Decision-making guide for the implementation of a

TWR*

project

*Treated Wastewater Reuse

BRL INGÉNIERIE

TWR facility in Roquefort-de-Corbières (Aude), operated by BRL Exploitation

This guide has been drawn up by BRL Ingénierie, as a continuation of its research and development activities in the field of treated wastewater reuse (NOWMMA project).

The NOWMMA project was a collaborative research and development project devoted to the design of a modular system adapted to the controlled reuse of treated wastewater for various purposes in France and the Mediterranean basin. It is based on an initial experimental application on the Pays de l'Or Agglomération territory, in Mauguio, Languedoc Roussillon.

An initial A index was published in 2017, followed by a B index in 2022, which was enriched by a wealth of additional feedback from experience and consulting engineering in France and abroad, as well as additional bibliographical research to flesh out the country fact sheets.

The present guide is index C, which incorporates updates to French regulations, notably with Decree no. 2023-085 of August 29, 2023, followed by the publication of decrees on TWR for watering green spaces and agricultural irrigation, respectively published on December 14 and 18, 2023.

Lastly, Decree no. 2024-33 of January 24, 2024 on water reused in the food industry and various provisions relating to the safety of water intended for human consumption completes the new French regulations.

Informations

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List of acronyms

ANSES : Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail

AOX : Composés organo-halogénés adsorbables

Asp : Aspersion

COT : Carbone Organique Total

Cu : Coefficient d'uniformité

DALY : Année de vie corrigée de l'incapacité

DBO : Demande Biologique en Oxygène

DBO5 : Demande Biologique en Oxygène à 5 jours

DCO : Demande Chimique en Oxygène

DGCIS : Direction générale de la compétitivité de l'industrie et des services

ECO : Economique (englobe toutes les activités humaines d'un projet)

EPA : U.S. Environmental Protection Agency

ETP : Evapotranspiration potentielle

EUT : Eaux Usées Traitées

FAO : Organisation des Nations Unies pour l'alimentation et l'agriculture

FaS : Filtre à sable

FIN : Finance (représente les ressources nécessaires à la réalisation d'un projet économique)

GaG : Goutte à goutte

HAA : Acides haloacetiques

HAN : Haloacetonitriles

Kc : Coefficient cultural

MF : Microfiltration

MES : Matières en suspension

NF : Nanofiltration

NFU : Nephelometric Formazin Unit

NOWMMA : New process for Optimizing Wastewater Reuse from Mauguio to the Mediterranean area

NPP : Nombre le Plus Probable

NTU : Nephelometric Turbidity Unit

OI : Osmose Inverse

OMS : Organisation Mondiale de la Santé (ou en anglais World Health Organisation (WHO))

QMRA : Evaluation quantitative des risques microbiens (en anglais Quantitative Microbial Risk Assessment)

REUT : Réutilisation des Eaux Usées Traitées (ou en anglais REUSE)

RFU : Réserve Facilement Utilisable

RU : Réserve Utile

SPD : Sous-Produits de Désinfection

STEU : Station de Traitement des Eaux Usées (ou station d'épuration (STEP))

List of acronyms (continued)

THM : Trihalométhanes

TOX : Composés organo-halogénés totaux

UF : Ultrafiltration

UFC : Unité Formant Colonie

UV : Ultraviolet

TWR facility in Roquefort-de-Corbières (Aude), operated by BRL Exploitation

Introduction

The reuse of treated wastewater (TWR) is a topical subject that has been the subject of numerous calls for projects around the world for decades. However, the use of treated wastewater (TWE), a non-conventional resource, for specific or multiple uses remains minor in France (apart from a few emblematic projects such as in Clermont-Ferrand, Noirmoutier, etc.), unlike in other countries.

Since 2010, the implementation and evolution of French regulations, and the formation of national working committees are evidence of the dynamism of this issue, which mobilises the energies of many players, such as industrialists, design offices and researchers. This dynamic could enable LWR to make a breakthrough in France. Without waiting for this confirmation, the research work carried out within the framework of the NOWMMA project has made it possible to draw up this guide, which is aimed above all at a public working within the geographical perimeter of the Mediterranean arc.

In light of the advances in WASP, this report presents an update of the NOWMMA guide by integrating:

- Further information on regulation at European level and in some countries country level,
- Presentation of emblematic LWR projects.

The implementation of a WAS project is a special process involving a large number of multidisciplinary actors, who are confronted with the specificities of TME use and the complex mechanisms involved in setting up a project.

This guide, which is mainly based on the studies of tasks 2 and 1 of the NOWMMA project, and to a lesser extent the other tasks, aims to:

- To be a decision support guide for the implementation of a WASR project;
- To provide the reader with preliminary and general knowledge on wastewater reuse (WWR).

A clear understanding of the framework and scope of this document is essential for its reading. First of all, this document is not intended to be a technical manual for the design and sizing of TWR water treatment plants. This document has been drawn up with the intention of providing an informative guide for the project owner of a future TWR project or for any person wishing to become involved in or to promote the implementation of a TWR project. The scope of this document does not therefore go beyond providing information and assisting in decision-making.

The aim of this guide is to enable the reader to assimilate the issues, obstacles and limits of TWR as a whole. It will also enable the reader to be aware of the different specificities of TWR, from project design to the operation of future facilities, in order to make the implementation of the project as efficient as possible. The various information gathered in this guide will enable the reader to develop a critical view of the various options that may be proposed to him/her by providing a knowledge base.

As TWR is a constantly evolving subject, the elements cited in this document do not constitute an exhaustive list of knowledge on TWR, but rather a status report on TWR at the time the document was written. In this sense, this new version of the guide will have the possibility of being enriched or amended by its authors, according to the progress made on the subject of TWR.

1- The reuse of treated wastewater (TWR)

1.1 What is TWR?

The French National Agency for Food, Environmental and Occupational Health Safety (ANSES) defines TWR as the final stage of a process that starts with the collection of wastewater, continues with a treatment operation to purify this water and ends with its storage before reuse. This last stage can however be completed by various tertiary treatments according to the downstream uses allowing an improvement of the water quality.

The reuse of treated wastewater (TWR) is a practice that aims to give a second life to TMEs discharged by treatment plants. WASR therefore consists of the use of a non-conventional water resource, which is the water leaving the wastewater treatment plant (WWTP).

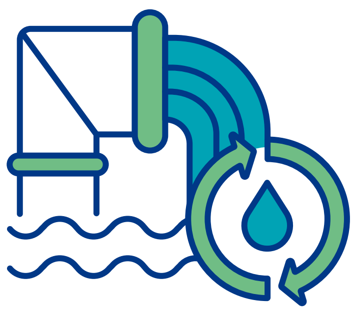
This resource, the quality of which varies according to the type of treatment of the WWTP, is improved by the implementation of tertiary treatments that are more or less effective according to the sanitary requirements for reuse, which themselves depend on the nature of the need to be met. It is therefore often a final filtration and disinfection operation that is more or less strict depending on the use.

1.2 In which water and territorial context can it be interesting to carry out LWR? With what objectives? With what tools to base the decision?

Agricultural irrigation is putting significant pressure on the world's freshwater supplies. In water-stressed countries, it may now be vital to turn locally to unconventional resources such as treated wastewater (TW).

General population growth, large-scale changes in diets, industrial development, etc., are leading to increasingly massive use of water resources, whether for drinking water production, crop irrigation, or material and energy production processes. The exodus of rural populations to the cities has the effect of increasing the volumes of water to be treated and discharged into the natural environment, most of the time in a more polluted form. This quantitative increase in demand for water is occurring at a time when access to the resource is becoming increasingly scarce and environmental protection issues are becoming more widespread.

Thus, the primary motivation for TWR will most often be the need to find an alternative to natural freshwater resources, which are under increasing pressure and are even causing shortages. In figures, the average annual renewable water per capita is expected to decrease from 6,600 m^3 in 2000 to 4,800 m^3 in 2025[1]. The first countries to be affected will be those currently under water stress, which is the case for the majority of countries in the Mediterranean basin, the target of the NOWMMA project. At the same time, population growth requires an increase in agricultural production but also generates more wastewater. It is estimated that agriculture accounts for 70% to 80% of the world's freshwater withdrawals[2]. The combination of all these factors provides a converging set of arguments for the overall use of TWR.



Economically, TWR can provide an opportunity for a country or territory to develop its agricultural production with less impact on its natural resources. Financially, TWR is generally uncompetitive with conventional water. However, in regions where freshwater resources are scarce and costly to exploit, and where other resource provision technologies such as desalination are expensive, TWR can be competitive in terms of the cost price of water production.

1 C. BOUTIN, A. HEDUIT, J.M HELMER. Final report on action 28: Reuse of treated wastewater in the framework of the ONEMA-CEMAGREF 2008 partnership agreement. November 2009. 100p.

2 WORLD HEALTH ORGANIZATION WHO Guidelines for the safe use of wastewater, excreta and greywater (Volume II Use of wastewater in agriculture). WHO. 225p. ISBN 978-92-4-254683-5

This being said, the relevance of using WAS for a given territory must be estimated more precisely by finely analysing its water context. For example, the discharge of a WWTP into a river located upstream of a catchment area constitutes an indirect reuse by providing low water support which may be significant for the river itself and/or for uses located further downstream. In this case, direct reuse of TMEs is not always relevant. This situation is found, for example, in many rivers on the Mediterranean coast which suffer from a water deficit and where the TMEs discharged into them are not considered a 'lost' resource. In other cases, particularly where TMEs are discharged to the sea or to a continental receiving environment with few permanent surface runoff issues, direct TME may be relevant to other water resource allocation scenarios.

In this case, LWR may allow the development of water uses via the provision of a new resource. But it could also allow a new distribution of the types of water resources according to the level of requirement of the uses in terms of quality. For example, the choice could be made to use TMEs for agricultural production in already existing irrigated areas in order to preserve, for uses such as drinking water supply, the freshwater formerly used in these areas. This shift in use can avoid the need to withdraw more freshwater resources while meeting the growing demand for water. This approach shows the interest of situating TMEs in relation to the overall mix of water resources in a territory.

For this, it will be useful to develop integrating tools such as water balances including all resources and uses, territorial approaches (understanding the socio-economic context and its evolution) and economic approaches such as **Cost-Benefit Analyses** in order to take into account the negative and positive externalities of TMEs and to compare different water resource allocation scenarios. Such a global approach has been adopted by BRLi, for example, on the scale of all the territories of Tunisia. It has made it possible to show, among other things, the interest that there could be in substituting fresh water coming from the dams in the North of the country and used in existing irrigated areas with the TMEs of the Tunis agglomeration, which are currently discharged into the sea and are sources of pollution. The dimension of the territory on which a systemic approach can be conducted, in a multidisciplinary approach integrating technical and socio-environmental aspects, is to be adapted according to the size of the project and its relative water weight compared to the other water resources present on the territory.

In parallel with integrated approaches that are long-term, it should be mentioned that projects that are more a matter of local opportunities, directly linking an expressed need with a source of TMEs available in a short time, may be satisfied with less in-depth studies than for large-scale projects, but without compromising on regulatory and health compliance.

Another type of approach, which is quite frequent, is in the context of the regularisation of indirect reuse situations. In this type of case, it is necessary to measure the positive and negative impacts of maintaining indirect reuse (taking into account the «cost of inaction»), even if it is not in line with a regulatory framework that has evolved for new projects, and to symmetrically measure the impacts of planning to comply with the regulations. In such an approach, we were able to show, in the La Paz WASP project in Bolivia (a case of indirect reuse in the current situation without treatment, but by dilution), the preponderance of social factors (difficult to monetise, which makes the CBA approach tricky) in guiding the decision between maintaining indirect reuse but with treatment, and moving towards direct reuse with treatment. Multi-criteria analysis» type tools seem well suited to guide the client in the final decision.

WWR will make it possible to meet quantitative objectives by providing a new water resource, but also qualitative objectives by limiting the impact of WWTP discharges on the natural environment. However, in addition to providing a regular water resource, WASP also makes it possible to restore a good quality water resource. Indeed, the tertiary or complementary treatment adapted to the use in good working order, guarantees a water quality suitable for use, of good quality, or even of better quality than that of the natural environment of the original resource (the qualitative objective being configurable). In this respect, it is worth noting the contribution that **Life Cycle Assessment** type approaches can make to the basis of a decision to use a TME as a substitute, from an environmental point of view.

It can therefore be seen that the question of whether or not to implement a WASTE project can be assessed from different perspectives, essentially linked to the scale of the reflection conducted, and that different tools, such as classic multi-criteria analyses, but also CBAs or LCAs, can be used as a basis for the implementation decision. But in many cases, given the exposure of many stakeholders covering all the states of society and the economic fabric, the decision to implement a WASTE project will be taken at a political level (even locally). It is therefore necessary to define in advance with the final decision-makers the method that will be used and the tools that will be employed.

1.3 What uses?

It should be noted that in most of the projects, even if the quantitative objective remains the priority, the qualitative objective is often associated and allows the safeguarding of natural areas or water tables. In some cases, WASP projects are motivated by the protection of an environment that is strongly subject to tourist pressure.

Other interests allow the development of WASP projects, particularly for agricultural irrigation. Indeed, the nature of the water from a WAS system offers the possibility of providing nutrients to the crop, which is deducted from fertilisers. However, this benefit must be qualified because other elements that are harmful to crops and soils can be brought in if WASTE is not controlled.

Some uses of water, such as irrigation of certain crops or green spaces, or washing of roads, do not necessarily require the use of very good quality water. The reuse of treated wastewater is therefore an alternative technical solution to reduce the pressure on the natural freshwater resource.

A non-exhaustive list of the most frequent uses is presented below:

- Agricultural irrigation
- Watering of green areas (public, golf, etc.)
- Washing of roads
- Recharging of groundwater
- Cooling or process water in industry
- etc.

Agricultural irrigation is the main and oldest purpose for wastewater reuse.

1.4 Agricultural irrigation: specificities of LWR

Agricultural irrigation is the oldest use of wastewater. Indeed, domestic wastewater has been used either directly or more or less diluted for centuries for irrigation purposes in various water-poor areas, Maghreb, Near and Middle East, South Asia (especially India). This type of use is still widespread and sometimes causes acute public health problems. In France, the emblematic example was the so-called «Achères» spraying. These are watering operations using urban effluents that are little or untreated, which began more than 150 years ago, at the time of Baron Haussmann[3].

Originally only a spreading of raw wastewater and an alternative sanitation technique, wastewater reuse is now more elaborate, especially when it incorporates tertiary treatment (this is called treated wastewater, or TWE, which is the subject of this deliverable). However, the evolution and use of irrigation equipment raises certain questions regarding the use of TMEs.

Two types of questions arise for each type of irrigation: one concerning operating methods with regard to health risks and the other concerning equipment maintenance constraints.

Generally speaking, there are several types of irrigation:

- **By submersion:** The water runs on the surface of the plot to be irrigated, either by means of a defined line (or with the aim of covering a good part of the surface.

- **By sprinkling:** the principle of this type of irrigation is to reproduce rain artificially by aerial distribution of water.

- **By localised irrigation:** the water is distributed to the crop in a localised way on a portion of the soil by means of small diameter pipes.

3 J. Dunglas - Wastewater reuse - Water Group - working paper n°5 - 2014 - French Academy of Agriculture

TMEs have a different composition from water normally used in agriculture due to the higher presence of plant nutrients, but also, theoretically, due to the risks of plant contamination (phytopathogenic[4] risk). Thus, regular measurements of the quality of the water used should be carried out.

The different risk thresholds evolve according to the regulations of each country, presented in the following section. It is interesting to note that the assessment of the health risks incurred by irrigators, residents and consumers of agricultural products in terms of contact with TMEs depends on the type of irrigation.

Flood irrigation involves covering part or all of the soil with water. Irrigators are therefore in direct and frequent contact with water. There may be some areas of stagnant water, which represents a high health risk associated with this type of water. There is no impact of TME on irrigation equipment as the water is simply delivered to the site and runs off the soil. The delivery of water by this technique is often poorly controlled and excess water tends to percolate below the root zones, or to return to the natural surface environment via the drainage ditches. In the case of TMEs, the use of this type of irrigation can result in an excessive input of certain elements to the soil (such as salt or pollutants) which can be harmful to both the crop and the soil.

Sprinkler irrigation is a very common irrigation technique. When using it with TMEs, a problem arises with sprinkler drift. Drift is the phenomenon of water droplets changing their trajectory due to the effect of wind. Thus there is a risk of contaminating people at the edge of the plots if the wind is strong enough. Research has been carried out for many years on this subject (including in the NOWMMA project) to characterise drift as a function of climatic and sprinkler operating conditions.

The last type, localised irrigation, is the only type of irrigation that limits the contact between users and water as much as possible. On the other hand, to distribute the resource in a localised manner, this irrigation technology, which can be buried, uses networks of pipes and emitters (drippers, mini-diffusers, micro-jets, etc.) with very small diameters that are sensitive to clogging. TMEs usually contain a higher concentration of suspended solids than conventional water, and require an adequate level of treatment. This type of irrigation offers the greatest sanitary safety in relation to the use of TMEs, but is the most costly in terms of transport and distribution.

It should be noted that the choice of irrigation type is influenced by many parameters, such as topography, soil type, weather conditions, maximum allowable cost per hectare of the installation, farmers' know-how, and the crop to be irrigated.

4 Theoretical risk to be qualified because the bibliographical study carried out on the subject in the framework of NOWMMA showed that this risk has never been established in the literature.

2- Prior knowledge

2.1 Health risk assessment parameters

Health risks are assessed by monitoring and analysing numerous water quality parameters. This section presents the main parameters monitored to control and monitor health risks. The minimum parameters to be monitored are for the most part determined by the regulations in force, however it may be relevant to go beyond these regulations in order to improve knowledge on WASTE (collect a maximum of data, understand the phenomena, etc.), and to take into account emerging pollutants such as endocrine disruptors...

2.1.1 Physico-chemical parameters

Temperature = a decrease in temperature impacts the efficiency of biological treatments and filtration rates (for membranes only). Conversely, an increase in temperature leads to bacterial growth and corrosion (production of H_2S in particular).

pH = indicates the degree of acidity or alkalinity of the water.

Turbidity = overall measurement of all particles in suspension in the water capable of reflecting a light beam: algae, clays, silt, organic particles, etc.

→ *References :*

Type	Base value
Groundwater	Low particulate matter and turbidity < 1 NFU
Surface water	2 NFU < T < 100 NFU
Severely eroded catchments	Up to 10,000 NFU

Conductivity = measurement in µS/cm or mS/cm of the electrical conductivity of water. This parameter makes it possible to assess the concentration of salts in the water. The higher the salinity of the water, the higher the conductivity.

→ *Reference :*

- drinking water (decree 11/01/07) = 200 to 1 100 µS/cm (at 25°C)w
- water irrigation (FAO - good irrigation practice) = 700 to 3 000 µS/cm (at 25°C)

Suspended solids (SS) = fine particles that give a turbid appearance such as sand, clay, micro-organisms, etc.

