LES SYNTHÈSES TECHNIQUES
DE L'OFFICE INTERNATIONAL DE L'EAU

The Circular Economy in the Field of Water

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April 2015

Office International de l'Eau

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This synthesis « **The Circular Economy in the Field of Water** » was performed by **Samia Boufous,** student in the AgroParisTech-ENGREF specialized master "Water Management" (post-master degree) in Montpellier.

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TECHNICAL SYNTHESIS

The Circular Economy in the Field of Water

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April 2015

Abstract

The main objective of the study is to present an overview of the reuse of treated waste water in France. France is fortunate to have abundant water resources which are generally much greater than demand. But resources are heterogeneously distributed in both time and space. Moreover, climate change is likely to aggravate water shortages. The Reuse of Treated Waste Water presents the major advantage of providing an alternative low-cost resource that can serve to limit water shortages, to better preserve natural resources and to contribute to integrated water management. RTWW is also proving to be an effective practice for economic and ecological reasons.

Having passed through waste water treatment plants (WWTP), waste water may be subject to additional purification and reuse especially for irrigation and watering green spaces. This reuse enables the mobilization of additional water resources in addition to protecting receiving waters inviting treated waste water. In France, any reuse must comply with conditions imposed by the decree of June 25, 2014, which takes into account recommendations made by ANSES, the national agency for food, environmental and work safety, in 2013.

This study sets out to advance various issues related to RTWW and highlight the regulatory context by paying more attention to irrigation reuse. It will also focus on the potential uses associated with appropriate processing techniques. The paper will thus demonstrate how RTWW is applied in France and what both the advantages and disadvantages relating to this practice.

Keywords

Reuse of Treated Waste Water (RTWW), Waste Water Treatment Plants (WWTP), irrigation reuse, alternative low-cost resource, potential uses, water shortages.

Table of contents

Abbreviations

RTWW: Reuse of Treated Waste Water

WWTP: Waste Water Treatment Plant

TWW: Treated Waste Water

IPCC: Intergovernmental Panel on Climate Change

AFSSA: French Agency for Food Safety

ANSES: National Agency for food, environmental and work safety

List of illustrations

List of tables

Introduction

The reuse of treated wastewater presents itself as a political and socio-economic issue for the future development of drinking water and sanitation services. It has the advantage of providing an alternative resource, to better preserve natural resources and contribute to integrated water management.

The issue of water and its reserves is a problem has weighed with people around the world for decades. Demographic growth, extensive agriculture, climate change are some of the many examples threatening the sustainability of resources. In this context, the reuse of wastewater appears to be a promising solution. It reduces the amount of water taken from the natural environment and thus conserves the resource.

I. Circular economy: definition and application in the field of water

1. Circular economy: a global challenge

Born at a time when resources were abundant and virtually free, the current economic model, called linear, always made extensive use of those resources, which led to the deterioration of our capital and contributed to climate change.

The circular economy takes its name from its opposition to the current economic model. It is based on a twofold process: first, systematically reduce the input of raw materials and energy and water flows at the production stage; secondly, ensuring a lengthening of the life-span of the products by developing their repair, reuse, and ultimately recycling.

2. The circular economy in the field of water

The circular economy applied to the field of water policy aims to limit the waste of resources and environmental impact. In this context, the RTWW proposes to recover the treated wastewater, after passing in wastewater treatment plant, to provide them an additional purification and to reuse it particular for agricultural uses.

To meet the demand of a world population and a growing irrigated agriculture, water resources are more than ever threatened and sharing ever more complex. The last 2014 IPCC report highlights, among other things, the increased pressure on the resources available in southern Europe in recent decades.

France is not immune to this water crisis and must make a change in its water sector. Achieving an effective combination of uses and resources, this is the challenge for multiple stakeholders in the water sector. The promotion of wastewater then appears as a major lever to create value by developing sustainable and profitable solutions.

II. Socio-economic and environmental issues

1. Objectives

In order to estimate the relevance of a project, an assessment of the interests and challenges involved is required. Among the benefits recognized in the reuse of treated wastewater, there are five main components (Lazarova et Brissaud, 2007):

- The alternative resource

The first lever for the use of treated wastewater in irrigation remains economical. The TWW has advantages in terms of availability. Spatial and temporal availability makes them a reliable water source, available throughout the year and independent of drought for irrigation and industrial uses.

