/L	≤0,5	≤0,5
11	Barium	mg/L	≤20	-
12	Boron	mg/L	≤2	≤4
13	Cadmium	mg/L	≤0,02	≤0,02
14	Total Chromium	mg/L	≤2	≤4
15	Chromium VI	mg/L	≤0,2	≤0,2
16	Iron	mg/L	≤2	≤4
17	Manganese	mg/L	≤2	≤4
18	Mercury	mg/L	≤0,005	≤0,005
19	Nickel	mg/L	≤2	≤4
20	Lead	mg/L	≤0,2	≤0,3
21	Copper	mg/L	≤0,1	≤0,4
22	Selenium	mg/L	≤0,03	≤0,03
23	Tin	mg/L	≤10	
24	Zinc	mg/L	≤0,5	≤1
25	Total Cyanide (as CN)	mg/L	≤0,5	≤1
26	Free active chlorine	mg/L	≤0,2	≤0,3
27	Sulphide (as H2S)	mg/L	≤1	≤2
28	Sulphites (as S03)	mg/L	≤1	≤2

	PARAMETERS	Unit of measure	Discharge in surface water	Discharge in the sewer system
29	Sulphates (as S04)	mg/L	≤1000	≤1000
30	Chlorides	mg/L	≤1200	≤1200
31	Fluorides	mg/L	≤6	≤12
32	Total phosphorous (as P)	mg/L	≤10	≤10
33	Ammonium (as NH4)	mg/L	≤15	≤30
34	Nitrous nitrogen (as N)	mg/L	≤0,6	≤0,6
35	Nitric nitrogen (as N)	mg/L	≤20	≤30
36	Greases and animal/ vegetable oils	mg/L	≤20	≤40
37	Total hydrocarbons	mg/L	≤5	≤10
38	Phenols	mg/L	≤0,5	≤1
39	Aldehydes	mg/L	≤1	≤2
40	Aromatic organic solvents	mg/L	≤0,2	≤0,4
41	Nitrogenous organic solvents	mg/L	≤0,1	≤0,2
42	Total surfactants	mg/L	≤2	≤4
43	Phosphorus pesticides	mg/L	≤0,1	≤0,1
44	Total pesticides (excluding phosphorous ones) where:	mg/L	≤0,05	≤0,05
45	- aldrin	mg/L	≤0,01	≤0,01
46	- dieldrin	mg/L	≤0,01	≤0,01
47	- endrin	mg/L	≤0,002	≤0,002
48	- isodrin	mg/L	≤0,002	≤0,002
49	Chlorinated solvents	mg/L	≤1	≤2
50	Escherichia coli	UFC/100 mL	note	
51	Acute toxicity test		The sample is not acceptable when after 24 hours the number of immobile organisms is equal or greater than 50% of the total.	The sample is not acceptable when after 24 hours the number of immobile organisms is equal or greater than 80% of the total.

CHAPTER 5

EMERGENCY PLANTS

In emergency situations caused by natural or human catastrophes, the normal functions of civil life are often compromised. The water resource may not be usable by part of the population due to damage to the distribution network, houses, and public buildings.

For this reason, it becomes necessary to respond promptly to the physiological needs of the population:

- quickly providing potable water;
- intervening quickly in case there are damaged sewer systems and treatment plants.

The primary problems related to damage caused to the collection networks and wastewater disposal system regard contamination of the environment and the risk of spreading diseases.
These serious problems can be updated or at least limited by intervening on the structures with quick reconstruction and with the prior purchase of adequate emergency facilities by the States.
In fact, various types of plants can be used that are capable of responding to the various emergencies, from the need to product potable water, to its collection and the treatment and disposal of wastewater.

In this regard, we distinguish the different types of systems according to the problems to be solved. Generally small systems are available, which are installed on wagons and transportable by means of tow bars (universal or suitable for NATO vehicles and adaptable to a wide range of military vehicles) or they can be larger in size and installed in containers. Further diversifications are also variable according to the timing of expected use, calculated for short, medium or long term.
Besides easy transport, another great advantage is that they can be independently run by diesel pumps or solar panels.