Chemical Oxygen Demand (COD) = the amount of oxygen consumed by oxidising materials in water, regardless of their organic or mineral origin. COD gives an overall measure of organic matter and certain oxidisable mineral salts (organic pollution).

Total organic carbon (TOC) = Total amount of organic matter including dissolved organic carbon and particulate organic carbon in water. TOC gives information on the organic load of a water (natural organic or entropic: industrial or agricultural). It is an indicator for monitoring organic pollution.

2.1.2 Bacteriological parameters

Total coliforms = a family of bacteria, many of which are indicators of faecal contamination. Total coliforms do not only originate from faeces but can also develop in natural environments.

Faecal or thermotolerant coliforms = faecal part of total coliforms. The presence of these coliforms is indicative of pollution of faecal origin.

Escherichia coli = Bacteria from the faecal coliform family, indicative of recent faecal contamination.

Faecal Enterococci = indicator bacteria of faecal contamination. They can survive longer in natural environments than total coliforms and E. Coli. They are evidence of past faecal contamination. They are very resistant and have a great capacity for growth.

Total flora = represents the microorganisms present in the water. A high total flora is indicative of a high presence of biofilm in the pipes. The development of biofilm increases the risk of clogging and bacterial growth.

F-specific RNA bacteriophages = F-specific RNA bacteriophages are viruses that infect Escherichia coli and have a structure and size comparable to the main enteric pathogenic viruses. They are proposed as indicators of faecal pollution of the water environment, as models of the behaviour of pathogenic viruses in the environment and as a tool for discriminating the origin of faecal pollution.

Spores of anaerobic sulphite-reducing bacteria = spore form, indicative of the effectiveness of the disinfection of a treatment system as they are more resistant than total coliforms and E. Coli. Not only of faecal origin.

Helminth eggs = eggs of parasites leading to animal and human parasitic diseases that can be transmitted to humans through direct contact with wastewater or indirectly through the consumption of products containing eggs.

Legionella = these bacteria are present in water, and are responsible for legionellosis. The recent emergence of this disease is explained by its affinity for modern water supply systems. Monitoring this parameter as part of a WASER project is justified if there is a risk of aerosol formation.

2.2 Regulation

2.2.1 Regulations vary from country to country where they exist

There is no single international regulation defining, for a given use, a treatment technology to be implemented.

The regulatory framework, when it exists, is country-specific and can even be different within a country: for example, the United States has different regulations per state. It imposes a quality of water that depends on the end use of the water in order to protect operators and users. Regulations differ from country to country. For some countries, there is no regulatory framework and in this case they rely on regulations already established by other countries or by the WHO.

The tables below aim to highlight this variability of regulations related to treated wastewater reuse, by grouping geographical areas together:

- Different parameters for characterising microbiological quality in different countries,
- Differences between regulated uses.

Characterisation of microbiological quality by country

Geographical area, country or organisation	Most demanding quality for faecal coliforms or E. coli	Comments
OMS (2012)	-	No E. coli concentration value but target of 10-6 DALYs per person per year, i.e. a reduction of pathogens to 7 logs
Europe	10 units/100 mL in E. coli	
Cyprus	15 to 100 units/100 mL in faecal coliforms depending on use	
Spain	From 0 to 200 units/100 mL in E.coli depending on the use	
USA	14 to 75 units/100 mL in faecal coliforms depending on the state	Some states have no values for faecal coliforms or E. coli but have values for total coliforms
Israel	No value for this parameter Faecal coliforms or E. coli	Has a total coliform value (12 units/100 ml (80%)
2.2 units/100 ml (50%))		
China	20,000 units/100 mL fecal coliforms	
Tunisia	-	No requirements on these parameters in NT 106.03

2.2.2 Examples of regulation

The main regulations are listed below.

Guidelines for the safe use of wastewater, excreta and grey water (1/5)

The WHO Guidelines for the safe use of wastewater, excreta and greywater (2006 edition) recommend that the following elements be taken into account when developing national regulations for the reuse of treated wastewater:

- **Identifying the hazards** associated with the reuse of treated wastewater;
- Production of evidence on **health risks and the effectiveness of health protection measures** to manage them;
- **Setting health-related targets** for managing health risks;
- **Implementing health protection measures** to achieve health-related objectives;
- **Evaluation and monitoring of the system.**

This pragmatic approach proposes the **definition of health-related objectives and the assessment of health risks resulting from wastewater reuse**. It differs from a normative approach based only on thresholds to be met. Thus, the objectives are not taken as absolute values, but more precisely as objectives to be achieved in the short, medium and long term, depending on the technical capacities of the country and its institutional and economic conditions. According to this approach, the following points can be noted:

- Quantitative microbial risk assessment (QMRA) is carried out by considering the transmission of infections resulting from various exposures for consumers of the reused products, agricultural workers and their families and the population near the reuse areas for different hazards and exposures.
- The applicable health protection measures to achieve the health-related objective of a tolerable burden of disease are defined for different combinations of cultural practices and treatment level for bioburden reduction.
- For chemical hazards, maximum tolerable soil concentrations for various toxic chemicals are set based on the health risk assessment with the objective of protecting human health.

Guidelines for the safe use of wastewater, excreta and grey water (2/5)

The WHO published guidelines for the safe use of wastewater, excreta and greywater in 2012. In these WHO guidelines for the use of wastewater in agriculture (volume II of the guidelines):

- The health-related objective adopted is that the additional burden of disease should be less than or equal to the tolerable value of 10-6 DALYs per person per year.
- A step-by-step methodology is proposed (if extensive and reliable epidemiological data are available, such as on the pathogens rotavirus, Campylobacter and Cryptosporidium):
  - Stage 1: Tolerable risk of infection,
  - Stage 2: QMRA,
  - Stage 3: Necessary pathogen reduction,
  - Stage 4: Sanitary protection measures to achieve the necessary pathogen reduction
  - Step 5: Surveillance/verification,
- For helminth eggs, as the numerous and reliable epidemiological data were not sufficient, a different methodology was used than before but still based on epidemiological and field studies.

In Volume II Uses of Wastewater in Agriculture, WHO shows the effects of wastewater use on soils, crops and livestock according to different physico-chemical parameters. Among others, wastewater containing:

- BOD5 of 110-400 mg/L will benefit the soil in several ways and productivity
- Suspended solids > 100 mg/L will be problematic for irrigation efficiency
- Conductivity > 3 dS/m will cause salinisation problems
- A pH of 7-7.4 will have no effect (outside the range of 6.5 and 8.5 there may be a risk of solubilisation of metals depending on the pH)
- Solubilisation of metals depending on the alkalinity of the soil)

The guidelines differentiate between types of irrigation and types of crops.

Guidelines for the safe use of wastewater, excreta and grey water (3/5)

Table of the Guidelines Volume II :

Health-related objectives for the use of treated wastewater in agriculture

Exposure scenario	Health-related target (DALYs per person per year)	Log10 of pathogen reduction required[a]	Number of helminth eggs per litre
Unrestricted irrigation	≤ 10−6[a]		
Lettuce		6	≤ 1[bc]
Onion		7	≤ 1[bc]
Restricted irrigation	≤ 10−6[a]		
Highly mechanised agriculture		3	≤ 1[bc]
Labour-intensive agriculture		4	≤ 1[bc]
Localized irrigation (drip irrigation)	≤ 10−6[a]		
Taller crops		2	Pas de recommandations[d,e]
Low-lying crops		4	≤ 1[bc]

[a] Rotavirus reduction. In the case of unrestricted or localized irrigation, the health-related objective can be achieved by a pathogen reduction of 6-7 log units (achieved through a combination of wastewater treatment and other health protection measures, including an estimated 3-4 log unit reduction due to natural die-off of pathogens under field conditions and removal of these pathogens from irrigated crops through routine domestic washing and rinsing operations; see Part 4. 2.1 (of the guidelines volume II) for more details; in the case of restricted irrigation, this is achieved by a reduction of pathogens by 2-3 log units (part 4.2.2 of the (guidelines volume II)).

[b] In case children under 15 years of age are exposed, additional health protection measures should be applied (e.g. water treatment to ≤ 0.1 egg per litre, protective equipment such as gloves, shoes or boots, or chemotherapy; see sections 4.2.1 and 4.2.2 (of the guidelines volume II) for details).

[c] The arithmetic mean over the entire irrigation season should be determined. An average value ≤1 egg per litre should be obtained for at least 90% of the samples, although occasionally some samples may reach high values (i.e. >10 eggs/litre). With some wastewater treatment processes (e.g. stabilisation ponds), it is possible to use hydraulic residence time as a proxy to ensure compliance with the ≤ 1 egg/litre condition, as explained in Section 5.6.1 (of the Volume II Guideline) and in Box 5.2 (of the Volume II Guideline).

[d] See section 4.2.3 (of the Guidelines Volume II).

[e] No crops should be picked up from the ground.

With regard to pathogens, the guidelines state that a pathogen reduction of 6-7 log units can be achieved by applying appropriate combined sanitary protection measures, each of which is associated with a reduction or range of reduction in log units.

Guidelines for the safe use of wastewater, excreta and grey water(4/5)

Table of the Guidelines Volume II

Pathogen reductions achievable through various health protection measures

Pathogen control measures[a]	Pathogen reduction (logarithmic units)	Notes
Wastewater treatment	1–6	The pathogen reduction to be achieved by wastewater treatment depends on the combination of sanitary protection measures chosen (as shown in Figure 4.1 (of the Guidelines Volume II); the pathogen reductions achieved for different wastewater treatment options are presented in Chapter 5 (of the Guidelines Volume II))
Localized (drip) irrigation (low crops)	2	Root crops and crops that, like lettuce, grow just above and partially in contact with the soil
Irrigation localisée (par goutte-à-goutte) (cultures de grande hauteur)	4	Crops such as tomatoes, where the harvested part is not in contact with the soil
Localized (drip) irrigation (tall crops)	1	Use of micro nozzles, directional nozzles, anemometer-controlled nozzles, downward-facing nozzles, etc.
Spray-free buffer zone (overhead irrigation)	1	Protection of people living in the vicinity of the sprinkler irrigation area. The buffer zone should be 50-100 m
Pathogen dieback	0,5 à 2 par jour	Pathogen dieback on the surface of the crop occurring between the last irrigation and consumption. The reduction in logarithmic units obtained depends on the climate (temperature, sun intensity, humidity), the time elapsed, the type of crop, etc.
Washing of products with water	1	Washing salads, vegetables and fruit with clean water
Disinfection of products	2	Washing salads, vegetables and fruit with a weak disinfectant solution and rinsing with clean water
Peeling of products	2	Fruit, root vegetables
Cooking of products	6-7	Immersion of the products in boiling or near-boiling water until they are cooked ensures the destruction of pathogens.

[a] Ces mesures sont décrites en détail au chapitre 5 (des directives volume II).

2012

World Health Organization (WHO)

Guidelines for the safe use of wastewater, excreta and grey water (5/5)

These multiple barriers, in order to be most effective, must occur at all possible levels of the chain: from the point of production of the TME, through the farmer and/or producer and/or trader, to the consumer or user.

With regard to helminth egg reduction, the Volume II guidelines provide examples of options for helminth egg reduction through two sanitary protection measures and associated verification requirements.

Table of the Guidelines Volume II

Options for reducing helminth eggs by sanitary protection measures for various numbers of helminth eggs in untreated wastewater and associated verification requirements

Health protection measure	Number of helminth eggs per litre of untreated wastewater	Reduction of helminth eggs to be achieved by the treatment (logarithmic units)	Monitoring/ verification level (helminth eggs per litre of treated wastewater)[a]	Notes
Treatment	103	3	≤1	The treatment must be shown to reliably achieve this water quality (see also Box 5.2 (in Guidelines Volume II))
	102	2	≤1	
	10	1	≤1	
	≤ 1	0	S. O.	The target of ≤ 1 egg per litre is automatically reached
Processing and washing of products	103	3	≤10	The reduction achieved by the treatment is followed by a reduction of one logarithmic unit by washing the products with a weak detergent solution and rinsing with clean water
	102	2	≤10	As above
	10	1	S. N/A	The required reduction of one logarithmic unit is achieved by washing the products with a weak detergent solution and rinsing with clean water
	≤ 1	0	S. N/A	The target of ≤ 1 egg per litre is automatically reached

S. N/A: not applicable.

[a] In the case of stabilisation ponds, the residence time in the pond can be used as a means of verification, as explained in Box 5.2 (of the Guidelines Volume II) (At present, there are generally no valid surrogate means of monitoring other treatment processes, although it is possible to develop such means locally).

[b] This is only valid if the practice of washing is common or if it can be effectively promoted and verified (see Table 4.3 (in Guidelines Volume II)).

Comments:

- Most countries that initiate TWR projects without their own regulatory framework use WHO health requirements.

- These include Germany, as well as other European countries without their own regulations for TWR.

technical sheet

REGULATION (EU) 2020/741 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 May 2020 on minimum requirements for water reuse (1/4)

On 5 June 2020, the European Parliament and the Council published the **Regulation on minimum requirements for water reuse**, in order to alleviate the pressure on water resources and promote the reuse of treated wastewater, in particular for agricultural irrigation. The regulation is intended to be flexible, to allow Member States to include additional measures. Until now there were no common environmental and health standards at EU level, this regulation aims to promote the circular economy, adapt to climate change and **establish minimum requirements for water quality**, monitoring and risk management provisions. It determines the responsibility of the different actors to ensure the protection of the environment and human and animal health.

The minimum requirements for reclaimed water for agricultural irrigation are as follows:

Minimum quality class of reclaimed water	Crop category (*)	Irrigation method
A	All food crops eaten raw where the edible part is in direct contact with reclaimed water and weeds eaten raw	All irrigation methods
B	Food crops eaten raw, the edible part of which is grown above ground and is not in direct contact with reclaimed water, processed food crops and non-food crops, including crops used as feed for milk or meat producing animals	All irrigation methods
C	Food crops eaten raw, the edible part of which is grown above ground and is not in direct contact with reclaimed water, processed food crops and non-food crops, including crops used as feed for milk or meat producing animals	Drip irrigation (**) or other irrigation methods that avoid direct contact with the edible part of the crop
D	Industrial, energy and seed crops	All irrigation methods (***)

(*) Si le même type de cultures irriguées relève de plusieurs catégories du tableau 1, les exigences de la catégorie la plus stricte s'appliquent.

(**) Drip irrigation is a micro-irrigation system that delivers drops or small streams of water to plants by dripping water onto the soil or directly below its surface at a very low rate (2-20 litres/hour) from a system of small-diameter plastic pipes with outlets called emitters or drippers.

(***) In the case of sprinkler irrigation methods, special care shall be taken to protect the health of workers and others present. Appropriate preventive measures shall be applied to this effect.

REGULATION (EU) 2020/741 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 May 2020 on minimum requirements for water reuse (2/4)

Quality requirements						
Quality class of the reclaimed water	Indicative technological objective	E. coli (number/ 100 ml)	DBO5 (mg/l)	MES (mg/l)	Turbidity (NUT)	Others
A	Secondary treatment, filtration and disinfection	≤ 10	≤ 10	≤ 10	≤ 5	Legionella spp.: < 1,000 cfu/l where there is a risk of aerosol formation Intestinal nematodes (helminth eggs): ≤ 1 egg/l for pasture or forage irrigation
B	Secondary treatment and disinfection	≤ 100	25	35 (more than 10,000 P.E.) 60 (from 2000 to 10000 P.E.)	-	
C	Secondary treatment and disinfection	≤ 1000			-	
D	Secondary treatment and disinfection	≤ 10000			-	

Reclaimed water is considered compliant when:

- the indicated values for E. coli, Legionella spp. and intestinal nematodes are met in at least 90% of the samples; none of the values measured on the samples exceeds the maximum deviation of 1 log unit from the indicated value for E. coli and Legionella spp. and 100% of the indicated value for intestinal nematodes
- the indicated values for BOD5, TSS and turbidity of category A are complied with in at least 90% of the samples; none of the values measured on the samples exceeds the maximum deviation of 100% of the indicated value.

REGULATION (EU) 2020/741 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 May 2020 on minimum requirements for water reuse (3/4)

Routine monitoring should be carried out at the following frequencies:

Minimum monitoring frequencies						
Quality class of the reclaimed water	E. coli	DBO5	MES	Turbidity	Legionella spp. (if applicable)	Intestinal nematodes (if applicable)
A	1x/week	1x/week	1x/week	Continuous	2x /week	2x /week or as determined by the recovery facility operator based on the number of eggs in the wastewater entering the recovery facility
B	1x/week	In accordance with Directive 91/271/EEC (Annex I, Section D)	In accordance with Directive 91/271/EEC (Annex I, Section D)	-		
C	2x/week			-		
D	2x/week			-		

As well as pre-commissioning validation monitoring of recovery facilities for Class A:

Quality class of the reclaimed water	Indicator microorganisms (*)	Treatment line performance targets (log10 reduction)
A	E. coli	≥ 5,0
	Total coliphages/F-specific coliphages/somatic coliphages/coliphages (**)	≥ 6,0
	Spores of Clostridium perfringens/sulphite-reducing anaerobic bacteria and their spores (***)	≥ 4,0 (in the case of Clostridium perfringens spores) ≥ 5,0 (in the case of sulphite-reducing anaerobic bacteria and their spores)

(*) The reference pathogens Campylobacter, rotavirus and Cryptosporidium may also be used for validation monitoring, instead of the proposed indicator microorganisms. The following performance targets, expressed as log10 reduction, should apply in this case: Campylobacter (≥ 5.0), rotavirus (≥ 6.0) and Cryptosporidium (≥ 5.0).

(**) Total coliphages are chosen as the most appropriate viral indicator. However, if analysis of total coliphages is not possible, at least one of them (F-specific coliphages or somatic coliphages) should be analysed.

(***) Clostridium perfringens spores are chosen as the most appropriate indicator of protozoa. However, sulphite-reducing anaerobic bacteria and their spores offer an alternative if the concentration of Clostridium perfringens spores does not validate the required log10 reduction.

2020

European Union (EU)

REGULATION (EU) 2020/741 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 May 2020 on minimum requirements for water reuse (4/4)

Note that these performance targets must be met at the point of compliance (the point at which a reclamation facility operator supplies reclaimed water to the next actor in the chain) and that 90% of the samples taken for validation must meet or exceed the performance targets.

If a biological indicator is not present in the raw wastewater in sufficient quantity to achieve a log10 reduction, the absence of this biological indicator in the reclaimed water means that the validation requirements are met.

Finally, the regulation provides elements to establish the risk management plan, additional requirements to be taken into account in specific cases and preventive measures to limit the risks related to the reuse of water.

Comments:

- Only describes agricultural practices, should be complemented with requirements for other types of use.

- The EU regulation is more restrictive than most countries. Indeed, if we look at the most restrictive quality

- The EU regulation is more restrictive than most countries, because if we look at the most restrictive quality (A), the quantities of the indicators are more numerous than in France, Spain or Israel.

- Routine monitoring frequencies are roughly in line with Spain.