- Conservation and preservation of resources

The RTWW plays a major role in the economy and the preservation of drinking water to domestic use as well as the control of the over exploitation of groundwater resources.

- Legislative and health aspects

In addition, reuse participates in the deployment of the WFD[1] for sustainable management of the resource. Its development is promoted in France by the Grenelle I law[2].

- The economic value added

The RTWW ensures water resources at low cost for uses other than human consumption by avoiding development costs, energy costs of the transfer and pumping new resources such as fresh water for the exploitation of deep aquifers or desalination of seawater.

Wastewater, even when treated, can recycle organic materials and offer a greater variety of nutrients than commercial fertilizers. The use of TWW can therefore reduce the demand for chemical fertilizers, especially when wastewater is not diluted, thus making crop nutrients more accessible to poor farmers. Also, it avoids the costs of disposal of wastewater nutrients. Indeed, in light of the global phosphorus crisis, wastewater can be important sources of this element. These benefits give irrigated land high values.

Its economic advantage also lies in the maintenance or development of economic activity (agriculture, golf courses...), with the creation of direct and indirect jobs and in promoting tourism in arid regions.

In some cases, the choice to meet irrigation water needs through the use of treated wastewater (rather than inter-basin transfers, for example) allows to mitigate conflicts of use and increase water autonomy.

- Qualitative and quantitative environmental benefits

Reduced discharges into surface waters: The elimination or at least reduction of discharges into surface waters through reuse prevents the possibility of anaerobic conditions in rivers and the eutrophication of lakes and reservoirs.

Spreading wastewater: The spreading of wastewater allows us to benefit from the natural properties of the soil. Indeed, the wastewater contains nutrients (nitrogen, phosphorus and potassium) and trace elements (iron, copper, manganese, zinc, etc.) that are beneficial for crops, and can significantly increase the yield. This increases the productivity of agricultural crops and quality of green spaces, recreational land and other improvements by the same way the living and the environment.

[1] The European Water Framework Directive (European Directive 2000/60 / FE) aims to achieve, by 2015, the "good state" ecological and chemical for all natural aquatic environments and preserve those in very good condition.
[2] The Grenelle I law or Law No. 2009-967 of 3 August 2009 relating to the environmental Grenelle implementation is a French law of programming that formalizes the 268 commitments of the Grenelle environment.

Prevent the diversion of water sensitive ecosystems: The diversion of rivers for agricultural, urban and industrial uses reduced river flow and has a harmful effect on the aquatic environment. Wastewater reuse reduces the pressure on ecosystems by reducing levies on rivers.

2. Risks and brakes

On the other hand, the challenges to be overcome in reuse projects can be classified into three categories:

a. Legal and health aspects

Raw wastewater contains various pathogens to humans. The major risk to the reuse of wastewater is the presence of pathogens or certain chemicals that have not been completely degraded during purification and thus exhibit disease transmission risks.

Annex 1 presents the dangers associated to the use of wastewater in agriculture, the main results are the presence of pathogens or certain chemicals products.

In agricultural use, we have to be careful not to bring the nutrients in excess because suspended matters protect microorganisms for many treatments, such as chlorine treatments or ultraviolet. Thus there is a competition between the removal of microorganisms and the preservation of suspended matters to an important agricultural productivity.

From a legal point of view, it appears through a few recent examples that regulation and the way it is applied have played and continue to play a decisive role in the restraint of the reuse of treated wastewater in France.

b. Socio-economic aspects

Social acceptability

The public perception of the use of wastewater in agriculture significantly varies from one community to another. Where there is water scarcity or where wastewater is seen as a resource upon which people rely for their livelihoods, its use in agriculture is likely to be more acceptable. However, where people see it as a nuisance due to odour, perceived health or environment impacts and lower property values, then it may be less acceptable.

To achieve general acceptance of wastewater use schemes, experience shows that active public involvement from the planning phase to the full implementation process is essential. The exchange of information between authorities and public representatives ensures that the adoption of a specific water reuse program will address real user needs and generally recognized community goals for health, safety, ecological concerns, program costs, etc. (World Health Organization, 2006).