Finally, these plants are useful not only in critical conditions. If fresh water sources are not available in the area, in small inhabited settlements the use of these systems can compensate for the shortage of supply sources. The water is supplied to the population through water tankers and drinkable well site.
If power is not available, there are various technologies available to make up for this difficulty. In addition to the solar panels already mentioned above, there are also gravity systems, as in the case of sodium hypochlorite dosing systems (already mentioned in chapter 2). This system uses the force of gravity, which allows the solution to pass from the tank (above) to the tub of the dispenser. Hypochlorite dispensing is adjusted by the displacement of a float that moves inside the dispensing tank, which closes the conduit between the tanks when the contents of the dosing tank is at the maximum, and reopens it when the level of the solution (and the float) is lowered. Liquid dispensing can be adjusted using a capillary through which the sodium hypochlorite is sent to the tank.

Returning to the emergency systems, we now report various solutions differentiated based on the source. Refer to the chapter on potable water for general indications on the various types of treatment used.

5.A FRESHWATER PURIFICATION PLANTS

There are various types of plants available for the purification of fresh water. They differ based on the level of turbidity of the available water.

For water with low turbidity there are two standard phases:

RAPID FILTRATION ON SAND

FILTRATION ON ACTIVE CARBON

DISINFECTION

In general this type of machinery is able to produce 5 m3/h of potable water.
When the quality of water allows, a single, simple filtration unit can be used.

Figure 1: Freshwater purification plants (low turbidity)

For water with medium turbidity, the standard succession stays the same but a preliminary sedimentation is added:

RAPID SEDIMENTATION

RAPID FILTRATION ON SAND

FILTRATION ON ACTIVE CARBON

DISINFECTION

For water with high turbidity, a preliminary treatment of quick sedimentation is always added to the standard treatment and can be also performed in this case with coagulants/flocculants (clariflocculation):

SEDIMENTATION / CLARIFLOCCU-LATION

RAPID FILTRATION ON SAND

FILTRATION ON ACTIVE CARBON

DISINFECTION

Whenever mobile systems are powered with solar panels, the water treatment is divided into quick sedimentation + microfiltration + ultrafiltration + final disinfection. In this case, the production yield is less because the use of alternative energy sources is not able to cope with the higher power, if not with significant costs.

Figure 2: Purification plants for water with high turbidity

5.B BRACKISH WATER PURIFICATION PLANTS

Also compact and installed on transportable wagons or containers, they particularly use the reverse osmosis treatment (with special membranes for brackish water) to treat the salt content. In particular, the phases, in order, are as follows:

Figure 3: Mobile plant for purification of brackish water

> FILTRATION > MICROFILTRATION > REVERSE OSMOSIS > DISINFECTION >

The entire treatment, if necessary, can also be preceded by careful iron elimination.

5.C SEAWATER PURIFICATION PLANTS

In this case the treatment always aims to intervene on the high salt content of the source through reverse osmosis (with specialized membranes for seawater). The various plants always offer the following phases, in order:

> FILTRATION > MICROFIL-TRATION > REVERSE OSMOSIS > REMINERA-LIZATION > DISINFECTION >

Whenever the plant does not provide the possibility of a preliminary filtration treatment, it can be performed through plants suitable for the purification of freshwater, with combination of filtration on sand + active carbon filtration.

Figure 4: Seawater purification plants

5.D WASTEWATER TREATMENT PLANTS

The disposal of wastewater is done through mobile plants that can be installed on containers and easily transported. Standard plants call for the following phases (for the techniques mentioned here, refer to the chapter on the purification of wastewater):

- pretreatment
- denitrification with MBBR
- biological oxidation with MBBR (Moving Bed Biofilm Reactor)
- filtration with MBR membrane (Membrane Bio Reactor)
- disinfection of the water
- dehydration of the sludge

These plants allow re-use and discharge on the ground. With this type of plant wastewater flows of up to 25 m3/day can be treated.
Other types of plants with variable flows can also be created based on need and installation requires small civil works.

Figure 5: Mixed technology MBBR plants + MBR

Plants that use MBBR technology implement a biological treatment of wastewater, as indicated by the abbreviation itself, which stands for moving bed biofilm reactor. This is a highly efficient process in which the microorganisms responsible for the purification process can grow onto special plastic element with high specific surfaces.
The specific weight of the plastic elements is similar to that of water. These elements are dispersed in the biological basin and make the biological sludge grow on the surface. The system works like a fluidized bed.