- The validation thresholds are comparable to those in France. A single verification of these parameters at commissioning.

technical sheet

Decrees of 14/12/2023 and 18/12/2023 on the use of water from urban wastewater treatment for irrigating crops or green spaces (1/4)

The regulation of wastewater reuse has been in a period of transition since 2020, when the European regulation of June 5, 2020 on minimum requirements for water reuse was published, which ended in December 2023 with the publication of new texts concerning industrial use (agri-food sector) and the transposition of the 2020 European regulation into French law (publication of the decree of August 29, 2023 on the uses and conditions of use of rainwater and treated wastewater, followed by the two decrees of December 14 and December 18, 2023, concerning watering of green spaces and agricultural use respectively).

These decrees represent the latest version of French regulations on TWR.
These decrees set out :

- **quality limits on certain parameters according to 4 water quality classes defined by the desired end use:**

PARAMETERS	Sanitary quality level of treated wastewater			
	A	B	C	D
Suspended solids (mg/ L)	< 10	Complies with French regulations on treated wastewater discharges for the plant outlet outside irrigation period		
5-day biological oxygen demand (mg/L)	< 10			
Escherichia coli (CFU/ 100mL)	≤ 10	≤ 100	≤ 1 000	≤ 10 000
Coliphage (specific F-RNA bacteriophages and/or somatic phages (*))	≤ 10	≤ 100	≤ 1 000	≤ 10 000
Clostridium perfringens (**)	≤ 10	≤ 100	≤ 1 000	≤ 10 000
Turbidity (NTU)	≤ 5	-	-	-
Others	Legionella spp.: < 1,000 cfu/l where there is a risk of aerosol formation Intestinal nematodes (helminth eggs): ≤ 1 egg/l for irrigation of pasture or fresh forage			

(*) Total coliphages are chosen as the most appropriate viral indicator. However, if total coliphages cannot be analyzed, at least one of them (F-specific coliphages or somatic coliphages) must be analyzed.

(**) Clostridium perfringens spores are chosen as the most suitable protozoan indicator. However, anaerobic sulfite-reducing bacteria and their spores offer an alternative solution if the concentration of Clostridium perfringens spores is insufficient to validate the required log10 reduction.

- **as well as distance constraints for sprinkler irrigation to guard against the phenomenon of dispersion (movement of water drops by the wind), terrain and monitoring frequencies.**

CHARACTERISTICS OF THE SPRINKLER	SENSITIVE AREA SPRAYING DISTANCE [1]	
Scope	With screen 2 and low pressure [2]	In other cases
Short range: < 10 m	5 m [3]	Twice the range
Medium range: 10 to 20 m	10 m [3]	
Long range: > 20 m	10 m [3]	

[1] Dwellings, courtyards and gardens adjoining dwellings, traffic routes, public places of passage and leisure, public buildings and company buildings, whatever the direction and speed of the prevailing wind.

[2] Shrubby vegetation or fixed or mobile screens such as walls, windbreaks, canisses, blackout panels, etc., the height of which must be at least equal to that of the peak of the sprinkler.

[3] This value is increased by the range for the area covered by the sprinkler.

2023

FRANCE

Decrees of 14/12/2023 and 18/12/2023 on the use of water from urban wastewater treatment for irrigating crops or green spaces (2/4)

The different water qualities for irrigation are defined in the table below:

TYPE OF USE	Sanitary quality level of treated wastewater			
	A	B	C	D
All food crops eaten raw whose edible part is in direct contact with treated wastewater and root crops eaten raw (1)	+	*	*	-
Food crops eaten raw, the edible part of which is grown on the surface and is not in direct contact with treated wastewater, processed food crops and non-food crops including those used to feed milk- or meat-producing animals (excluding fresh fodder, pasture, industrial crops, energy crops and seed crops).	+	+(2)	*	-
Fresh forage and pasture	+	+	*	-
Industrial, energy and seed crops	+	+	+	+

+ authorized,-: forbidden, *: possible by setting up an appropriate barrier system as defined in section 2.

(1) The reuse of treated wastewater is forbidden for watercress cultivation.

(2) Irrigation for fruit growing is forbidden during the period from flowering to picking for unprocessed fruit, except in the case of drip irrigation.

The different qualities of water for watering green spaces are defined in the table below:

TYPE OF USE	Sanitary quality level of treated wastewater			
	A	B	C	D
Green spaces open to the public	0	1	Forbidden	Forbidden
Green spaces with restricted public access	0	0	1	Forbidden

technical sheet

Decrees of 14/12/2023 and 18/12/2023 on the use of water from urban wastewater treatment for irrigating crops or green spaces (3/4)

The following constraints apply to irrigation:

NATURE OF THE ACTIVITIES TO BE PROTECTED	LEVEL OF SANITARY QUALITY OF TREATED WASTEWATER		
	A	B	C et D
Water level (1)	20 m	20 m	50 m
Aquaculture (except filter-feeding shellfish) Fish farming including recreational fishing	20 m	20m	50m
Shellfish aquaculture Filter-feeding shellfish	50 m	50 m	200 m
Swimming and water activities	50 m	50 m	100 m
Livestock watering (2)	50 m	50 m	100 m
Watercress farming	50 m	50 m	200 m

(1) With the exception of bodies of water used as outlets for the wastewater treatment plant, and private bodies of water to which access is regulated and where no activities such as swimming, water sports, fishing or livestock watering are practised.

(2) In the case of sprinkling, animals must not be in the field at the time of the operation, and troughs, if sprinkled, must be rinsed before use.

- In the case of land with no vegetation cover and a slope greater than 7%, only localized irrigation is authorized.
- Irrigation of water-saturated land with treated wastewater is prohibited, in order to avoid any runoff of treated wastewater off-site.
- In karstic environments, irrigation is only possible with A and B quality water, and only on land with thick soil (minimum one meter) and plant cover. In addition, if the slope exceeds 3%, irrigation must be localized.

Parameters	FREQUENCY OF ANALYSIS FOR A USE REQUIRING A MINIMUM OF SANITARY QUALITY WATER			
	A	B	C	D
Suspended solids	1 per week	Compliant with directive 91/271/EEC		
5-day biological oxygen demand	1 per week	Compliant with directive 91/271/EEC		
Escherichia coli	1 per week	1 per week	1 every 15 days	
Coliphage (specific F-RNA bacteriophages and/or somatic phages)	1 per week	1 per week (1)	1 every 15 days (1)	
Clostridium perfringens	1 per week	1 per week (1)	1 every 15 days (1)	
Turbidity	Continuously	-	-	
Escherichia coli	1 per week	1 per week	1 every 15 days	
Legionella spp (if applicable)	1 every 15 days			

(1) Discount expected only if used on crops eaten raw, with the edible part in direct contact with water.

Decrees of 14/12/2023 and 18/12/2023 on the use of water from urban wastewater treatment for irrigating crops or green spaces (4/4)

Constraints on watering green spaces :

NATURE OF THE ACTIVITIES TO BE PROTECTED	LEVEL OF SANITARY QUALITY OF TREATED WASTEWATER		
	A	B	C et D
Water level (1)	20 m	50 m	100 m
Aquaculture (except filter-feeding shellfish) Fish farming including recreational fishing	20 m	50m	100m
Shellfish farming Filtering shellfish fishing on foot	50 m	200 m	300 m
Swimming and water sports	50 m	100 m	200 m
Livestock watering	50 m	100 m	200 m
Watercress farming	50 m	200 m	300 m

(1) With the exception of the body of water used as an outlet for the wastewater treatment plant and private bodies of water where access is regulated and where no activities such as swimming, water sports, fishing or livestock watering are practised.

Parameters	FREQUENCY OF ANALYSIS FOR A USE REQUIRING A MINIMUM OF SANITARY QUALITY WATER			
	A	B	C	D
Suspended solids	1 per week	1 every 15 days	1 per month	
Chemical oxygen demand over 5 days				
Escherichia coli				

Comments:

- The setting of targets is governed by a risk analysis according to the uses.
- Authorisation for the use of TMEs is given at departmental level, the approach is decentralised.
- The transmission of information is systematic:
  - o On a regular basis between WWTP operators, local authorities and users.
  - o In case of exceedance of limit values, for a stop of the TWR if necessary.

technical sheet

OPINION from the «Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail» (ANSES) of 15/03/2023 on the draft decree relating to 'the conditions for the production and use of treated wastewater [from urban wastewater treatment] for the irrigation of crops or green spaces' of 29/08/2023

ANSES stresses the persistent chemical and microbiological risks involved, despite treatment. It recommends rigorous risk management, including barriers to limit exposure and appropriate safety distances during spraying. The Agency insists on the need for reinforced monitoring of water, soil and agricultural product quality.

It recommends clarifying definitions, reinforcing monitoring criteria, particularly for pathogens, and adopting safety barriers. It also advocates shared responsibility between the various players and rigorous management of irrigation-related risks.

Royal Decree 1620/2007 of 7 December 2007 (1/2)

Spanish regulations set quality limits and analysis frequencies by type of use grouped by sector of use (urban, agricultural, etc.).

URBAN	Suspended matter	Nematodes	Escherichia coli	Turbidity	Legionella
Unity	mg/L	Œuf/10L	UFC /100mL	NTU	UFC/L
Private gardens, sanitary appliances	≤ 10	≤ 1	0	≤ 2	≤ 100
Parks, road washing, fire brigade water	≤ 20	≤ 1	≤ 200	≤ 10	≤ 100
Frequency of analysis	1 per week	2 per month	2 per week	2 per week	1 per month

AGRICULTURE	Suspended matter	Nematodes	Escherichia coli	Turbidity	Legionella
Unity	mg/L	Œuf/10L	UFC /100mL	NTU	UFC/L
Human food, direct contact of water with fresh edible food	≤ 20	≤ 1	≤ 100	≤ 10	≤ 1000
Human food, direct contact of water with edible food which is subsequently processed (not fresh food), cattle feed, aquaculture	≤ 35	≤ 1	≤ 1000	X	X
Spot spraying (no contact with food), flower crops, non-food industrial crops, cereals and oilseeds	≤ 35	≤ 1	≤ 10 000	X	≤ 100
Frequency of analysis	1 per week	2 per month	1 per week	1 per week	Once or twice a month

Note: *The thresholds for human consumption and for localised watering do not seem consistent.*

Note: *The high legionella value for «Human food, direct contact with fresh edible food» (higher than for «Localized watering»), contact of water with fresh food» (higher than for «Localized spraying»).*

2007

SPAIN

Royal Decree 1620/2007 of 7 December 2007 (2/2)

INDUSTRY	Suspended matter	Nematodes	Escherichia coli	Turbidity	Legionella
Unity	mg/L	Egg/10L	UFC/100mL	NTU	UFC/L
Cleaning process water, non-food industry	≤ 35	X	≤ 10 000	≤ 15	≤ 100
Cleaning process water, food industry	≤ 35	≤ 1	≤ 1000	X	≤ 100
Refrigeration, evaporative condensers	≤ 5	≤ 1	0	≤ 1	0
Frequency of analysis	Once a day to once a week	Once a week	1 to 3 times a week	Once a day to once a week	3 times a week

RECREATIONAL USES	Suspended matter	Nematodes	Escherichia coli	Turbidity	Legionella
Unity	mg/L	Egg/10L	UFC /100mL	NTU	UFC/L
Golf	≤ 20	≤ 1	≤ 200	≤ 10	≤ 100
Ornamental ponds	≤ 35	X	≤ 10 000	X	X
Frequency of analysis	Once a week	twice a month	1 to 2 times a week	Once a week	Once a week

ENVIRONMENT	Suspended matter	Nematodes	Escherichia coli	Turbidity	Legionella
Unity	mg/L	Egg/10L	UFC /100mL	NTU	UFC/L
Recharge of aquifers by percolation	≤ 35	X	≤ 1000	X	X
Aquifer recharge by direct injection	≤ 10	≤ 1	0	≤ 2	X
Watering of woods, green areas, and others not accessible to the public, forestry	≤ 35	X	X	X	X
Frequency of analysis	Once a day to once a week	Once a week	2 to 3 times a week	Once a day	Once a week

Notes:

Spain is the most active European country in the field of WASTE with 10% of its treated wastewater recycled. More than 150 LWR projects have been implemented in recent years.

technical sheet

2011

Measures, Limits and Procedure for Reuse of Treated Wastewater – No. 145116 (1/2)

The latest amendment to Greek legislation on the reuse of treated wastewater was in 2011. As in other countries, it defines water quality limits to be respected according to the intended use of the TME. It also defines the frequency of analysis to check compliance with these limits.

This regulation defines three different qualities of water which will be referred to here as quality 1, 2 or 3:

- **QUALITY 1 :**

  - Controlled irrigation: including areas not open to the public, agricultural and industrial plots, pastures, trees (except fruit trees), provided that harvesting is carried out out out of contact with the soil, seed crops and products that are treated before consumption. **Overhead irrigation prohibited**

  - Industrial use: single-use cooling water

  - Groundwater recharge: The recharge of aquifers which does not fall within the cases described in Article 7 of Decree 51 / 03.02.2007, by percolation through a layer of soil of sufficient thickness with appropriate properties

- **QUALITY 2 :**

  - Uncontrolled irrigation: All crops (fruit trees, vines, vegetables and all crops producing edible products). **No restrictions on irrigation methods.**

  - Industrial use: All uses except that listed in quality 1

- **QUALITY 3 :**

  - Urban uses: various urban uses (irrigation of green spaces, fire reserves, road washing, etc.). **Irrigation by sprinkling prohibited**
  - Recharging the water table by wells
  - Peri-urban uses: irrigation of forests and groves

Measures, Limits and Procedure for Reuse of Treated Wastewater – No. 145116 (2/2)

QUALITY	E. Coli (cfu/100ml)	DBO_5 (mg/l)	MES (mg/l)	Turbidity (NTU)	Treatment required	Frequency of monitoring
1	200 (median)	In accordance with CMD 5673/400/1997	In accordance with CMD 5673/400/1997		Secondary biological treatment and disinfection	DBO_5, MES, N, P as described in 5673/400/1997 E. Coli: once a week Continuous chlorine if chlorination used
2	5 for 80% of samples 50 for 95% of samples	10 for 80% of the samples	10 for 80% of the samples	2 (median)	Secondary biological treatment followed by or more advanced treatment and disinfection	DBO_5, MES, N, P as described in 5673/400/1997 Effluent turbidity and permeability: 4 times per week for plants > 50,000 p.e., 2 times per week in other cases. E. Coli: 4 times/week for plants > 50,000 p.e., twice a week in other cases. Continuous chlorine if chlorination used.
3	2 for 80% of samples 20 for 95% of samples	10 for 80% of the samples	2 for 80% of samples	2 (median)	Secondary biological treatment followed by tertiary treatment and disinfection	DBO_5, MES, N, P as described in 5673/400/1997 Turbidity and effluent permeability: 4 times per week for plants above 50,000 p.e., 2 times per week in other cases. Continuous chlorine if chlorination is used.

Notes:

- *This legislation also sets concentration limits for 19 heavy metals and recommendations for the exploitation and use of TMEs for agricultural purposes with regard to the nutrients and toxic substances they contain.*
- *74 parameters to be followed for the Greek regulation may entail high costs.*

US Environmental Protection Agency (1/2)

As an early adopter of WASTE, the US has gained some experience. The United States has a two-tiered regulatory system: a federal level that provides a general framework for all its states and a state-specific regulatory framework that can be more restrictive. This general framework is provided by the U.S. Environmental Protection Agency (USEPA). Thus, the guidelines for wastewater reuse were established in 1980 and then updated regularly, in 1992, 2004 and the latest version in force in 2012.

Currently 43 states have regulations in place for wastewater reuse in the broad sense. However, while 43 States have regulations in place for the use of TMEs for agricultural irrigation of non-consumptive crops, only 16 States have regulations in place for the use of TMEs for groundwater recharge.

The quality limits presented below are classified by type of use for some States.

A simplified non-exhaustive list of quality parameters is presented.

Urban use - not limited								
Parameter	Arizona	California	Florida	Nevada	New Jersey	North Carolina	Texas	Washington
DBO_5 (mg/l)	/	/	60	30	/	15	5	30
MES (mg/l)	/	/	5	30	5	10	/	30
Turbidity (NTU)	5	10 (media filter) 0,5 (membrane filter)	2-2,5	/	2	10	3	5
Total coliforms (cfu/100ml)	/	240	/	23	/	/	/	23
Fecal coliforms (cfu/100ml)	23	/	25 (and 75% below the LQ)	/	14	25	75	/

Urban use -limited								
Parameter	Arizona	California	Florida	Nevada	New Jersey	North Carolina	Texas	Washington
DBO_5 (mg/l)	/	/	/	30 (average over 30 days)	/	15	15-30	30
MES (mg/l)	/	/	/	30 (average over 30 days)	30	10	/	30
Turbidity (NTU)	/	/	/	/	/	10	/	/
Total coliforms (cfu/100ml)	/	240 (only one value above for 30 days)	/	23	/	/	/	240
Fecal coliforms (cfu/100ml)	800	/	/	/	400	25	800	/

US Environmental Protection Agency (2/2)

Agricultural use - food crops								
Parameter	Arizona	California	Florida	Nevada	New Jersey	North Carolina	Texas	Washington
DBO5 (mg/l)	/	/	60	/	/	15	5	30
MES (mg/l)	/	/	5	/	5	10	/	30
Turbidity (NTU)	5	10 (media filter) 0.5 (membrane filter)	2-2,5	/	2	3	3	5
Total coliforms (cfu/100ml)	/	240	/	/	/	/	/	23
Fecal coliforms (cfu/100ml)	23	/	25 (and 75% below the LQ)	/	14	75	14	/

The US.EPA also defines limits and recommendations for the use of treated wastewater for many sectors:

- **Urban uses:**
  - Unrestricted: Urban use where public access is not controlled
  - Limited: Urban use for applications where public access is limited, controlled and users are informed of the presence of TMEs
- **Agricultural uses:**
  - Food crops: Agricultural use for growing crops for food consumption
  - Non-food crops: Agricultural use for the cultivation of products intended for food consumption after modification or products not intended for food production
- **Water reservoirs**
- **Use for environmental purposes**
- **Industrial use**
- **Groundwater recharge**
- **Drinking water production**

Similarly, the regulations define minimum distances for sprinkler irrigation, recommendations for use and recommendations for project design.

Notes : *Many Latin American countries rely on the US.EPA recommendations for the implementation of WASTE projects.*

Australia has its own EPA and produces guidelines on the same model as the US EPA.

In addition, the regulations in Israel are similar to those described here, and in particular to the Californian model.

The Californian model is often given as an example.

Ministry of health and Ministry of Environmental Protection (1/4)

This country was among the first users of LWR. As early as 1952, it allowed WWR for agricultural irrigation. Today, about 85% of treated wastewater is reused in agricultural irrigation. The country has therefore gained experience, especially over time.

As a preamble, the regulation defines 5 levels of treated wastewater quality depending on the treatments implemented at the treatment plants and their performance:

- Very high quality treated wastewater: Treated wastewater from tertiary treatment with an E. Coli concentration below 10 CFU/100 ml;
- High quality treated wastewater: Treated wastewater from biological treatment (activated sludge with a mass load consistent with the desired quality, coupled or not with primary sedimentation) with a quality of «20/30» (BOD5 and SS concentration);
- Wastewater treated by oxidation tank (lagoon, etc.) with at least 15 days of residence time;
- Medium quality treated wastewater: Treated wastewater from biological treatment (activated sludge with a mass load consistent with the desired quality, coupled or not with primary sedimentation) with a quality of «60/60» (BOD5 and SS concentration);
- Low quality of treated wastewater.