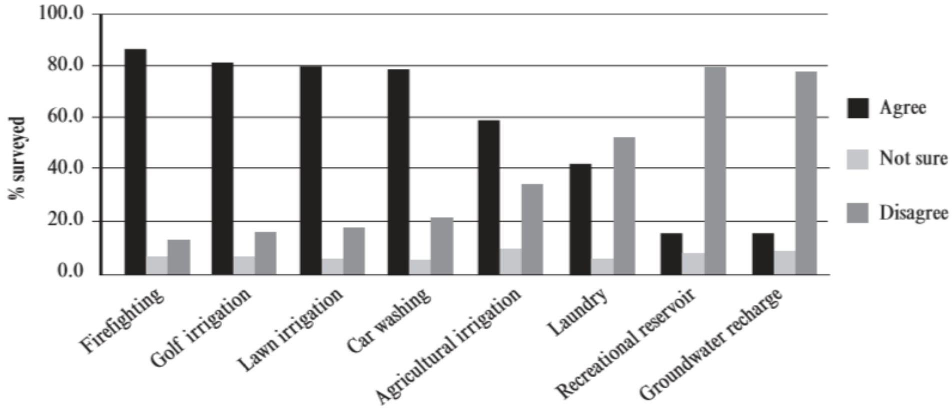

Figure 1: Attitudes towards wastewater use options (Organisation mondiale de la Santé, 2006)

As figure 1 demonstrates, the public is more likely to accept wastewater use where there is a perception that there will be limited contact with the wastewater.

The cost of reuse

The reuse of wastewater has high costs (infrastructure funding dedicated to tertiary treatment, storage and distribution network, operating costs), which is often greater than the simple water catchment where they are abundant. Under these conditions, it is mainly areas of very high water stress, where demand is strong, that can develop this technique initially pending the acquisition of a larger French experience that mechanically allows lower processing costs.

c. Environmental and agronomic aspects

Risk of soil pollution: It is possible that the items are made in excess. In this case, there is a risk of soil pollution and reduction in yield. The rates of nutrients (mainly nitrate) and salinity of the water used (due to soil degradation) are important. We must find the right balance between the level of treatment, the crop needs and the soil type. For irrigation, we must take into account the influence of excess of boron and other trace elements, allocation efficiency by salinity, the risk of soil alkalizing by excess of sodium, leaves burns by salt in the case of spraying (Aviron-Violet, 2002).

Risk of conventional water sources pollution: The impact on groundwater quality depends on several factors such as irrigation rate, quality of irrigation water, the treatment applied to wastewater by soil, aquifer vulnerability, the form in which irrigation is performed, the rate of the artificial recharge compared with the natural rate, the original quality of underground water and its potential use, the time under irrigation and the type of crops (World Health Organization, 2006).

3. Solutions and prospects

Health risk solutions

Concerning health risks, the first concern of the authorities, the WHO[3] recommends implementing measures that allow compliance risk threshold 10^{-6} DALY per person per year[4], for the reuse of treated

[3] Guideline for the safe use of wastewater, excreta and grey water, volume 2 : waste water use in agriculture WHO 2006

[4] DALY (Disability-Adjusted Life Years) : Adjusted life years on disability: The sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability.

wastewater in irrigation. This leads to provide for pathogens concentration of helminth eggs, less than 1 egg per liter in annual average and a reduction of 6 log[5] for viruses, bacteria and protozoa.

These reductions are achieved by a combination of health measures including (Agence Française de Développement, 2011):

- ✓ The wastewater treatment itself;
- ✓ The restriction on the type of crop and the choice of irrigation techniques;
- ✓ The respect of a period between irrigation and consumption of products;
- ✓ Control of human exposure to treated recycled water to farmers on the one hand and consumers (product washing, cooking) on the other.

Solutions to the risks of soil pollution and groundwater

In order to avoid the negative effects on the environment of using wastewater for agriculture due to its infiltration, it is recommended to (World Health Organization, 2006):

- ✓ improve agricultural irrigation practices ;
- ✓ establish criteria to operate wells used to supply water for human consumption in the surrounding areas (establish safe distances to the irrigation site, depth of extraction and appropriate construction) ;
- ✓ promote wastewater use for agriculture, preferably in zones where aquifers are less vulnerable ;
- ✓ systematically monitor groundwater.