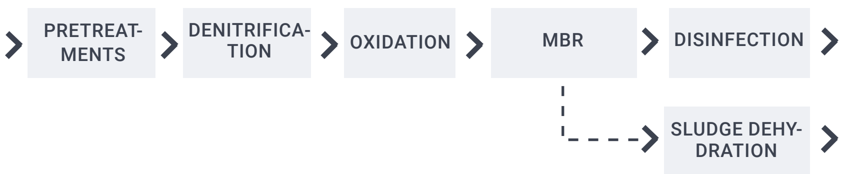
The use of this technique is being imposed in lieu of activated sludge and is particularly indicated for the removal of nitrogen, phosphorous, and organic carbon. A further advantage is due to the fact that this technology concentrates an effective purification treatment in a very small area, reducing the bulk. They are also created in a plant that does not combine this technique with MBR and, in that case, the succession of the purification phases is as follows:

PRETREATMENTS > **DENITRIFICATION WITH MBBR** > **OXIDATION WITH MBBR** > **SEDIMENTATION OF LAMELLATE PACKS** > **DISINFECTION** >

SEDIMENTATION OF LAMELLATE PACKS - - > **SLUDGE DEHYDRATION** >

The MBR membranes discussed above are ultrafiltration membranes specifically used in wastewater treatment. This treatment replaces the usual secondary sedimentation treatments. This plant offers a purification quality that is high enough to allow this water to be re-used in agriculture.

For this technology, plants are also possible that use only this technique, without including the MBBR biomass reactors. The order of the phases is:



5.E ROTO-TANICA: THE WHEEL TANK FOR TRANSPORTING WATER

IIn some countries critical situations occur that are also linked to the poverty of the inhabitants and the territory. In these situations, even the means to get water are difficult to find.
Francesco Anderlini and Stefano Giunta, two young men from Genoa with degrees in Industrial Design patented the “Roto-tanica” in 2006. This object was created to improve situations for supplying water in areas that do not have a distribution network.
Their professional skills combined with particular sensitivity to humanitarian issues led them to create a simple yet useful and innovative product.

Roto-Tanica is a system for transporting liquids that uses the principle of the wheel to facilitate transport, removing the need to lift the load which simply rolls along, preventing physical fatigue. It is particularly indicated in situations where it is not possible or not convenient to use other mechanical and/or motorized means of transport.

It is essentially made up of two elements: a circular tank (hygienic and hermetic) that contains the water to be transported and a metal “handle” for pushing it.

The plastic polymer container with its particular circular shape (which takes

advantage of the width of the radius) and high thickness is able to resist the stress it could be subjected to during intensive use at full load.
The galvanized iron handle is designed to ensure excellent grip and to be easily removed from the jug.

So it is an agile and resistant tool that can make water transport safe and quicker. The object has a slight concavity at the rotation axis in order to allow the load to be carried on the head if desired, after removing the handle. This is to reduce any hesitation of possible users and especially to comply with local traditions.

Traditionally, in developing countries, women and children are required to perform the hard task of procuring water, travelling tens of kilometres to collect a few litres of water from rare wells. Roto-Tanica was designed to meet this need. In fact, it can transport 18 litres at a time, avoiding a second or third trip to the well. It is also designed in a playful manner, transforming the tiring daily activity into a typical "game" like pushing a wheel with a stick.

In the beginning, there was little interest in the product. Nevertheless, the two designers did not give up and in 2013 an anonymous donor contacted the "Lions Water for Life MD108 NPO" and offered the ability to produce the first 100 Roto-Tanicas to verify their usefulness in the field. After experimentation in Italy on terrain similar to African terrain, the "Lions Water for Life MD108 NPO" took some samples to Burkina Faso during the 2014 mission and gave them to the school in the village of Zekounga to try them out in daily life.

During its first uses in Burkina Faso Roto-Tanica earned the consent of the village chiefs, a determining detail for the success of the experiment.

Figure 6: The Roto-Tanica in Burkina Faso

CHARACTERISTICS

- Made in Italy
- Stackable
- Can be completely emptied
- Airtight lid
- Non-toxic recyclable material certified for the transport of potable liquids
- Structure designed to withstand stress
- Textured rolling surface to improve steering on loose ground
- Handle with quick removal system
- Concave side surfaces

SPECIFICATIONS

- Capacity 18 litres = 12 bottles of water
- Weight 3 Kg
- Diameter 16” (406 mm)
- Height 200 mm
- Positioning on the pallet: 6 Roto-tanicas per level (h 200 mm), a total of 30 on a 1 metre high pallet and a total of 60 on a 2 metre high pallet.

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This publication was created with
the contribution of the **Idro Group**

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Graphic design: **WAD Agency S.r.l.**
Printed in June 2015

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