The quality of the treated wastewater and the barriers between it and the irrigated crops (fruit) determine the possibilities of use. Barriers taken into account include The distance between the fruit and the treated wastewater, the resistance to solar radiation, the type of irrigation (drip), the presence of chlorination.

There are also requirements in terms of:

- Location of this type of irrigation to avoid contact between treated wastewater and the public (public buildings, roads, etc.). The same applies to crops sensitive to contamination and drinking water installations (networks, etc.).
- Signposting of treated wastewater networks to avoid misuse and poor connections, especially with drinking water networks.

Ministry of health and Ministry of Environmental Protection (2/4)

Finally, Israeli regulations define 4 categories (reverse alphabetical order in Europe) depending on the type of irrigated crop with requirements for the quality of treated wastewater, type of treatment and location:

	A Cotton, sugar beet, cereals, seeds for dry fodder, forest irrigation, etc.	B Green fodder, olives, peanuts, citrus fruits, bananas, almonds, nuts, etc.	C Fruit trees, vegetable canning, cooked and peeled vegetables, green belts, football fields, golf courses	D Unrestricted crops including vegetables eaten raw, parks and lawns
Effluent quality				
Total BOD5 (mg/l)	60	45	35	15
Dissolved BOD5 (mg/l)	-	-	20	10
Suspended solids (mg/l)	50	40	30	15
Dissolved oxygen (mg/l)	-	0.5	0.5	0.5
Coliforms (u/100 ml)	-	-	250	12 (80 %) 2.2 (50 %)
Free residual chlorine (mg/l)	-		0.15	0.5
Mandatory treatment				
Sand filtration or equivalent	-		-	Exigé
Chlorination (minimum contact time, min)	-		60	120
Distances				
Residential areas	300	250	-	-
Surfaced roads	30	25	-	-

technical sheet

Ministry of health and Ministry of Environmental Protection (3/4)

It should be noted that in the light of its experience, Israel changed its regulations in 2007 to include parameters related to salinity, heavy metals and nutrients:

Unrestricted irrigation			
Conductivity (dS/m)	1,4	As (mg/L)	0,1
BOD5 (mg/L)	10	B (mg/L)	0,4
Total TSS (mg/L)	10	Be (mg/L)	0,1
COD (mg/L)	100	Cd (mg/L)	0,01
NH4 (mg/L)	10	Co (mg/L)	0,05
Total N (mg/L)	25	Cr (mg/L)	0,1
Total P (mg/L)	5	Cu (mg/L)	0,2
Cl (mg/L)	250	Fe (mg/L)	2
F (mg/L)	2	Hg (mg/L)	0,002
Na (mg/L)	150	Li (mg/L)	2,5
Faecal Coliforms (CFU/100 mL)	10	Mn (mg/L)	0,2
OD (mg/L)	<0.5	Mo (mg/L)	0,01
pH	6,5-8,5	Ni (mg/L)	0,2
Residual Cl2 (mg/L)	1	Pb (mg/L)	0,1
Anionic detergent (mg/L)	2	Se (mg/L)	0,02
Sodium Adsorption Ratio (SAR) (mmol/L)	5	V (mg/L)	0,1
CN (mg/L)	0,1	Zn (mg/L)	2
Al (mg/L)	5		

Ministry of health and Ministry of Environmental Protection (4/4)

Finally, Israel has embarked on a policy of developing the use of treated wastewater for irrigation, based on sharing the cost of treating reused water with other water users.

Thus, Israel has put in place a set of measures to encourage the development of wastewater reuse projects in the agricultural sector:

- The establishment of quotas for farmers for water withdrawal and treated wastewater. Allocation of a bonus of 20% of the volume of wastewater for farmers who agree to exchange part of their annual quota of water withdrawn from the environment for a volume of wastewater.
- The introduction of a progressive tariff based on the quota allocated per farm.
- A significant increase in the price of water to reflect the local scarcity of water resources. Thus, in the 1990s and 2000s, water prices for agricultural use rose sharply (68%).
- Subsidies for the reuse of wastewater for irrigation to create a price differential in favour of treated and recycled domestic wastewater compared to abstracted water (three times lower). The difference between the cost of producing treated wastewater and the price of selling it to farmers is borne by domestic users.
- Finally, it is worth noting this key sentence in the Israeli water law: «Israel's Water Law includes sewage water in its definition of «water resources».

TUNISIA

1989

technical sheet

Standard NT 106.03 on the use of treated wastewater for agricultural purposes (1/1)

The quality of treated wastewater and the frequency of physico-chemical and microbiological analyses must follow the requirements of the **NT 106.03 standard** for the use of treated wastewater for agricultural purposes. This standard was developed in 1989 on the basis of recommendations made by the WHO and partially incorporates the parameters of the NT 106.02 standard on effluent discharges into the water environment.

Parameter	NT value 106.03
BOD5 (mg/L)	30
COD (mg/L)	90
TSS (mg/L)	30
pH	6.5-8.5
Conductivity (µS/cm)	7000
Salinity RS (g/L)	4.4
Chlorides Cl (mg/L)	2000
Fluorides F (mg/L)	3
Organochlorines (mg/L)	0.001
Arsenic As (mg/L)	0.1
Boron B (mg/L)	3
Cadmium Cd (mg/L)	0.01

Parameter	NT value 106.03
Cobalt Co (mg/L)	0.1
Chromium Cr (mg/L)	0.1
Copper Cu (mg/L)	0.5
Iron Fe (mg/L)	5
Manganese Mn (mg/L)	0.5
Mercury Hg (mg/L)	0.001
Nickel Ni (mg/L)	0.2
Lead Pb (mg/L)	1
Selenium Se (mg/L)	0.005
Vanadium V (mg/L)	0.1
Zinc Zn (mg/L)	5
Nematode eggs (n/100 mL)	0.1

Remarks:

- Standard NT 106.03 is only demanding on the parameter «intestinal nematode eggs». This parameter is not included in standard NT 106.02 (discharge from WWTPs), which is currently replaced by ***governmental decree n°2018-315 of 26 March 2018*** *for the protection of the environment, which sets quality objectives, particularly for 4 microbiological parameters: faecal coliforms, faecal streptococci, salmonella and cholera vibrios.*

- Tunisian regulations do not differ according to the uses and type of crops grown with treated wastewater. It only considers agricultural use.

- The revision of the Water Code (currently underway) differs from the old version in the importance it gives to non-conventional water, particularly TMEs, which should facilitate the revision of the regulatory framework.

Crops allowed to be irrigated with treated wastewater are: industrial crops, cereal crops, fodder crops, fruit trees, fodder shrubs, forest trees, floral plants for drying or industrial use.

A specification for the use of TMEs for agricultural purposes is approved and imposes conditions on:

- The level of water quality;
- The level of storage and distribution of the water;
- The level of direct use of TMEs;
- The level of protection of ground and surface water resources.

3- Treatment

3.1 PRE-TREATMENT

Pre-treatment makes it possible to eliminate the coarsest materials that could hinder the proper functioning of the works (blockage, abrasion of electromechanical equipment, etc.) or reduce the efficiency of the treatment processes (oxygen transfer, etc.) that will follow. They can be mechanical (coarse to fine screens generally between 60 mm and 3 mm or even sieves generally between 0.4 and 2 mm between 200 µm and 1,500 µm) or use physical phenomena (such as decantation for sands or flotation for greases).

The water then passes through a degreaser/desander which allows the removal of dense or abrasive particles and floating particles. This degreasing/sanding step may be optional in the case of screening, in which case it is referred to as compact pre-treatment (suitable mainly for small treatment plants).

3.2 PRIMARY TREATMENT

Once pre-treated, the water remains loaded with suspended solids and dissolved organic and mineral molecules. The purpose of primary treatment is to remove suspended solids. Generally, the gravity settling process to remove them uses the slightly higher density property of wastewater than water. The settling process takes one or two hours. It is also possible that the TSS is slightly lighter than water, in which case flotation is preferred for TSS removal.

Decanting or flotation can be coupled with a coagulation and flocculation step to retain colloidal material (fine suspended particles). This is referred to as physical-chemical settling or flotation. Primary treatment remains an optional treatment step.

3.3 SECONDARY TREATMENT

Secondary treatment aims to eliminate dissolved organic and mineral molecules. It consists of biological treatments, involving living micro-organisms (mainly bacteria) that use the pollution contained in the water as a substrate. Several processes exist, the best known being the activated sludge process.

Depending on the process, it is possible, with varying degrees of difficulty (sometimes with the addition of reagents), to eliminate carbon, nitrogen and phosphorus pollution from water.

3.4 TERTIARY TREATMENT

The purpose of tertiary treatment is to further eliminate the classic parameters (mainly COD, BOD5, SS) but also pathogenic germs.

3.4.1 Élimination supplémentaire des MES

For a better elimination of suspended solids and organic matter, it is necessary to implement the treatment process with a filtration stage: filtration on granular media (sands, etc.), mechanical screening or filtration on membranes (MF, UF, NF and RO). Infiltration-percolation is also possible. The performances of these techniques are given in the following table.

	MF	UF	NF	OI	Filtration on granular medium	Infiltration-percolation
DBO	75 - 90	80 - 90	COT : 90 - 98	COT : 90 - 98		60 - 100
DCO	70 - 85	75 - 90				30 - 50
MES	95 - 98	96 – 99,9	40 - 60	90 - 98	1 to 8 mg/L	65 - 95

(Source : Boutin & al., 2009)

3.4.2 Specific elimination of pathogens

There are 4 main disinfection processes:

3.4.2.1 Treatment by chlorination

Chlorination is the most widely used process for wastewater disinfection. However, this technique is increasingly being questioned.

Chlorine has a proven bactericidal activity, but its optimisation is complex. Moreover, the formation of toxic by-products (chloramine, THM, HAA, HAN, etc.) with a persistent action in the environment as well as the risks linked to the transport, storage and handling of the product call into question the use of this disinfection technique.

Furthermore, the effectiveness of chlorine against viruses is not well established.

Finally, as mentioned above, chlorination has a persistence in water that can be beneficial (avoiding recontamination in transport/distribution networks of treated wastewater, etc.) but also harmful (for irrigated crops, receiving environments such as rivers, etc.). Dechlorination of the water may therefore be necessary, which makes the reuse of treated wastewater more complex.

During chlorination treatment, chlorine can be used in the form of chlorine gas or concentrated sodium hypochlorite solutions. The same treatment process is used for both disinfectants: a mixing tank equipped with an injection and homogenisation device, then a contact device, accompanied by regulation of the disinfectant dose according to needs, and finally, if necessary, dechlorination (this stage is sometimes not respected).

The effectiveness of the treatment is closely linked to the action of the mixture and the dosage.

Two phases of inactivation of pathogenic germs follow one another during this treatment: a first brief phase during which free chlorine remains and ensures the essential elimination of germs, and a second, much longer phase of reduced effectiveness during which chloramines intervene.

The effectiveness of the chlorination disinfection system therefore depends on three main parameters: temperature, contact time and the dose of chlorine injected. For a given initial dose and contact time, the quality of disinfection is closely linked to the speed of the initial mixing, which in turn depends on the technology used.

A minimum dose of 7 mg/l of chlorine is required at 5°C with a contact time of 40 min to obtain a 4 log unit abatement of E. Coli and faecal streptococci.

3.4.2.2 Ozonation treatment

The well-known bactericidal and virucidal properties of ozone have led to the development of drinking water treatment with this gas in Europe and the USA. This is why most of the literature on ozone disinfection is related to drinking water treatment. Very few are related to wastewater disinfection.

Ozone (O3) is an unstable and odorous gas produced industrially in an effluent treatment plant by passing dry air or oxygen between two electrodes subjected to a potential difference of 15,000 volts.

Ozone treatment is equivalent to UV treatment for the disinfection of wastewater, although ozonation has an advantage in that it has a pronounced disinfecting effect on viruses and protozoan cysts.

Ozonation treatment is not only very effective, but also does not cause any toxicity and improves the chemical quality of the effluent (colour, nitrite, COD, SS). On the other hand, ozonation is sensitive to the organic matter contained in the suspended solids present in the effluent, which requires prior filtration. In addition, this type of process has very high installation and operating costs: 2 to 3 times higher than chlorination treatment and higher than UV treatment.

The ozonated gas is brought into contact with the effluent to be disinfected in compartmentalised tanks by means of an injector, porous tubes or a special dispersion turbine. The supply of ozone is adjusted to the needs as the treatment progresses.

In general, 4 tanks are used: the first two ensure the mixing and the effluent-ozone contact, the next two optimise the treatment.

Dissolved ozone will oxidise many metal cations and halides, and will also react with organic matter to form very unstable ozonides whose disinfectant activity is totally unknown. Ozone acts on membrane proteins and on the energy potential of microorganisms. Its powerful oxidation limits the risks of bacterial revival. Like chlorination, ozonation forms DBPs (bromates, etc.), some of which are potentially dangerous for the environment and health.

3.4.2.3 Ultraviolet treatment

Ultraviolet light has been known to be germicidal since the end of the last century. UV technology is commonly used for disinfection of treated wastewater in the USA and Canada. This disinfection technique is considered by many authors as one of the best alternatives to chlorination,

The UV disinfection process has several advantages:

- No storage, dosing or handling of chemicals,
- Highly compact, resulting in a small footprint and civil engineering,
- No modification of the physico-chemical characteristics of the effluent and no creation of toxic by-products,
- High efficiency against viruses (higher than chlorine),
- No sensitivity of the yield to temperature variations.

This process is more economically advantageous than the ozonation process for the treatment of wastewater, as it has lower installation and operating costs. However, a major disadvantage of this process is the possible photo-reactivation of certain micro-organisms that have been subjected to UV radiation.

UV radiation are electromagnetic waves with a wavelength between 100 nm and 400 nm. UVC, between 200 nm and 280 nm, is the most potent germicide, the most commonly used wavelength being 254 m.

UV radiation is emitted by high or low pressure mercury vapour lamps. Excitation of the mercury atoms by an electrical discharge results in the emission of radiation at a wavelength of 254 nm. The effluent passes in a thin layer through a contact chamber where it is subjected to this radiation. To ensure satisfactory disinfection at all times, the device must provide a minimum UV radiation dose of 16 mWs/cm^2 at the furthest point from the contact chamber, regardless of the incoming flow rate and the quality of the water to be disinfected (Dupontreue, 1989). The design generally provides for a flow rate of 100 mWs/cm^2 and a contact time of 10 to 20 seconds.

The UV wastewater treatment method is based on the inactivation of micro-organisms: the genetic material, and more precisely the DNA and RNA molecules, absorb the energy of UV radiation.

The most common mechanism of inactivation is the formation of dimers between two adjacent pyrimidine bases (Thymine and Cytosine) on the same DNA strand, which can lead to the interruption of DNA transcription and replication. The higher the amount of these dimers in the nucleic acid molecule, the more difficult cell duplication becomes. The germicidal effect of UV is therefore not an immediate destruction of the micro-organisms, but essentially their inability to multiply.

3.4.2.4 Infiltration treatment

Controlled infiltration into the soil appears to be an appropriate technique for disinfection in coastal areas, especially for the protection of sensitive areas. Indeed, this technique is rustic and simple and allows disinfection throughout the year (unlike lagooning). This process is derived from very old purification techniques. In the 19th century, the effluents of several large European cities were treated in spreading fields. The modern version of this process is called infiltration percolation.

Because of its effectiveness on the organic and bacterial load, controlled infiltration into the soil is a good alternative technique to a treatment plant or tertiary treatment, particularly in areas without a direct outlet, either to protect the water table, in coastal dune areas, or to avoid concentrated discharge into the sea or alluvial plains, or to limit bacteriological pollution of rivers. Other advantages are attributed to it: no production of sludge, no consumption of energy and reagents, low cost. Its main disadvantage is the size of the treatment area: approximately 1 m² per inhabitant equivalent. However, this constraint is only one tenth of that imposed by lagooning. Because of the difficulty, or even impossibility, of measuring, few monitoring values are available in the literature.

Infiltration percolation is a technique for aerobic biological treatment of effluent on fine granular media. The principle is based on the use of different zones:

- A first surface filtration zone allowing the retention of suspended matter not eliminated during the upstream treatment. This retention has the effect of clogging the zone, thus limiting the speed and lateral distribution of water in the filter beds. Too much clogging would be harmful because it would deprive the filter bed of oxygen. It is therefore essential to set up drying and unclogging phases in this zone.

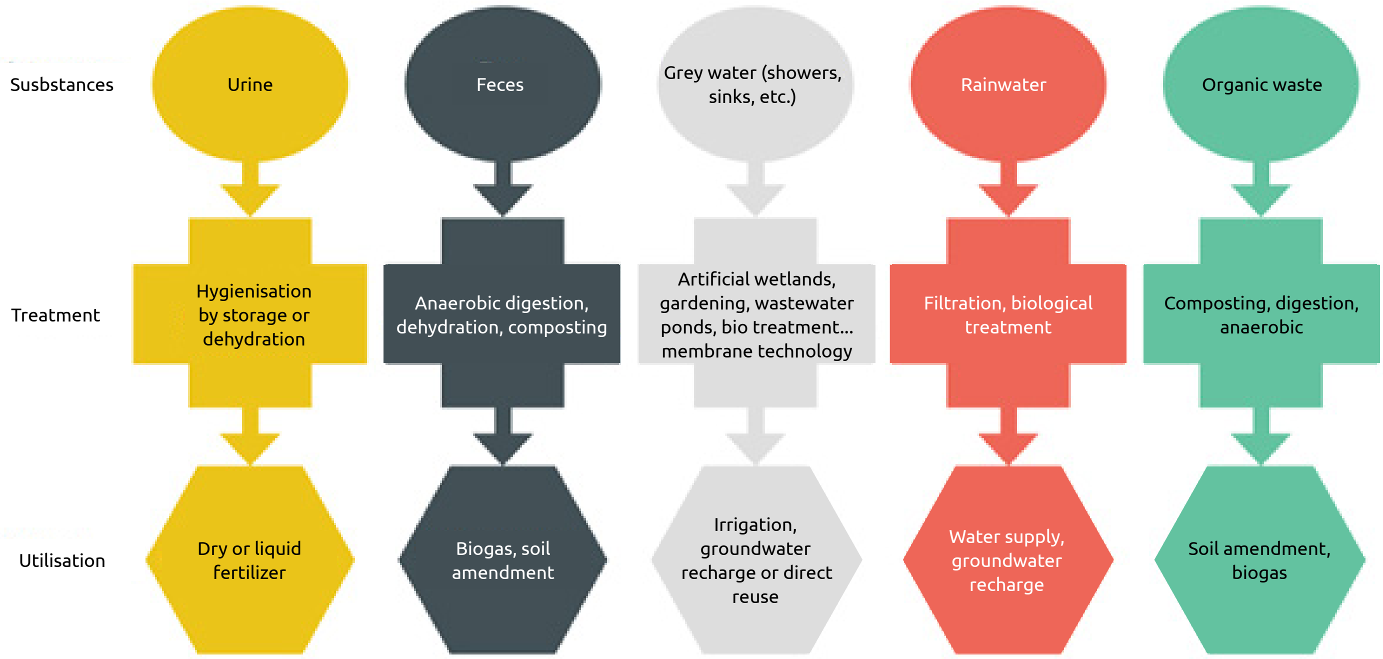
- Then comes the upper zone of the gravel pack, unsaturated, with vertical flow, where the water is purified. Due to its granular nature, this zone allows the fixation of bacteria responsible for the oxidation of dissolved pollution. The decontamination process is effective if the effluent's residence time in the gravel pack is sufficient. To achieve this, either the thickness of this zone must be increased or the pollutant load must be reduced. Preferential paths for the effluent through the gravel pack should be avoided.