Annex 2 shows, by pollutant, recommendations to limit some of the environmental impacts described above.

III. The regulatory context

1. Globally

The WHO recommendations are the only ones internationally. They are a source of inspiration for many countries around the world, including France. Their first appearance was in 1989 with the book "Health guidelines for the use of wastewater in agriculture and aquaculture". By 2000, some applications were revised based on epidemiological studies. The review by WHO, based on a quantitative risk analysis approach appeared on 2006. This revision refined the WHO standards. The changes focused on the standard of "helminth eggs" that for some categories increased from 1 to 0.1 egg / litre.

It is interesting to note that the 2006 WHO recommendations not only focus on direct health considerations but broaden the thinking of other complementary aspects (socio cultural, environmental, economic, financial and political) with a health link.

The recommendations of the WHO in 2006 are:

- Remind the concept of assessment / risk management,
- Describe the evaluation methods of the risk
- Fix the means to reduce (all or part) concentrations of microbial germs
- State of health protection measures fit for the uses related to RTWW.

2. In France

[5] It is a division of the concentration of pathogens by one million (10^{-6}).

In 2008, the French Agency for Food Safety (AFSSA) reported an initial opinion about the health risks for humans and animals via oral exposure to treated wastewater used for watering and agricultural irrigation.
In 2010, AFSSA has completed its analysis with an assessment of risks related to the reuse of a specific type of sewage, effluents from processing plants of animal by-products, for irrigating crops intended for human or animal consumption.

- Decree of August 2, 2010

In 2010 a new law was developed governing reuse projects. This is the "Decree of August 2, 2010 on the use of water from the purification treatment of urban wastewater for irrigation of crops or green areas."

The standards used by the decree of August 2, 2010 are higher than those recommended by the World Health Organization (WHO) for developing countries.

The decree defines 4 levels of health quality (A, B, C and D) of TWW associated with constraints of use, land and distance. The most demanding category is A because it's about the irrigation of unprocessed crops and watering green spaces open to the public. The less demanding category is D and which concerns the irrigation of forests with controlled access.

- Recommendations of ANSES[6]

In 2012, ANSES aimed to complement the regulation of August 2, 2010 about the reuse of treated wastewater and clarify the regulatory framework for crop irrigation, watering golf courses and green areas by spraying. They consider the necessity to limit the human exposure of wastewater treated during spraying operations.

The main objectives of this review are:

- Assess the health risks related to RTWW by spray for irrigating crops and watering green spaces for respiratory and muco-cutaneous way;
- Confirm or deny the criteria and values adopted by AFSSA under spray irrigation;
- Provide recommendations to supplement and clarify the regulatory framework of spray irrigation to landscape mentioned in the decree of August 2, 2010 and replace experimentation provided in its Article 4. This recommendations include treatment levels and propose ways to control the risk of spray irrigation;
- Assess the health risks associated with RTWW for washing roads.

Accordingly, ANSES provides a set of recommendations on:

- Treated wastewater quality,
- Supervision of wastewater reuse practices treated by spraying,
- Limitation of human exposure of affected populations: residents, bystanders and professionals (watering of golf, parks and crop irrigation).

- Decree of June 25, 2014 modifying the Decree of August 2, 2010 on the use of treated wastewater for irrigation of crops or green areas

[6] ANSES : The national agency for food, environmental and work safety

Based on the expertise of ANSES, the decree of June 25, 2014 fixed the technical requirements applicable to building owners and operators of wastewater treatment plants and irrigation systems, for the TWW in irrigation or watering crops or green spaces.

This decree brings new provisions, including:

- For irrigation or spray irrigation systems: it removes the experimental application file, sets specific technical requirements and complete the information to be entered in the irrigation program;
- It specifies the technical requirements for the design and management of the distribution network, storage of treated wastewater and the maintenance of the irrigation or watering equipment;
- Modify, within the framework of quality monitoring program for treated wastewater, the frequency of periodic monitoring checking the health level of quality of treated wastewater;
- It mentions a specific rule on health quality levels of treated wastewater to the wastewater treatment plants showing a low battery level of raw water;
- It specifies the procedure to follow in case of change of the elements of the licensing file.