- Finally, there is the lower, saturated zone, through which the groundwater flows horizontally and which discharges the treated water.

3.4.3 Adapting treatment and use to raw wastewater

The rules for reuse of treated wastewater differ according to the use to which it is put. Thus, depending on its nature and origin, wastewater is more suitable for some uses than others.

Similarly, depending on the initial quality of the water and the target quality of the water at the outlet, certain treatments are to be preferred. The following table summarises the recommended optimisations according to the type of raw water, treatment and subsequent use envisaged.



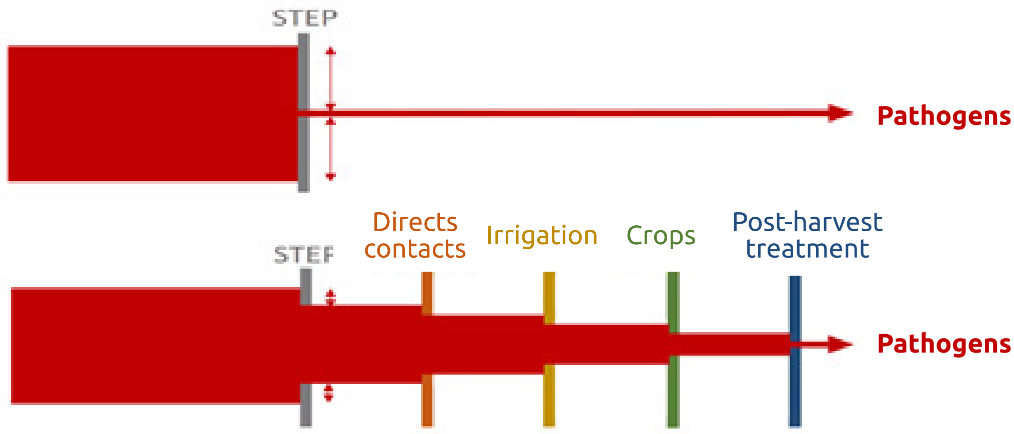
Source: UNESCO-PHI/GTZ (2006, fig. 4, p. 15).

3.5 Sewage treatment not necessarily the only safety bulwark

The treatment of wastewater at the wastewater treatment plants themselves or as a supplementary treatment to them increases the safety of the overall chain of reuse of the treated wastewater. However, additional barriers or protective measures can be taken into account to achieve the required (or desired) safety level.

The multi-barrier approach allows the pressure on the treatment to be lowered, as the water quality objectives at the level of use are the result of several activities that each represent barriers to health risks.

Diagram of the barrier approach for agricultural use



Source: INRAE

This approach considers all the processes and measures to reduce the probability of contact with micro-organisms that are potentially infectious and to achieve the level of health risk that is acceptable for the use in question.

The barriers are very diverse activities that allow the supply of the TME to be secured in terms of quality, they can apply to:

- direct contact: spreading of TMEs, fencing, spray drift requirements, physical and vaccination protection of people in contact with the water;
- Groundwater recharge methods: infiltration into impermeable media, such as clay layers before injection into the groundwater table, which can become very effective barriers;
- irrigation methods: need to use drip, sprinkler, open channel methods
- crop restrictions: types of products allowed, application of restrictions, education of farmers and the population
- post-harvest treatment: wearing of protective clothing required for workers, washing of harvested products, etc.

This can also concern the upstream part of the treatment system and the support of implementation of WASTE water management, such as:

- Wastewater collection: access rights, use rights, e.g. banning certain activities to be connected to the network (e.g. slaughtering),
- Monitoring: setting up a monitoring system for controls;
- Awareness campaigns on the invisible risk of pathogens that must accompany the promotion of these practices.

In the following table, we have transcribed examples of barriers and their effectiveness.

Organisations and references	List of additional barriers or protective measures	Reduction of pathogen exposure in log units	Number of equivalent barriers
WHO Guidelines for the safe use of wastewater, excreta and greywater 2012	See WHO fact sheet in paragraph 2.2	-	-
European Union EU Regulation on minimum requirements for water reuse 2020	Access control	-	-
	Additional measures for disinfection or removal of pollutants	-	-
	Specific irrigation techniques that reduce the risk of aerosol formation (e.g. drip irrigation)	-	-
	Specific requirements for sprinkler irrigation (e.g. maximum wind speed, distance between sprinklers and sensitive areas)	-	-
	Specific requirements for agricultural land (e.g. slope, water saturation of the soil and karst areas)	-	-
	Helps eliminate pathogens before harvest	-	-
	Establishment of minimum safety distances (e.g. from surface waters, including sources for livestock, or from activities such as aquaculture, fish farming, shellfish farming, swimming and other aquatic activities)	-	-
	Signage at irrigation sites indicating that reclaimed water is being used and is not suitable for consumption	-	-
AFNOR Standards NF ISO 16075 of 2015: Guidelines for the use of treated wastewater in irrigation projects: - Part 1: the basis of a reuse project for irrigation (cancelled on 03/03/2021) - Part 2: Project development (cancelled 10/03/2021)	Drip irrigation at more than 25cm	2	1
	Drip irrigation at more than 50cm	4	2
	Irrigation goutte-à goutte souterraine sans remontée capillaire d'eau à la surface	6	3
	Underground drip irrigation without capillary rise of water to the surface	2	1
	Irrigation of fruit trees by sprinklers and micro-sprinklers, at more than 50cm from the water jet	4	2
	Light disinfection	2	1
	High-level disinfection	4	2
	Separation of vegetables from irrigation water (drip irrigation) by a UV-resistant tarpaulin	2 à 4	1
	Natural or facilitated inactivation of pathogens by stopping or interrupting irrigation before harvest	0,5 à 2 par jour	1 à 2
	Washing of fruit and vegetables with potable water before sale	1	1
	Disinfection and rinsing with potable water of fruit and vegetables before sale	2	1
	Peeling of fruit and root vegetables	2	1
	Immersion in boiling water or high temperature cooking of products	6 à 7	3
	Restriction of access for 24 hours after irrigation	0,5 à 2	1
	Access restriction for 5 days after irrigation	2 à 4	4
	Forage or sun-dried crops harvested before consumption	2 à 4	2
	Irrigation at night, when the public does not have access to irrigated parks, sports fields and gardens	0,5 à 1	1
	Controlled sprinkler irrigation, minimum distance of 70m from dwellings or places accessible to the public	1	1

Organisations and references	List of additional barriers or protective measures	Reduction of pathogen exposure in log units	Number of equivalent barriers
AUSTRALIAN GUIDELINES Australian Guidelines for Water Recycling: Managed Aquifer Recharge (NRMM, EPHC, et NHMRC – 2009) Australian Guidelines for Water Recycling: Stormwater Harvesting and Reuse (NRMMC, EPHC et NHMRC – 2009) Australian Guidelines for Water Recycling: Augmentation of Drinking Water Supplies (NRMMC, EPHC et NHMRC – 2008) Australian Guidelines for Water Recycling: Managing Health and Environment al Risks (NRMMC, EPHC et AHMC – 2006)	Cooking or processing of products	5 to 6	-
	Peeling food before consumption	2	-
	Drip irrigation	2	-
	Drip irrigation with limited soil-food contact (e.g. tomatoes)	3	-
	Underground drip irrigation without soil-food contact (e.g. apples)	5	-
	Underground irrigation of soilless crops	4	-
	Interrupted irrigation	0,5 log/day	-
	Interrupted irrigation for parks and sports fields (1 to 4 hours)	1	-
	Controlled sprinkler irrigation (micro-sprinklers, anometric systems, inward projection, etc.)	1	-
	Drip irrigation of bushes and plants	4	-
	Underground irrigation of bushes, plants or lawns	5,6	-
	No public access during irrigation	2	-
	No public access during irrigation and restricted contact at other times (e.g. irrigation of food crops)	3	-
	Buffer zones (25-30 m)	1	-

4- Making a TWR project viable

Twr is a specific subject that involves a large number of actors for the implementation of a project. Its specificity and innovative nature, particularly with regard to the control of health risks, make it a difficult subject to implement in a project. In order to make a TWR project viable, it is important to ensure that certain tasks are carried out correctly. By way of illustration, a list of tasks, which is not intended to be exhaustive, is presented below.

4.1 Learn about the politics of the country

As stated in the previous section, the regulatory aspect is a key aspect in the implementation of a WASP project. The first obstacle to a project may be the country's policy. It is essential to define the project around the rules required by the country. In some countries, WASP is very underdeveloped or even non-existent, so there are no standards, or they are based on standards already established in other countries such as the United States or the WHO. If there are no rules governing WASTE, it will still be necessary to be aware of the administrative procedures that need to be carried out for the project to be validated. The following questions need to be answered:

Are there any regulations on TWR?

- If yes, be aware of operational legislation for WASTE, and standards or guide values (especially if they are to be included in the regulations).
- Be aware of any constraints related to the use of TMEs, including prohibited areas (e.g. urban use)
- In the absence of specific regulatory texts on TMEs, a search for current or completed projects will be necessary to position the project in the framework of the development of the topic in the country

How do I build my TWR project?

- Respect, within the identified regulatory framework if any, the country-specific standards for each type of use
- Build on the results of similar references to the project in the country

Will the regulation on WASP change or be created?

- Anticipate the evolution of the regulations in order to be compliant in the future and/or not to be blocked during the implementation of the project.

4.2 Define the purpose of the LWR project

A clear definition of the project and its objectives is essential to start and justify the installation of a WASTE system. Furthermore, the objective set will influence the technologies used. Indeed, depending on the desired use, the water treatment will have to be more or less advanced.

Whatever the aim of the project, it should be coherent and focused. It can be linked to different types of issue:

- Quantitative: water shortage, water stress, groundwater recharge, etc.
- Environmental: protection of the environment, limitation of discharges into the natural environment.
- To improve the economic context by providing a new resource and encouraging development.

Defining the project's objectives and challenges in the short, medium and long term will thus enable the project to be projected and integrated into the development of the region in which it is to be set up, which favours both the integration of the project into other development projects and a better awareness of the actors, facilitating its implementation.

ISSUES

What are the quantitative issues?

- Water scarcity
- Water stress

What are the qualitative issues?

- Protection of the environment
- Controlling health risks

GOALS

What are the quantitative objectives?

- Provision of a resource directly available
- Groundwater recharge

What are the quality objectives?

- To improve the sanitary quality of a discharge
- Limit the volume of TMEs discharged into the natural environment

IMPACTS

What economic impacts?

- What economic impacts?
- Agricultural development of a region
- Sustaining an agricultural sector threatened by increasing water stress
- Offering a community an alternative water resource to drinking water for watering green spaces, washing roads, etc.
- To increase the competitiveness of industries that may consume non-potable water in their processes
- Develop the attractiveness of areas: encourage the creation or maintenance of leisure activities, such as golf, etc.

The framework for the implementation of a WASP project can be simply summarised in the following table:

	ISSUES	GOALS
Quantity	Judging a situation of water stress or shortage hindering economic development	Provision of an additional water resource
Quality	Protecting the natural environment (areas of ecological interest, catchment areas, bathing areas, etc.)	Reduce direct discharges into the natural environment

It should be noted that LWR should not be considered as an end in itself, especially if only the quantitative issue is to be considered. It can be one solution among others (resource transfer, intra-annual storage, etc.).

4.3 Define the location of the TWR system and the uses concerned

A Treated Wastewater Reuse system has several levels:

- Treatment: generally additional treatment downstream of a WWTP, but it can also be a lagoon combining secondary and tertiary treatment, a membrane bioreactor that already achieves good performance in terms of bacteriological abatement, etc. ;
- Storage, to be sized to buffer the gap between the continuous supply and the often more irregular demand for water;
- Pumping (WASP processes are most often pressurised);
- Routing: this is the «critical» part that can have a prohibitive impact on costs, while complicating the control of health risks;
- Distribution to the plot: the user's internal network, which may be a farmer, a golf course, a local authority for its green spaces, etc., or even within an industrial process.

Once the TWR opportunity has been identified, the location of the plant should be chosen in advance in the course of the project stages. In fact, in many cases, the cost price of TWR water is not very competitive compared to that of so-called «conventional» water, and even if this resource is not in competition, the user's ability to pay is limited.

In this respect, the main lever that can be used is at the level of transport. Therefore, at the feasibility study stage, it is advisable to take into account the potential uses, giving particular importance in the analysis to their distance from the source (usually a WWTP).

Another important lever is the treatment requirements to be agreed. The regulations, concerned with the application of the precautionary principle, are fairly strict with regard to health risks. However, in most countries, they still allow projects with good to intermediate water quality (in the French example: quality level B, or even C in limited cases). It should be taken into consideration that with such quality objectives, the financial profitability of a WASP project can be favoured.

Thus, in the feasibility phase, the developer will be keen to identify his needs, filtering them through criteria such as remoteness and the quality of water required at the point of use (plus possibly others specific to the project).

4.4 Identify the actors involved in the TWR project

The developer should pay particular attention to the identification of the chain of actors between the WWTP effluent used and the point(s) of use, ensuring that the tasks of each actor are clearly defined, particularly with regard to health issues, without neglecting the potential risk of pathogen re-development in the conveyance network. The number and type of actors involved in a TWR project is specific to the project itself. Indeed, depending on the end use and objectives of the project, the stakeholders involved will differ. The stakeholders involved will include both the stakeholders of the TWR project in the strict sense of the term, but also the managers of the sanitation sector, because of the link between TWR and sanitation, as well as external stakeholders who could be indirectly impacted by the project.

The project stakeholders include:

- The project owner and any entity representing it whatever the phase of the project's progress
- The community or region hosting the TWR project
- The project's financiers
- The administrative and regulatory actors
- The specifiers (consulting engineers, project managers, etc.)
- The manufacturer(s) of the technological solution(s)
- The analysis laboratories for monitoring the quality of the distributed water
- The end user(s)
- The operator(s)
- Residents / external stakeholders

External stakeholders are represented by the surrounding populations or professionals, who must be informed of the implementation of a TWR project and the measures that this implies.

Two types of communication must be put in place to make the project viable: good internal communication between all the actors in the TWR project and good external communication (towards external actors): public awareness meetings, dissemination of information through the press, creation of a website, etc.

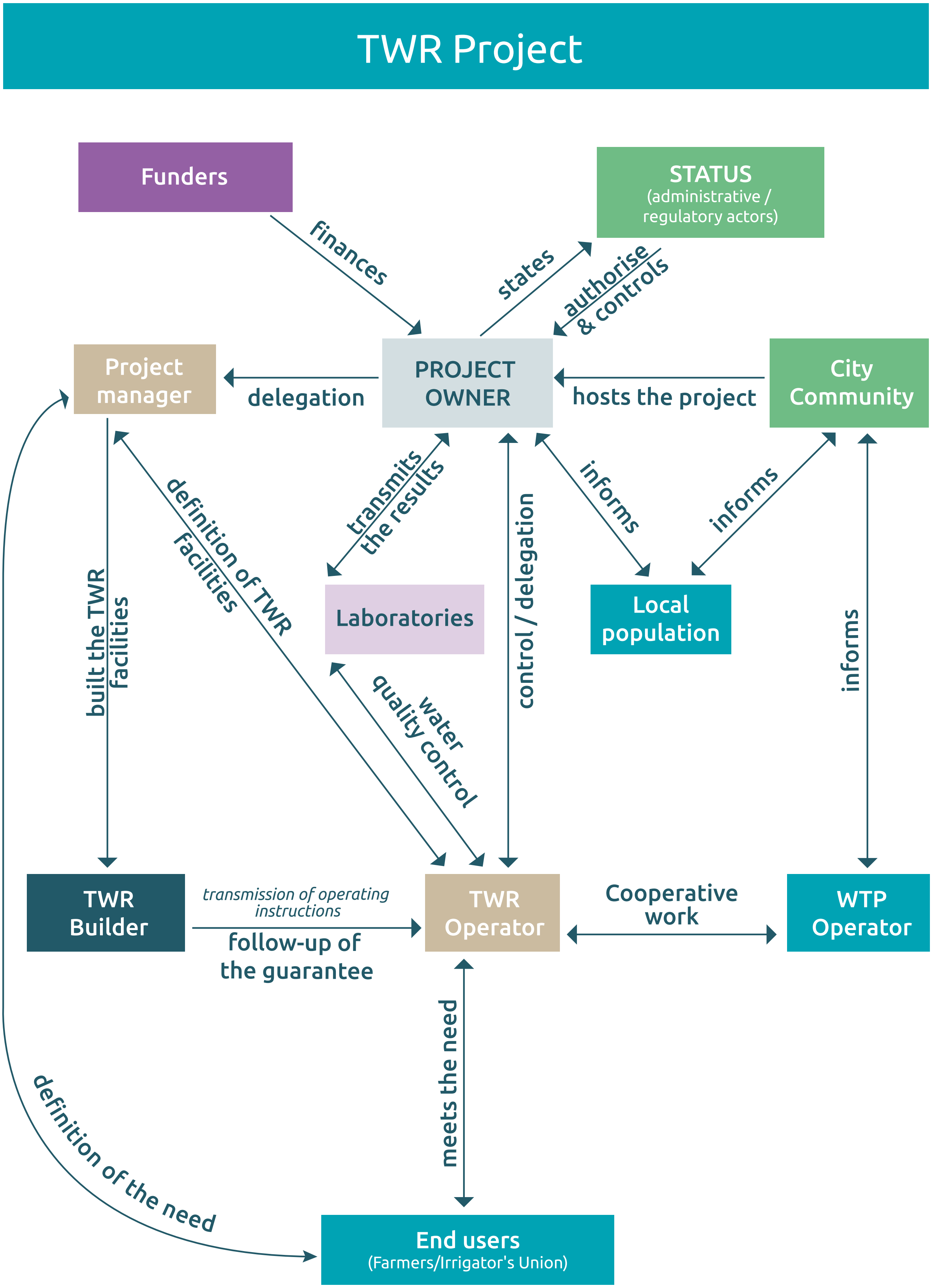
It is important, from the outset, to establish the roles and duties of each member within the project so that no issue is overlooked. It is important to report regularly on the actions and progress of each member and to communicate regularly between all members so that each knows the progress of the other. Internal communication alone, even with the national services responsible for administrative/regulatory procedures or the funders, is not enough to enable the implementation of a TWR project with a good level of preparation.