As in other countries like Spain, Italy or Israel, RTWW in irrigation should pave the way for a framework for other uses such as washing roads or aquifer recharge (Condom et al., 2012). Tunisia already recycles its wastewater to recharge aquifers, benefiting the purifying powers of the soil. The first regulatory link is finally in place in France hoping that the following gets under way quickly to allow the multi-use pathways to meet the needs of the territories (Actu-Environnement, 2014).

IV. Treated wastewater: potential uses and associated processing techniques

1. Review of current reuse

Depending on user quality requirements, two major classes of reuse can be defined:

Non-potable uses are mainly:

- Agricultural irrigation: Fodder or vegetables, cereals, fruit trees, forests, grasslands, etc.
- Industrial applications: cooling circuit process water (process), steam generators, cleaning equipment, construction, paper, textile, etc.
- Urban uses: firefighting, washing of roads, wastewater recycling a building, watering parks, golf courses, cemeteries, etc.
- Recreational uses: artificial lakes and ponds, support for low flow of water courses, maintenance of natural habitats and wetlands, snow production, fisheries, etc.
- Recharge groundwater: the fight against the intrusion of sea water or brackish water in the case of overexploitation of the aquifer, supplying groundwater in critical situations, storing treated water in anticipation of future uses.

Potable uses are mainly:

- Indirect production of drinking water: increased water availability, production methods often linked to groundwater recharge; use following a natural environment passage.
- The direct production of drinking water: use after extensive treatment; Factory Windhoek (Namibia) is the best known example of producing drinking water from treated wastewater but this practice is not widespread.

2. Treatment techniques

The quality of the TWW required for RTWW depends on the purpose for which it is intended. Conventional wastewater treatment (activated sludge in particular) may be insufficient for certain reuses. Direct reuse of treated wastewater biologically cannot be considered without subjecting them to one or more additional treatments to minimize health risks in:

- cultivated products;
- the quality of the intake air, as irrigation or watering can be used in spraying, causing the formation of aerosol germ carriers.

These treatments also aim to protect the storage and distribution systems against the development of biomass and clogging.

The choice of the tertiary treatment method depends on several factors, the most important being the quality of the effluent, the type of the reuse, quality requirements and size of facilities. Depending on local conditions and the technical and economic criteria, different extensive or intensive technologies may be considered.

Existing combinations for the additional treatment of TWW are described below from the least to the most demanding in terms of elimination of suspended matters. It means that it goes from a simple secondary treatment following disinfection in order to irrigate agricultural crops until a complete tertiary treatment by coagulation, clarification, filtration and disinfection for the supply of water used for swimming.

The different diagrams are divided into 2 categories:

Conventional diagrams:

- Disinfection by lagoons, ozonation or ultraviolet
- Filtration + UV / O_3 disinfection
- Physico-chemical treatment by coagulation, flocculation with or without clarification + filtration + disinfection UV / O_3

Membrane diagrams:

- Microfiltration membranes (MF) or ultrafiltration (UF) immersed + disinfection UV/ O_3
- Sand Filtration + MF or UF membranes for external circulation + disinfection UV/ O_3

3. Financial evaluation generated by the RTWW

In a RTWW project, the question of costs is involved. Existing experiences indicate that the most significant expenditure concerns the construction of the treatment plant and the development of network and storage tanks.

Compared to the overall cost of treatment of urban waste water, the additional investments for tertiary treatment rarely exceed more than 30% the cost of secondary treatment (Lazarova et Brissaud, 2007). The largest investments are related to membrane processes. The costs are also strongly influenced by local constraints: price of the construction site, distance between the site and consumers.

In terms of funding, the sanitation fee collected from urban populations producing wastewater may include the amortization of the investment and the exploitation of the tertiary treatment required for the reuse.

4. Storage

Any reuse facility requires more or less storage. To regulate the daily variations of the outflow of the treatment plant, the volume of the reserve will be the equivalent of 24 to 72 hours of consumption if it faces the risk of interruption of water supply or some failure in treatment systems (Aviron-Violet, 2002).

In truly deficient regions in water resources, storage is inter-seasonal: it stores unused water in winter, which will be used during the summer. The storage volume is then the equivalent of several months' consumption (Aviron-Violet, 2002).