By definition, TWR is a continuation of a water treatment system, which implies a dependence on the treatment actors. If the operator of the wastewater treatment plant is not already an internal member of the WASP project, it is vital to establish good communication and information exchange capacity with him. Indeed, the operating conditions of the plant strongly influence the choice of the type of treatment or performance/operation of the TWR facilities.

External stakeholders indirectly impacted by the TWR project (e.g. people living in the vicinity of agricultural fields irrigated with TMEs) must be informed and made aware of the TWR project in order to avoid any misunderstanding or fear leading to social rejection of the project. (see Social acceptability below)

It is possible, depending on the scope of the project and the desired use(s), that the list of stakeholders to be brought together may be reduced, due to the combined responsibilities of some entities. However, in the case where each of the entities listed in this paragraph is independent, the number of actors to be brought together is substantial and requires a communication plan to be drawn up before the project starts. Poor communication can lead not only to a long and difficult implementation of the project but also to its possible abandonment.

The flow chart below shows the multiplicity of actors involved in TWR in a complex case where most entities are well separated:



Example of an organisation chart of TWR actors

4.5 Learn about social acceptability

TWR often comes up against the sensitivity, or even the cultural or religious discomfort, of the populations towards the reuse of water containing human waste. It is important to gauge the social acceptability of the TWR project to the populations and entities concerned. Social unacceptability can be an obstacle to the implementation of a TWR project despite compliance with legislation. TWR is often an emerging issue, which has not yet become part of everyday life, at least in most countries. To find out the opinion of the population concerned on the project, it is advisable to:

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- Raise awareness of the problem among the population or stakeholders in the future settlement area of the TWR problem
- Carry out information and communication campaigns with users in order to provide them with all the necessary information and to ensure that the population is aware of all the aspects of and in particular the health aspects.
- Carry out surveys among the population to assess their attitudes towards TWR.
- It is interesting and useful to carry out these surveys at different stages of the awareness campaign in order to estimate the effect of the information/awareness campaigns.
- Facilitate the integration of the WASP project with the population by making it part of an overall water management policy.

Following the example of what has been done in certain projects cited as examples of success (Le Port in Reunion, Clermont-Ferrand, etc.), a sentinel network led by independent health professionals could be set up to detect possible health risks (the aim being to demonstrate that there are none).

4.6 Warnings for designing a TWR project

When designing the facilities, there are a number of aspects to be considered in addition to those of a conventional water supply/distribution system:

- The choice of treatment technologies will need to be adapted to the intended use (see the section on the objectives of WASP). The parameters to be monitored throughout the treatment process for the selected project should be carefully targeted and health risks assessed.
- The WASW system should be matched to the WWTP (variation in secondary effluent quality, quality of WWTP operation, ...)
- Uses may be seasonal or non-continuous, in which case storage or discharge should be possible during the period of non-use of the MWWTP. In the case of storage, problems of water quality degradation may occur and it will be necessary to monitor the quality throughout this period.
- Facilities will depend on the number and type of populations involved (see section on social acceptability).
- The limitation of energy consumption should also be taken into account so as not to make the financial constraint unacceptable (additional treatment, pumping, etc.)

4.7 Warnings for the operation of a TWR project

Once the project has been designed, in order for it to be sustainable, it will be necessary to:

- When several operators take turns in the processing/routing chain, the roles of each should be clearly defined (by means of agreements), to avoid duplication and overlapping of tasks, or a contrario gaps arising from misunderstandings between parties;
- Carry out regular analysis and monitoring of certain parameters chosen according to the project, at certain key points of the installations. The list of parameters to be monitored can be established on the basis of the parameters defined in the regulations in force. It may be useful to go beyond the regulations in order not to underestimate the risks, for example with regard to salinity, legionella and/or emerging pollutants.

In addition, it will be necessary to ensure that all the usual precautions are taken at the level of the operating personnel, as the image projected by the internal actors of the project must be exemplary with regard to the external actors.

4.8 Financial and economic aspects

- In order to calculate the financial and economic interest, it is necessary to evaluate :
- [FIN] The amount of investment in the works
- [FIN] The energy consumption of such a system
- [END] The operating/maintenance costs
- [END] The quantification of the beneficiaries of the WASTE
- [END] The volume of WASTE by use
- [ECO] Added value per m3 of water reused
- [ECO] Number of jobs created
- [ECO] Number of jobs maintained
- [ECO] Cost of negative impacts avoided if this project had not gone ahead
- [FINE and ECO] The time period considered in the analysis
- [ECO]: Induced effects: improvement of health conditions, environment, etc.

Thus, the profitability of the project must be studied in order to determine its financial and economic viability, based on the above factors. When there is no alternative resource to WASTE, the economic aspect should as far as possible take precedence over the financial aspect, which can always be resolved by monetising the indirect benefits (the keys to these considerations being held by public policy actors).

The analysis tools to be favoured in a feasibility study are:

- [FIN] multi-criteria analysis
- [ECO] cost-benefit analysis (CBA), or even life cycle analysis (LCA).

The financial analysis must integrate in a transparent way within the community of internal actors the identification of who bears the investment costs, the operating/maintenance costs, and how they are passed on by the community (especially if an economic interest is proven) and the final users, with what distribution key.

4.9 Summary

Technical considerations

- Make an inventory of available resources around the project location (raw water distributor, groundwater, etc.), and carry out a comparative technical-financial study to ensure the appropriateness of the WWTP project
- Favour a tertiary treatment facility close to an existing wastewater treatment plant and be well informed about the performance of this WWTP. Indeed, depending on the quality of the water produced by the WWTP, some systems will be more efficient than others and/or less expensive.
- Optimise the choice of nearby uses (nature, location) so as not to increase treatment and transfer costs (piping, pumping, etc.) in a prohibitive manner, particularly in cases where gravity transfer is technically difficult.

Economic considerations

- Understand the dynamism of the sanitation sector in terms of wastewater collection and treatment in the area of the future WWR project site
- Ensure that there is a real demand for treated water, by building the project in consultation with the future beneficiaries around a territorial development or wealth creation project

Legislative and socio-environmental considerations

- Check the compatibility of the location of the use sites with the regulations. *If it is located near urban areas, this may create constraints for the population, especially in terms of distribution (e.g. spraying) in relation to the regulations. The distance to be respected will also depend on the policy of the country. The health risks of the chosen treatment will have to be assessed.*
- Understand the level of social acceptability of the populations surrounding the project; if necessary, undertake awareness campaigns

Operational considerations

- Equip the contracting authority with the appropriate skills
- Recruit specifiers, operators and managers with sufficient guarantees to ensure the success of the project
- Ensure a good definition of the chain of actors and their respective missions

5- Barriers to the implementation of TWR projects

Many TWR projects have already been implemented, but a number of obstacles have arisen, leading to difficulties in implementation, delays or even the abandonment of the project.

It is advisable to draw on the experience of these projects and to pay particular attention to anticipating the obstacles in the gestation of a TWR project. This identification can help to avoid major modifications to the system after design (not only technical, but also organisational, environmental, social, etc.), which could alter the project and generate significant additional costs.

The following paragraphs present a list of the most frequent obstacles encountered. These feedbacks are mainly from projects carried out in the years 2000 and 2010. The country and/or project that has been the subject of a brake is indicated in brackets.) Of course, the aim here is not to stigmatise, but rather to highlight the problems encountered at given times on real projects. Some of these problems may have been resolved by the time this document was distributed.

5.1 Barriers related to the management of TWR

- Lack of an institutional framework for allocating the costs of tertiary treatment, which makes the price of treated water to be paid by farmers more expensive than conventional water (most countries at a more or less pronounced stage: Morocco, France, etc.). Israel is a reference in terms of Israel is a reference in terms of setting up an institutional framework (see paragraph 2.2).

- Lack of regulations and standards, and therefore of benchmarks for water quality according to need (urban market gardening in Ouagadougou, Burkina Faso);

- Overly restrictive standards (Milan grassland watering, Italy);

- Evolution of the legislation in force: in the case of the presence of legislation on TWR it can be very useful to find out about the prospects for its evolution. Indeed, it is possible that this may have an impact on the steps to be taken as well as on the human and financial resources to be implemented (projects in the pipeline in France, such as that of the commune of Le Port in Reunion, with the revision of the of 2010 in June 2014 and April 2016).

5.2 Organisational barriers

- Lack of clarity in the distribution of roles between actors (groundwater recharge in Nabeul and Korba, Tunisia: There is no written agreement between the different actors) generating concrete questions in terms of responsibility and obligations: Who is the owner/manager of the TWR facilities? What are the obligations of water supply/consumption in quality and quantity?Etc.
- Poorly defined cost coverage (groundwater recharge in Nabeul and Korba, Tunisia): Who is responsible for the investment/operating costs of the complementary treatments required for Who bears the investment/operating costs of the additional treatments required for TWR and the associated networks and reservoirs? The domestic user (e.g. through the sanitation fee)? Beneficiaries of TWR (farmers, etc.)? State (subsidies, etc.)? The same applies to the benefits of TWR.
- Insufficient communication with irrigators and entities related to environmental uses, which may environmental uses, which can generate misunderstandings and even tensions (groundwater recharge in Korba, Tunisia in Korba, Tunisia: farmers' protest against the limitation of volumes withdrawn).

- Lack of an operator officially and legally responsible for monitoring TWR (urban market gardening in Ouagadougou, Burkina Faso): Monitoring of good practices, monitoring of coherence with agricultural development, communication/education, etc. Poor social acceptability / reluctance of the population (Greece): The population may have only a partial idea of wastewater treatment (confusion between raw/treated wastewater or between REUT/AEP, etc.) with altered preconceived ideas and in the background a health fear (quality of consumed products, etc.) or even a quality of products consumed, etc.) and even environmental fears.

- Insufficient communication with local residents to prevent (Limagne Noire in France: confusion on the origin of an olfactory nuisance: an olfactory nuisance encountered was unjustly attributed to the TWR).

- Insufficient communication (during breakdowns, maintenance, etc.) between the wastewater treatment plant between the wastewater treatment plant operator and the operator of the MWR facility, even though by definition they have definition, they have strong interfaces.

5.3 Barriers related to knowledge on TWR

- Limited scientific monitoring (impacts, etc.) (groundwater recharge in Nabeul and Korba and hydrological support of the Korba lagoon, Tunisia): Research projects, analytical monitoring, etc.

- Lack of periodic analysis of water, soil and harvested crops (irrigated areas with TMEs, Tunisia)

- Lack of knowledge of the state of the art, due to the lack of reference works on LWR as there may be for example in irrigation (General).

- Lack of long-term vision (several decades) of the impacts of LWR due to its generally recent nature in a majority of countries.

- The above points generate limited scientific knowledge (groundwater recharge in Korba, Tunisia).

5.4 Financial and economic barriers

- Cost price per m^3 too high, marketing of TMEs difficult (Kossodo station in Ouagadougou, Burkina Faso) due to competition with other resources.

- Lack of financial profitability for farmers (Tunisia) in the sense of the relationship between the costs (especially energy costs for complementary treatment and pumping) and the benefits provided pumping) and the benefits provided (increased crop yields, increased product quality, higher selling prices, etc.). No possibility to grow high value crops (no vegetable crops irrigated with TMEs).

- Cost of a parallel network too high (example of Greece in its wish to use TEE only for flushing toilets).

- Distance from possible end uses too great (excessive network investment costs)

- Establishment without any real need in the vicinity, too much competition from other conventional resources

- Obligation to prioritise the budget of local authorities, which is sometimes to the detriment of TWR (Spain - Barcelona).

5.5 Water quality problems

- Too poor water quality at the outlet of the WWTP (Tunisia) which can disturb or even prevent the operation of the complementary treatments necessary for the TWR to function (departure of sludge from the WWTP clogging filters, etc.). This poor quality can also generate operating constraints (cleaning of lagoons, washing of filters, clogging, etc.) or premature wear (corrosion, etc.).

- The problem of corrosion and clogging in the installations for a perimeter far from the treatment plant due to a long residence time in the WWTP network during the period of which allows the activation of anaerobic phenomena and bacterial growth inside the pipes. This problem highlights the importance of the choice of irrigation equipment (materials, irrigation technique and equipment, etc.) but also of the quality of water treated for the necessary TWR. Silt build-up in golf course storage lakes due to TSS carried by the effluent, hence periodic cleaning of storage lakes is imperative (Tunisia). This problem is partly inherent to the choice of complementary treatment technique chosen for TWR (lagoons have a treatment function with, in particular, a retention of SS).

- Irrigation of turf is more restrictive in terms of quality in golf courses: turf (GREEN) is very sensitive and requires more maintenance (Tunisia) due to the potential presence of different components in the wastewater.

- Risk of recontamination of water in an open-air storage pond, due to high presence of birdlife (Noirmoutier, France).

5.6 Design issues

- Lack of available irrigable areas in the vicinity of the treatment plants.
- Equipped areas that do not correspond to the planned irrigated areas. This problem, which is due to a lack of definition of needs or design, generates a problem of profitability and a counter-reference that is detrimental to the development of TWR.

The list of known and identified problems of a TWR project is not, as previously stated, exhaustive but presents a global vision of the obstacles to the implementation of a TWR project. The anticipation of these problems will allow a better vision of the feasibility of a project.

5.7 Decision-making scheme

Below is an example of a decision tree that draws on the different barriers outlined above. The creation of such a scheme requires the prioritisation of the obstacles that may appear to have the greatest impact on the project. This prioritisation is specific to the location of the project and requires reflection prior to any action.

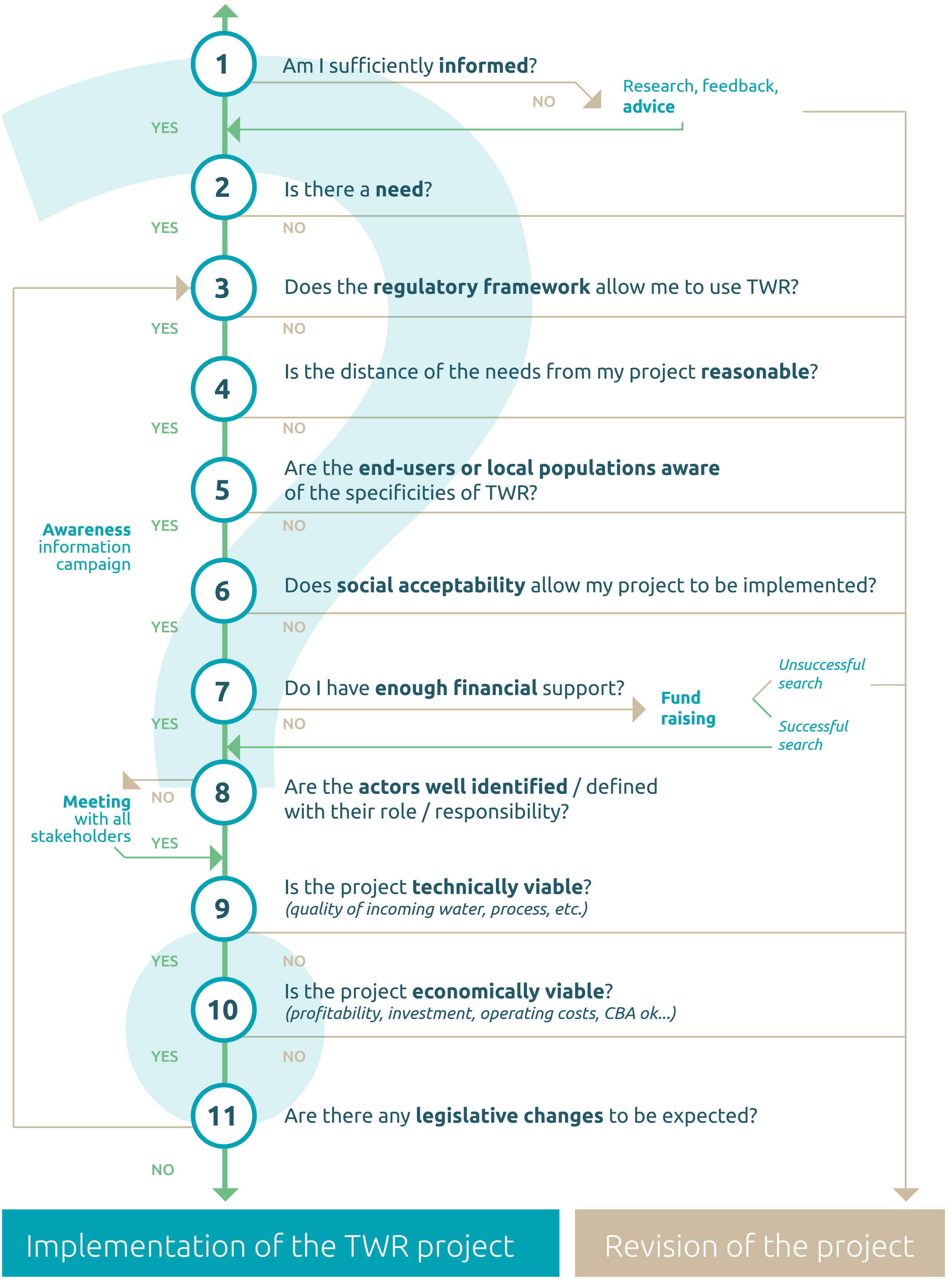
The example below presents a possible decision scheme from the point of view of the project owner of the TWR project. It should not be considered as a model to be replicated in all cases, but rather as a reminder of the points of attention to be considered throughout the process of implementing a TWR project.

For example, the order of tasks can be reviewed. Some of the tasks can be dealt with at the same time, rather than one after the other, thus limiting the number of feedback loops.

As mentioned above, the technical definition of the project in terms of quality, in particular the definition of the level of processing and uses, may be the subject of several iterations. This is a specific feature of TWR.

More obviously, as for any hydraulic development project, the service envelope may be reviewed in terms of density and/or distance in order to optimise the financial profitability of the development.

The issues of a TWR project



6- Example of a TWR installation

6.1 Feedback from the NOWMMA project

The information provided in this section is based on the feedback from the different NOWMMA project members and Deliverable 5.1 - Technical Evaluation of Systems and Design Notes.

The following sheets present examples of treated wastewater reuse equipment and systems that were implemented, studied and optimised during the NOWMMA project. The filtration and disinfection equipment used in 3 treatment processes are presented:

- A «sand filter and short storage» process;
- A «sand filter and long storage» process;
- An «ultrafiltration and storage» process (with the option of an immersed UV system).

These filters were fed with water from the wastewater treatment plant of the Communauté de Communes du Pays de l'Or (in Mauguio, near Montpellier).

In addition to the sheets on the treatment systems tested during NOWMMA, sheets on the different irrigation methods are available, presenting the specificities of each with respect to TWR.

6.1.1 Proposed branches

The choice of a WAS treatment system or an irrigation method for the use of TMEs should be made after taking into account the following criteria:

- The final use of the TMEs: in fact, the type of use determines the minimum water quality imposed by the different regulations (see 2.2 Regulations). For example French regulations require an A quality for the use of TMEs for irrigation of green areas open to the public green spaces open to the public, whereas a C quality is sufficient for irrigation of cereal crops;
- The level of qualification of the future operators: operating a sand filter is relatively simple, whereas operating an ultrafiltration system requires higher qualifications;
- The quality of the water leaving the wastewater treatment plant: The quality and variability of the concentrations of the water leaving the WWTP determines the types of TWR processes to be implemented depending on the use;
- The volume and frequency requirements for the desired use: this criterion will determine the volume of water to be produced and the storage to be set up;
- The financial criterion which will determine the investment and operating possibilities.

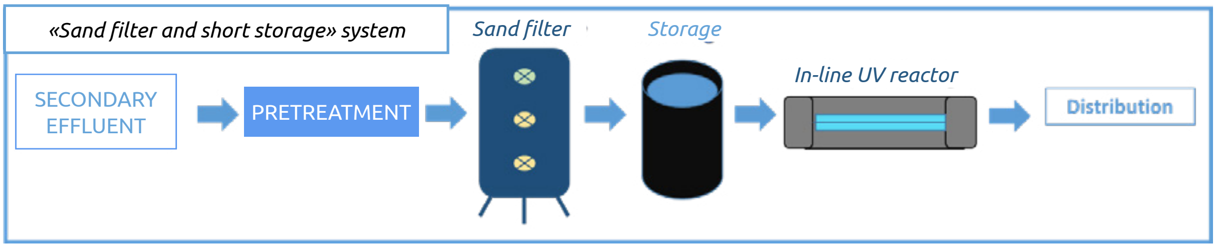
During the operation of the following systems during the NOWMMA project, algal growth occurred at the clarifier outlet at the level of the secondary effluent pumping to the WASTE systems. In order to overcome the possible dysfunction linked to this phenomenon, a pre-treatment is recommended to avoid the problem of clogging and thus improve the operating conditions and performance of the treatment plants.

Branch

Sand filter - short storage

1/2

How it works



Schematic of sand filter and in-line disinfection system - NOWMMA

The diagram above shows the pipeline. It is composed of:

- A sand filter that performs the filtration stage by allowing the removal of suspended matter and particles present in the water by percolation through a sand bed.
- A storage facility.
- An in-line reactor type UV disinfection system for the elimination of pathogens. The in-line UV reactor is a cylinder containing one or more UV lamps whose purpose is to irradiate micro-organisms to neutralise them.
  It is placed after the filtration stage because a high concentration of suspended matter impairs its performance.

The short storage format means that there is no need to wait for a treatment time between the treated water production and distribution phase. In fact, with this system, the sand filter, which is capable of producing water continuously (excluding washing cycles, once a day in normal operation), will fill a storage tank downstream. When the downstream user calls for flow, the water will be treated by the UV reactor at the same time as the distribution phase.

Performances

The performance of the system was determined by means of measurement campaigns carried out within the NOWMMA project. These measurement campaigns were based on the monitoring of physico-chemical and bacteriological parameters, in particular with the aim of positioning the performance of the system in relation to the French regulations in force on TWR.

The performance objective of the systems corresponds to quality level A of the French regulations. It is important to note that the performance of the Mauguio wastewater treatment plant already allows it to reach quality level A for the physico-chemical parameters, except for a few exceedances.

Concerning the performance of the filtration stage (sand filter), all the effluents comply with quality level A at the outlet of the filter (a level already almost reached at the outlet of the WWTP).

fichetechnique

Sand filter - short storage

Performances (continued)

Concerning the performances on the bacteriological parameters, achieved by the UV reactor on this line, it can be observed that this line allows the production of quality A water with regard to the parameters Escherichia Coli and Enterococci, i.e. a good elimination of these indicators of faecal contamination. The regulation is also based on the elimination of the parameters Bacteriophage RNA-F specific and BASR spores. For the latter (spores) it was not possible to reach level A. The performance on these parameters is determined by the abatement produced by the die (4 log). Although the filter allows the elimination of these parameters, they are not sufficiently present upstream of the filter, so the abatement achieved is not sufficient for A quality.

This simple system is not very sensitive to variations in the quality of the secondary effluent. In fact, in the event of a one-off malfunction of the wastewater treatment plant, this system makes it possible to absorb the variations and degradation of the incoming water (to a certain extent) to produce good quality water. This is a significant advantage of the system, as the operator of the wastewater treatment plant and the operator of the TWR systems may be different.

Exploitation

This system requires little experience to operate and minimal maintenance (checking that all components are working properly). Indeed, the sand filter is an efficient and relatively rustic process with a long life span (with a sand change every 5 to 10 years).

The UV reactor does not require any particular maintenance apart from regular checks of the measuring devices. The cleaning of the lamps is simple to implement by means of an automatic lamp cleaning system integrated in the UV reactor. In addition, the lamps can be changed according to their service life.

Summary

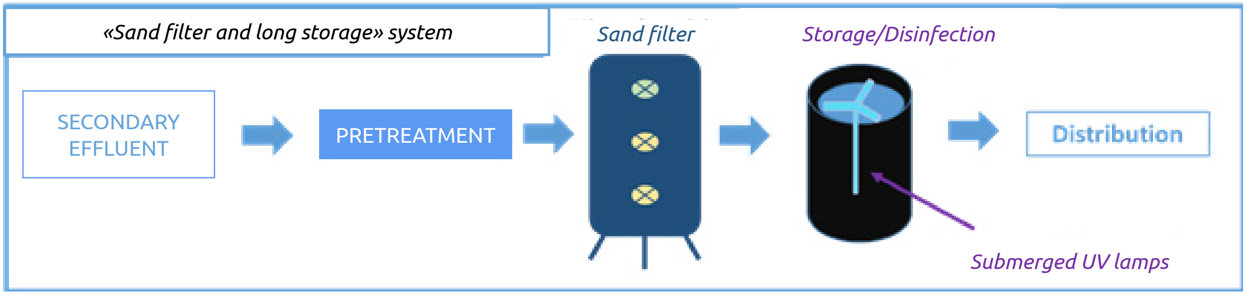
	BENEFITS	DISADVANTAGES
	• Easy to use • Low maintenance • Low-tech maintenance • Well-known and proven process • Not very sensitive to changes in raw water quality • Compatible with large tanks (but not tested in the (but not tested in NOWMMA) • Moderate cost	• For the most demanding uses in terms of quality objectives and the most sensitive: Despite a high level of performance, does not reach the potential of an ultra-filtration.

Branch

Sand filter - long storage

1/2

How it works



Schematic of sand filter and long term disinfection system - NOWMMA

The diagram above shows the pipeline. It is composed of:

- A sand filter which carries out the filtration stage by allowing the removal of of suspended matter and particles present in the water by percolation through a sand through a mass of sand;
- A storage facility;
- A UV disinfection system such as immersed UV lamps: in this case the UV lamps are lamps are mounted on a module floating in the tank and disinfect the water in contact with them. Unlike the in-line reactor, the operation of these lamps is independent of the water demand..

The long storage format means that it is necessary to wait for a latency (or treatment) time between the treated water production and distribution phase. With this system, the sand filter, which is able to produce water continuously (excluding washing cycles, once a day in normal operation), fills a storage tank downstream. This tank is equipped with UV lamps which allow the disinfection of the water and the preservation of its quality over a long storage time. This disinfection thus requires a treatment time before distribution.

Performances

The performance of the system was determined by means of measurement campaigns carried out within the NOWMMA project. These measurement campaigns were based on the monitoring of physico-chemical and bacteriological parameters, in particular with the aim of positioning the performance of the system in relation to the French regulations in force on TWR.

The performance objective of the systems corresponds to quality level A of the French regulations. It is important to note that the performance of the Mauguio wastewater treatment plant, where the different treatment plants are located, already allows for the achievement of quality level A for the physico-chemical parameters with a few exceedances.

Concerning the performance of the filtration stage (sand filter), all the effluents comply with quality level A at the outlet of the filter (a level already almost reached at the outlet of the WWTP).

technical sheet

Sand filter - long storage

Performances (continued)

Concerning the performance on bacteriological parameters, achieved by the UV lamps immersed in this system, it can be observed that this system does not allow the production of A quality water but only B quality water with regard to bacteriological parameters. However, this level of quality is sufficient for many uses. The importance of matching the level of treatment to the type of use is therefore demonstrated.

In the event of a need for water of B quality or lower, this system has the advantage of a reduced footprint compared to the «sand filter and short storage» system, while maintaining simplicity of operation and good reliability.

Exploitation

This system requires little experience to operate and minimal maintenance (checks that all components are working properly). Indeed, the sand filter is an efficient and relatively rustic process with a long life span (with a sand change every 5 to 10 years).

UV lamps do not require any particular maintenance. However, it is important to note that in case of replacement of a lamp it will be necessary to completely empty the storage tank to have access to the disinfection system.

Summary

BENEFITS			DISADVANTAGES
	• Easy to use • Low maintenance • Low-tech maintenance, especially for UV lamp replacement	• Complete emptying of the tank necessary for maintenance of the UV • Does not guarantee water quality A • Not suitable for large tanks	

Branch

Ultrafiltration - storage (submerged UV option)

How it works

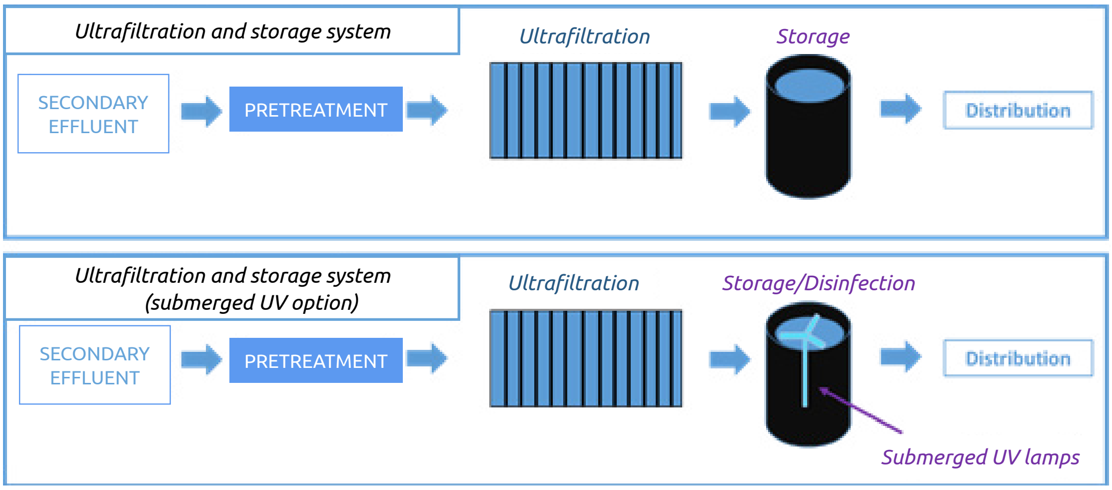


Diagram of ultrafiltration and long storage (with or without submerged UV option)

The diagram above shows the pipeline. It is composed of:

- Ultrafiltration, which is a membrane filtration process allowing purification of the water through fibres which will then retain suspended matter, particles suspended matter, particles and all bacteriological elements. Ultrafiltration can stop finer elements compared to the sand filter. Indeed, it can stop bacteria and certain viruses.
- A storage facility
- *(Optional: UV disinfection with submerged UV lamps)*

The operation is as follows: the filtration stage carried out by ultrafiltration allows both the elimination of particles in suspension and indicators of faecal contamination. The water produced is of very good quality and stored in a tank before distribution.

UV disinfection using immersed UV lamps can be installed in the storage tank to compensate for any malfunctions in the filtration stage or to ensure that the quality of the water is maintained over the long term as a preventive measure. No variation or deterioration of the water quality in the storage tank was observed.

Performances

The performance of the system was determined by means of measurement campaigns carried out within the NOWMMA project. These measurement campaigns were based on the monitoring of physico-chemical and bacteriological parameters, in particular with the aim of positioning the performance of the system in relation to the French regulations in force on TWR.

Ultrafiltration - storage (submerged UV option)

Performances (continued)

The performance objective of the treatment plants corresponds to quality level A of the French regulations. It is important to note that the performance of the Mauguio wastewater treatment plant, on which the various treatment processes are located, already allows the A quality level to be reached for the physico-chemical parameters, with a few exceedances.

The ultrafiltration process allows the production of very good quality water, quality A and above.

Contrary to other systems, the quality of the water produced depends solely on the performance of the ultrafiltration and its production capacity. For information, the production phase of the ultrafiltration is alternated with numerous washings to avoid clogging. In the event of malfunctions in the wastewater treatment plant, leading to deterioration in the quality of the secondary effluent, the frequency of washing cycles will have to be increased, which will be detrimental to the operation and therefore the supply of treated water. If the deterioration is too great it may be necessary to stop production to protect the membranes, to the detriment of service continuity.

This system is relatively sensitive to variations in the quality of the water leaving the treatment plant, which will mean greater maintenance requirements. It should be noted that, even under these conditions, this system still produces water of excellent quality.

Exploitation

Ultrafiltration is a process that requires qualified personnel and specific time allocated to maintenance and operation. This implies higher operating costs, trained personnel and safety equipment for handling the chemicals needed for the washing phases.

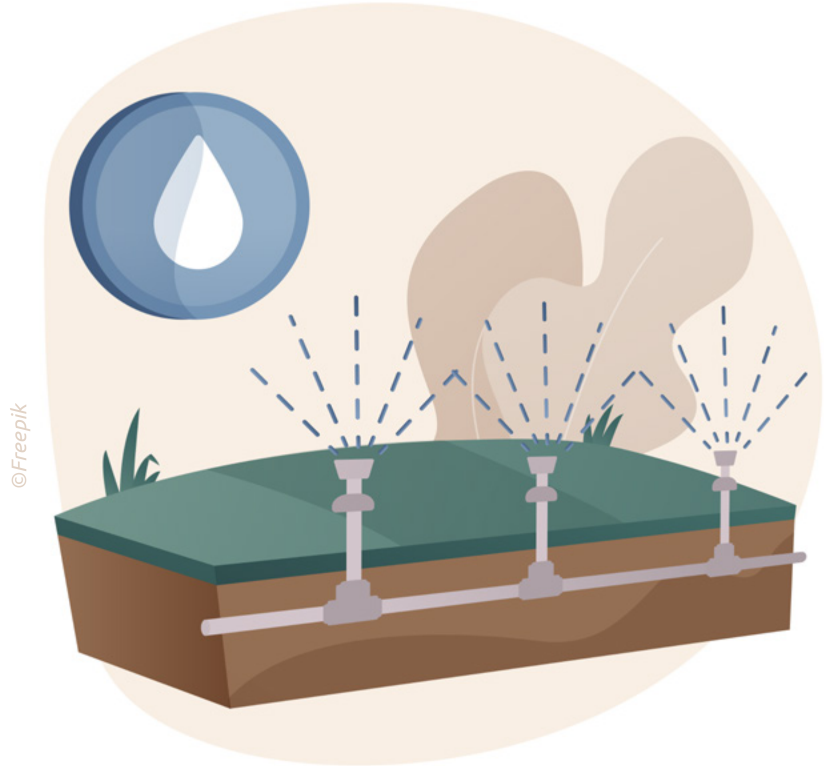
Submerged UV lamp option*: The UV lamps do not require any special maintenance. However, it is important to note that if a lamp is replaced it will be necessary to completely empty the storage tank to gain access to the disinfection system, or to provide a lifting system.*

Summary

BENEFITS		DISADVANTAGES
	• Very good performance in any situation • Does not require disinfection (optional)	• Investment costs • Maintenance and operation specific • Sensitivity to effluent quality secondary

6.1.2 IRRIGATION METHODS

Below are **two irrigation modes** observed during the NOWMMA experiment.



Localized drip irrigation

How it works

Drip irrigation is the process of bringing water under pressure through a system of pipes. This water is then distributed in the field by a large number of drippers distributed along the rows of the plantations.

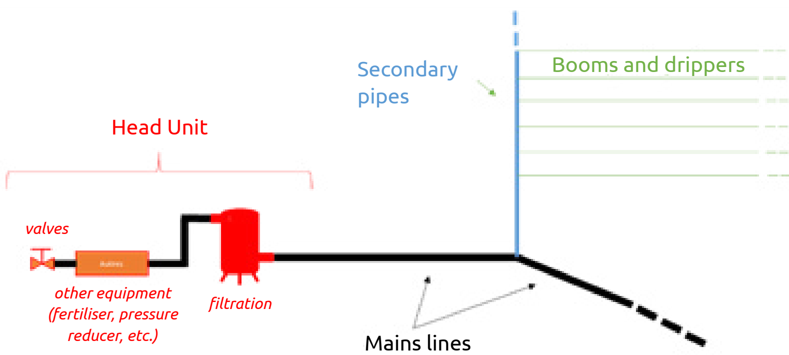
The wetted area of the soil is the area in the immediate vicinity of the plant roots. Therefore, this irrigation method has a high degree of water distribution efficiency. Drip irrigation is also called micro-irrigation. This type of irrigation allows a more efficient application of water to the plant than other irrigation methods.

The pipes on which the drippers, or sheaths, are placed can be distributed on the surface of the plot or buried (more or less deeply) depending on the operating needs of the plot and the crop. It should be noted that a buried network allows the exploitation of the plot with fewer constraints than a surface network, at the expense of the ease of maintenance of the network. On the other hand, it requires earthworks, and presents risks of crushing and root intrusions.

Design data

The information below is an example of a localized irrigation system and is intended to provide information on the operation of this type of system. A localized irrigation system usually has several components for water distribution:

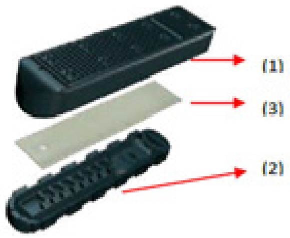
- **A head unit:** including flow control equipment, water quality (filtration) or fertilisation equipment
- **Main, secondary pipes**: allowing the water to be conveyed to the distribution booms
- **Drip lines**: drip lines laid out on the plot as needed, above or below ground
- **Drippers**: devices that allow the distribution of water to the crop. The spacing, type and distribution rate are determined according to the crop, the soil quality, the water quality and the configuration of the plot.



Simplified schematic of a localized irrigation system

Design data (continued)

There are several types of drippers, i.e. integrated or external, self-regulating or not, etc. **Below is an example of an integrated self-regulating dripper:**



The use of self-regulating drippers guarantees a homogeneous distribution even when pressures vary significantly. The dripper, integrated in the liner, consists of a filter (1), a labyrinth (2) and a silicone membrane (3). This type of dripper is called a long-circuit dripper with turbulence effect. This is because the energy in the liner is dissipated by the path of the water through the labyrinth (friction) and by turbulence caused by the sudden change in direction of the water. The diaphragm at the outlet of the labyrinth serves as a check valve and contributes to the regulation of the flow.