V. Feed-back experiences

1. Diversity of RTWW projects

The reuse of wastewater is a widespread practice in areas affected by water shortages. The Mediterranean basin is one of the world regions where agricultural reuse of urban wastewater is most practiced. It is widely used in Israel. Spain and Italy are the two European countries where reuse is developing quickly, either in the form of new infrastructure or by compliance ancient practices that consisted in irrigation with untreated wastewater without regulatory framework. Other countries are significantly falling behind on this point, which is clearly the case of France. Waste water is also used for the irrigation of green spaces (parks, sports grounds and golf courses), mainly in countries subject to high water stress: public gardens and golf courses in Abu Dhabi in the United Arab Emirates, Olympic Park, zoo, parks in Australia (Jimenez et Asano, 2008).

Over the last decade, the volume of wastewater reused has increased from 10 to 29% per year in Europe, the USA and China, and up to 41% in Australia. These results should not obscure the fact that only 5% of treated wastewater is reused, a volume of 7.1 km^3 per year, compared with 10 000 to 14 000 km^3 of renewable fresh water and easily accessible (Lazarova et Brissaud, 2007).

The treated water reuse percentage can vary considerably depending on the project (from 4% in Clermont-Ferrand to 100% in Amman). It seems, however, that this practice always allow the maintenance or the development of economic activity (agriculture, golf ...), with the creation of direct and indirect jobs.

2. RTWW in France

The RTWW is still very underdeveloped in French territory (19 200 m3 / day): the volumes involved represent about 2% of the volumes reused in other European countries, such as Spain and Italy (Commissariat Général du Développement Durable, 2014).

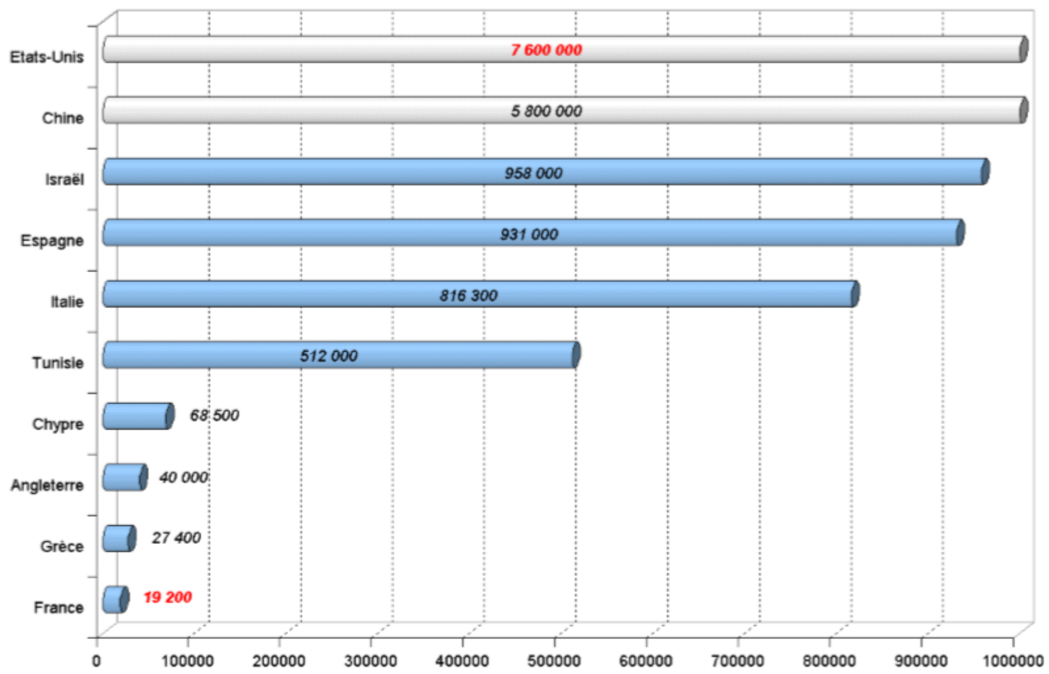

Figure 2: Average daily volume of recycled water for irrigation of crops (m^3 / day) (Jimenez et Asano, 2008)

In France, water availability does not involve the systematic use of this practice. Water resources are generally higher than demand and the country is rather far from being in short supply. Indeed, the overall net consumption is about 12 km^3 per year (about 36% of samples), a much lower amount compared to the mobilized water resources in France in the order of 175 km^3 per year, in which 100 km^3 recharge groundwater. This observation could, in itself, justify the poor development of water reuse. However, it must be kept in mind that the situation is that there are, firstly, strong variations to interannual differences in rainfall and secondly, strong geographic disparities in the territory due to climate, the network drainage, geology and population density (Lazarova et Brissaud, 2007).