Operating recommendations

A well-dimensioned and regularly controlled filtration is essential to guarantee a clogging-free installation. Indeed, because of their very small cross-section, drippers are sensitive to clogging. The classic maintenance applied to this type of installation is as follows:

- Control of the overall flow rate of the installation
- Control of the homogeneity of the drippers' flow rates
- Regularly check that the head unit equipment is working properly, especially the filtration system filtration system if present. In the NOWMMA project, filtration was carried out by the In the NOWMMA project, filtration was carried out by the treatment systems, i.e. sand filter and ultrafiltration.
- Washing of the irrigation system with acid and chlorine in order to remove biological and physical clogging that may have and physical clogging that may have developed. The recommendations are at least a washing before and after each and after each irrigation campaign.
- Regular flushing of the network in order to evacuate suspended particles that may be present in the network to avoid clogging. in the network to avoid clogging of the drippers

Specificities related to TWR:

For use with water from WAS, particular attention must be paid to the problem of clogging the drippers. Indeed, TMEs are generally more loaded with suspended particles than conventional water (see deliverable 2.4).

It is recommended to perform regular tests on the irrigation network to determine the homogeneity of the distribution of the network. Tests such as the Keller and Karmeli test are easy to implement and provide a good estimate of distribution homogeneity.

The advantage of this type of installation is that it allows localized water distribution by limiting the contact of TMEs with the public. For safe distribution, and if compatible with cultivation and harvesting, it will be possible to bury the entire network. In addition, this type of installation is subject to few constraints with respect to current regulations on TMEs compared to other irrigation methods such as sprinklers.

Summary

BENEFITS	DISADVANTAGES
• Accurate water supply • Reduction of losses and wastage by evapotranspiration • Ease of nutrient supply • Easy adjustment of water supply • Easy automation	• Risque de colmatage (théoriquement accru en REUT) • Coût d'investissement élevé • Accumulation de sel localisée à la surface du sol • Exposition aux dégradations animales

technical sheet

Spraying

How it works

The principle of sprinkler irrigation is to reproduce natural rainfall in an artificial and controlled way. This is achieved by using equipment called sprinklers, which allow water to be distributed from the air.

As with drippers, there are several types of sprinklers, depending on the flow rate to be distributed, the type of crop and the use. Indeed, the same needs will not be found for the irrigation of green spaces as for agricultural crops.

Distribution by this method of irrigation is more homogeneous over the whole plot but is more subject to evaporation losses than localised irrigation.

Different types of spraying

Design data

The information below is an example of a localized irrigation system and is intended to provide information on the operation of this type of system.

The sprinkler irrigation system is similar to drip irrigation, consisting of a head unit (with valves, meters, pressure reducers, etc.), main and secondary pipes and sprinklers. It is not necessary to set up a filtration system as elaborate as the localized irrigation because of the low sensitivity of sprinklers to clogging.

The sprinklers should be arranged to provide full coverage of the plot to ensure even distribution.

Operating recommendations

Maintenance of this type of installation is low and is limited to checking that the equipment in the head unit is working properly, that the various pipes are in good condition, and that the sprinklers are working properly (rotation, reach, blockage).

Specificities related to TWR:

Sprinkler irrigation is not very sensitive to clogging because of the large distribution cross-sections compared to the size of the particles in suspension. However, contrary to localized irrigation, the aerial irrigation mode is highly sensitive to wind, which causes a drift phenomenon.

Drift is the phenomenon of modification of the trajectory of water drops undergoing the wind. Thus, there is a risk of hitting people on the edge of the plots if the wind is strong enough. The work of IRSTEA, as part of the NOWMMA project, is also available. It has made it possible to assess this risk.

In the case of plots bordered by public accesses, it is therefore necessary, as required by several pieces of legislation, to set up barriers to limit the drift phenomenon. Also, minimum safety distances must be respected to avoid any contact of the public with the water from the TWR water treatment plant.

It should also be noted that aerial distribution means that plants, leaves and soil are covered with water, which results in a higher likelihood of contact with TMEs than with localized irrigation. Signage or access control to plots is recommended.

Summary

BENEFITS	DISADVANTAGES
• Low sensitivity to clogging compared to drip irrigation • Easy to operate • Low equipment requirements • Low maintenance	• Wind hazard to maintain irrigation (general for all sprinkler installations) • Air dispersion (drift) to be controlled with respect to health risks (specific to TWR) • Contact with TMEs applied to soils and crops (specific to TWR)

technical sheet

6.2 USE OF RUT IN THE WORLD

The following examples are taken from the literature and in particular from the 2017 United Nations Wastewater Report. These examples are quite emblematic and are presented according to the purpose of the reuse. This purpose can be single or multiple.

6.2.1 Use of raw wastewater in Ghana

Ghana is a good example of urban and peri-urban agriculture using informal irrigation with untreated wastewater from streams or drains. In Kumasi and Accra, where the main treatment plants hardly function, wastewater is very often used to irrigate crops. This practice, which is not uncommon in urban centres in many African countries, feeds the population, provides employment and alleviates the poverty level of many Ghanaians, while helping to conserve freshwater resources.

In Accra, the EUB irrigates more than 15 types of vegetables on plots ranging from 22 to 3,000 m² per farmer. This irrigation provides an annual income of US$400 to US$800 for the farmers. The annual market value of the production is estimated at US$14 million and improves the quality of life of 200,000 people. In Kumasi, 115 km² of land is under cultivation.

However, there are public health concerns, especially regarding microbial contamination of these agricultural products. Analyses of vegetables sold in markets have revealed the presence of faecal coliforms and helminth eggs.

6.2.2 TMEs made drinkable in Namibia

Faced with water scarcity due to population growth, and therefore increased needs, and with declining rainfall following the 1957 water crisis, reuse for drinking water production seemed the only viable solution. This led to the first implementation of direct potable water reuse in the city's wastewater recycling plant. This is the longest experience in the world in this field since 1969. During more than 40 years of operation, the safety has been monitored through epidemiological examinations and no health problems have ever been reported.

Water quality is assured by a multi-barrier approach. A new plant dating from 2002 is equipped with technological improvements.

The effectiveness of the multi-barrier approach relies on very effective information policies and public awareness campaigns for public acceptance.

The viability of the project is based on the absence of water-related health problems; the multi-barrier approach; the reliability of operation, on-line processes and water quality control; and the fact that there are virtually no alternatives.

Treatment is provided by powdered activated carbon, pre-ozonation, coagulation, dissolved air flotation, dual media filtration, main ozonation, bio-activated carbon filtration, granular activated carbon filtration, ultrafiltration (cut-off 0.04 µm), disinfection by chlorination (with Cl2 chlorine gas) and stabilisation (with NaOH). The performance of this treatment plant allows for the TWR of 21,000 m³/day.

6.2.3 TWR for industrial use in South Africa

Since 1980, South Africa has been a pioneer in the in-house treatment and recycling of wastewater in the industrial sector.

ESKOM is the main state-owned electricity company and one of the largest in South Africa. Large amounts of water are used in the hinterland thermal power plants, mainly for cooling purposes, which results in a large amount of 'blowdown' water (i.e. water from the cooling plants). This water cannot be discharged until it has been treated because of its high salinity and the presence of pathogens and chemical additives.

In the early 1980s, ESKOM started to install reverse osmosis plants to treat the blowdown water. The Lethabo power plant in Sasolburg in the Free State province is currently equipped with such a plant with a capacity of 12 million litres per day. Some of the purified water is returned to the concentrated cooling water circuit, while some is used as feed water for the ion exchange process, another desalination process. The water from the latter process, which has very low levels of total dissolved solids (TDS), is reused in the plant.

6.2.4 TWR for agriculture: Example of Tunisia

Water reuse has been a priority for Tunisia since the early 1980s, when the country launched a nationwide water reuse programme to increase its available water resources, following initial WWR projects in the 1960s. Most urban wastewater is treated with secondary biological treatment using activated sludge, and less frequently with tertiary treatment.

Restrictions on the use of treated wastewater to protect public health have received considerable attention and are in line with WHO recommendations (WHO, 2006b). Tunisian regulations allow the use of secondary treated effluent on all crops except vegetables, intended for raw or cooked consumption. The regional agricultural services are responsible for supervising the use of treated wastewater, and collect very small fees from farmers. Farmers should pay for water for irrigation according to the volume required and the area to be irrigated. This practice is not widespread.

Despite strong government support for the use of treated wastewater, farmers still prefer to irrigate with conventional water for reasons related to the quality of the TMEs produced (regular technical problems with WWTPs), lack of trust and communication between users and sanitation stakeholders, regulations on crop selection, or other agronomic considerations. Farmers in the drylands of the South also express concern about the long-term effects of saline wastewater on their crop yields and soils. In addition, they consider that sanitary restrictions prevent them from growing high-value crops such as vegetables. However, in areas of high water stress where few alternatives to WAS are available, farmers seek to use WAS to maintain their activity despite poor water quality (e.g. El Aguila perimeter in Gafsa). In order to address these problems, Tunisian decision-makers have been working to strengthen coordination and adopt demand-driven approaches to improve planning for wastewater reclamation, and irrigation projects using safely treated effluent.

In Korba, for example, a groundwater recharge project aims to limit saltwater intrusion due to overexploitation of the water table while preserving the region's market gardening activities, which depend on groundwater resources. After a maturation phase, a percolation infiltration system via basins allows the infiltration of TMEs into the water table. However, the project had to be interrupted for organisational and financial rather than technical reasons.

6.2.5 TWR for environmental purposes: The example of natural groundwater recharge in Mexico and Italy

The Tula Valley in Mexico is a very telling case of unplanned water reuse. For over 110 years, up to 52 m³/s of wastewater from Mexico City has been used to irrigate this valley. This has resulted in the accidental recharging of an aquifer that is used to supply water to some 500,000 people, including for drinking. Due to natural processes, this water supply is of sufficient quality. Recharging the aquifer has also had a positive impact on the local environmental, social and economic situation, and has also contributed to the development of this poor region.

In Milan, groundwater recharge was implemented to preserve the natural environment. After sand filtration and ultraviolet treatment, the treated water is returned to the aquifer. The water can then be drawn from the aquifer free of charge by farmers. The project, which cost 89 million euros, costs the community 80 cents/m³.

6.2.6 TWR for green spaces and entertainment venues: example of a golf course in Australia

The sewage pipe that runs through the Pennant Hills Golf Course carries wastewater from about 1,000 homes to the coastal town of Manly, where it receives primary (very shallow) treatment before being discharged into the sea. The project therefore involved using this untreated wastewater, which was contributing to the pollution of the ocean. In addition, there was a technical constraint that the golf club should not disrupt the flow and pressure required to convey the remaining effluent to Manly, during peak flushing and showering hours (morning and evening),

The system has reduced the golf course's drinking water consumption by 92%, earning it an award from Sydney Water. The company no longer needs to supply the golf course with 70,000 m³ of drinking water per year because of the use of the treated wastewater on site.

In addition, the nitrogen in the wastewater has made fertilisation of the golf course almost unnecessary, as small amounts of nitrogen accompany each watering of the greens. The savings in fertilizer are offset, however, by the need to amend the soil with gypsum to compensate for the excess sodium in the reclaimed water.

Overall, the system has proven to be a cost-effective way to protect against drought and reduce water supply constraints in the Sydney area. And the golfers are apparently happy..

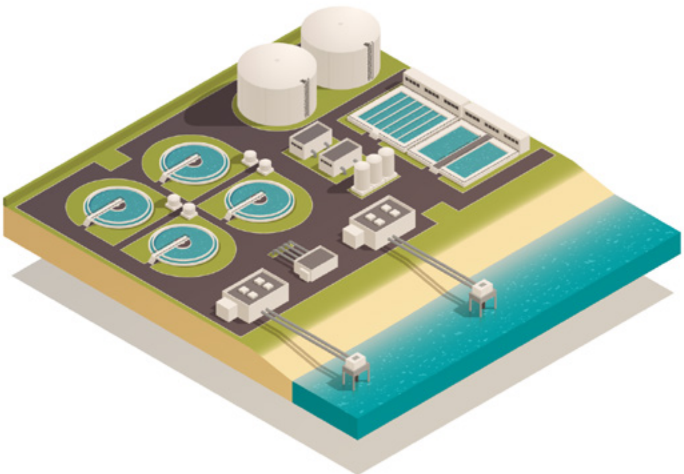
6.2.7 TWR for energy production and saving: example of Japan

In Japan, the 2015 Sanitation Law requires sanitation operators to use biosolids as a carbon-neutral energy source. The 2.3 million tonnes of biosolids produced in the country each year by the 2,200 wastewater treatment plants in operation can generate 160 GWh of electricity per year. In 2016, 91 plants recovered biogas for electricity while another 13 produced solid fuels. The city of Osaka provides a good example with 6,500 tonnes of biosolids-derived fuel produced per year from 43,000 tonnes of wet sewage sludge for electricity and cement production.

As financial support for sewage operators investing in energy reuse from biosolids, preferential pricing is applied to biosolids electricity based on a fixed price per kWh.

The Government of Japan encourages innovation by providing subsidies for advanced biosolids reuse technologies. Private financing is also encouraged through a special depreciation measure to reduce the tax burden on private companies that invest in energy reuse equipment used in wastewater treatment plants. By-products such as fuel derived from biosolids are being standardised in order to establish a market for these products.

6.2.8 TWR and waste recovery



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Wastewater treatment allows this water to be treated and returned to the environment without causing irreversible degradation. This method of management is highly fossil fuel intensive and is not very conducive to resource recovery. However, wastewater can be used in a number of ways: reuse of the wastewater itself, but also of the by-products of the treatment process (sludge, grease, sand, etc.) and the use of the energy potentially contained in the wastewater (heat, sludge methanisation, etc.).

Here are some examples of possible valorisation to be developed:

- **Recovery of phosphorus from wastewater** is achieved by precipitation of struvite. The most financially attractive solutions are those that involve upstream recovery, which relieves the operator of the need for costly extraction of unwanted struvite from the treatment system. However, as far as the marketing of the recovered phosphorus is concerned, there are currently no financial solutions to compete with commercially available mineral phosphate fertilisers (Schoumans et al., 2015). Short-term price volatility, long-term price increases and political concerns about phosphorus scarcity (in relation to issues of food insecurity and environmental degradation) may increase the emphasis on phosphorus recycling over unsustainable mining.
- **From wastewater to liquid fuel for transport**. The idea of producing biofuels for transport is based on the conversion of nutrients in wastewater into microalgae biomass (i.e. microalgae that grow in wastewater), which in turn is converted into biofuel. This approach has many advantages and can be used to treat wastewater, capture carbon dioxide, or produce alternative and sustainable energy without competing with the agricultural sector for water, fertiliser and land. In the United States, the NASA-led Offshore Membrane Enclosures for Growing Algae (OMEGA) project is conducting feasibility studies for the production of jet fuel using microalgae cultivation in floating offshore tanks that are 'fed' by urban wastewater (Trent, 2012).
- **Bio-oil from wastewater algae**. In New Zealand, the National Institute of Water and Atmospheric Research (NIWA) has demonstrated the commercial viability of producing bio-oil from microalgae grown with wastewater at the Christchurch treatment facility (Craggs et al., 2013). Carbon dioxide is added in 'high loading algae ponds' to promote conversion of algal biomass to energy efficient bio-oil*.
- **Production of biodegradable bioplastic**. Biodegradable bioplastic produced using microalgae grown in wastewater has the potential to replace traditional petroleum-based plastic at lower costs. Once made economically viable, this process could revolutionise the polymer field, offering new opportunities for sustainable, bio-based products, as well as providing additional benefits such as carbon sequestration, reduced environmental footprint and dependence on oil, and better end-of-life solutions.

- **Production of cosmetic ingredients from wastewater using microalgae**. Since July 2015, the Algae Biomass Energy System Research and Development Center at the University of Tsukuba, Japan, has been conducting research on algal biomass and industrial applications to synthesise algal oils with a view to establishing an «algal industry» combining biofuel production, wastewater treatment and algal oils for cosmetic and medical products.
- **Grey water for drinking water production for the Concordia base in Antarctica**: At the Concordia Antarctic base, a Franco-Italian research station located 1,600 km from the South Pole, grey water (from bathrooms and kitchens) has been treated by membrane technology to produce the base's drinking water since 2005. The technology implemented is linked to research conducted for long-duration space flights.

6.2.9 Summary of TWR experiences around the world

According to the UN, it is estimated that in 2017, **20% of wastewater was returned to the environment with appropriate treatment**. These figures tend to increase as experience is gained and regulations evolve as a result. National regulations reflect the country's experience with TWR, both in terms of duration and number. Some international projects provide a more global and common vision of TWR. These projects allow the pooling of usable data in order to refine national regulations.

The countries with the most developed water treatment strategies are the highest income countries (30% of wastewater is not treated in high income countries compared to 92% in low income countries in 2015, according to the UN). And depending on the challenges faced by the countries, the projects carried out, and therefore the feedback, differ according to the intended use of the TWR projects.

6.2.10 What about TWR in France?

In this chapter, we list the projects we know of in France. Even if they are not numerous, the development of LWR projects is dynamic:

- Irrigation of cereals (grain and seed maize, grain and seed sunflower, wheat, etc.), tobacco, market gardening (onion and potato field crops) - Clermont Ferrand wastewater treatment plant (63),
- Irrigation of potatoes - Noirmoutier water treatment plant (85),
- Irrigation of coal for freight - Cherbourg wastewater treatment plant (50),
- Watering of public green spaces - Cavalaire and Croix-Valmer water treatment plant (83),
- Watering of golf courses - Saint-Gildas-de-Rhuys wastewater treatment plant (56),

In addition, a series of very advanced projects such as:

- Watering of the stadium - Dinard water treatment plant (35),
- Watering of the Agde golf course - Agde wastewater treatment plant (34),
- Watering of the Grande Motte golf course - La Grande Motte wastewater treatment plant (34),

Finally, projects are being studied, including some of the most innovative.

For example:

- Reuse of treated wastewater for artificial snowmaking in the Les Houches ski area in Chamonix (74),
- Reuse of treated wastewater for artificial snowmaking in the Valberg ski resort (06),
- Reuse of treated wastewater to produce drinking water (surface water recharge via a dam) in Sables-d'Olonne (85).).

7- Conclusion

As a reminder, this document is an informative document intended for the project owner of a WASR project or for anyone wishing to get involved or to initiate such a project. This document provides general requirements for the successful implementation of a treated wastewater reuse project. It presents an overview of the success and failure factors of this type of project that have been encountered, either through feedback from the literature or from the experience developed during the NOWMMA project.

The main difficulty in implementing a WASP project lies in the multiplicity and multidisciplinary nature of the actors involved in the use of treated wastewater, which is a new and sensitive issue in some countries due to the apprehension it may arouse in the populations or responsible decision-makers.

The current awareness of a trend towards increased scarcity of resources in certain regions of the world requires the efficient implementation and optimal management of projects of this type in order to inject useful and reassuring feedback. To this end, it is proposed to take into account the recommendations included in this document, but also to give particular importance to feedback from similar projects in order to understand recurring problems.

In conclusion, it should be noted that this document may continue to be enriched or amended by its authors, depending on the progress made in the field of TWR, in particular the continuation of R&D work and the capitalisation of feedback from around the world.

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TWR *

Decision making guide
for the implementation of a
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