France therefore knows only local and seasonal episodes of water resource deficits. Thus, the reuse of wastewater is restricted to particular regions (especially islands).

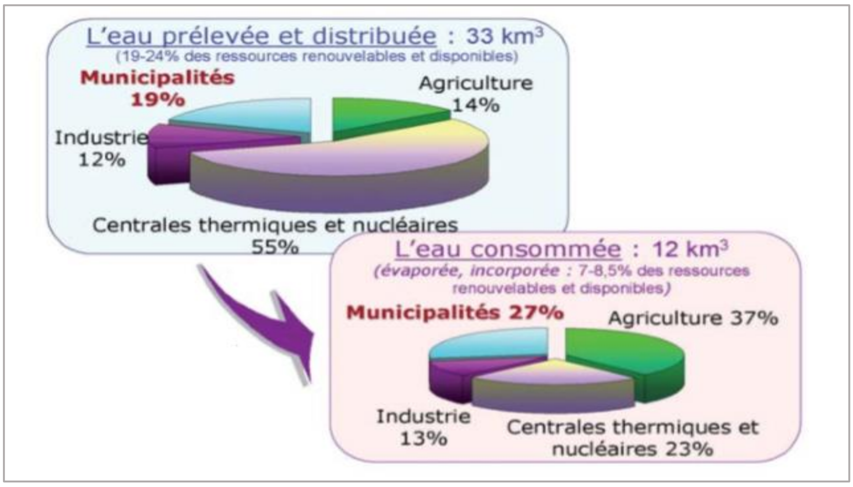

Figure 3:Water samples by sector in France and the portion consumed after use (Lazarova et Brissaud, 2007)

a. Case 1: Partial reuse of water from the treatment plant in Clermont Ferrand for a supplemental irrigation

The project involves irrigation of farmland of black Limagne in about 700 ha for 800 000 m^3 per year of water reused downstream the wastewater treatment plant in Clermont Ferrand. The water used undergoes a final lagoon in an unused settling ponds of a sugar factory situated on the edge of the WWTP before pumping into irrigation areas.

The justification for the mobilization of TWW is the absence of groundwater on the one hand and the high cost to apply a surface pumping in Allier more than twenty kilometers from the site. The aim is also to develop supplementary irrigation, to deliver on due date seed corn.

The results can be considered as exemplary: good technical control of the tertiary treatment throughout the years of experience, institutional arrangements perfectly operational despite the multiplicity of stakeholders, encouraging economic results for farmers.

The project was made possible by a public subsidy rate of investment of 65%, including a European subsidy. The case is also interesting because of the establishment of an epidemiological survey which was conducted by the Regional Health Observatory, in the pilot phase of 50 ha. No special events were observed during the three years of the study. Technically, the project is very specific by the pooling of purifying works between the sugar factory and tertiary treatment.

The project keeps 60 agricultural jobs and releases an agricultural value of 1.66 euros per m^3 used. Induced effects are related to agricultural activity and protection of water resources.

This project required a high-energy dialogue between all stakeholders, it is a reflection of a good technical analysis of existing opportunities.

b. Case 2: The promotion of treated wastewater in agricultural in the islands of France

In the islands, small watersheds, or in limited capacity water table, water resources may be insufficient. These communities resort to more and more remote resources to satisfy their needs, which forces them to pay more and more to cope with growing needs. This situation has resulted in many reuse operations in the islands of Ré, Noirmoutier, Oléron, Porquerolles, but also more recently in Pornic in the Loire Atlantique, Chanceaux sur Choisille in Indre et Loire, The Revest of Bion in the Alpes de Haute Provence, Noisilly in Indre et Loire. Wastewater reuse allowed to maintain or develop an agricultural activity or, as in Pornic, to significantly reduce the cost of watering a golf course.

Take for example the island of Noirmoutier which for over 30 years has irrigated its farmland from treated wastewater, thus creating a situation of reciprocal benefits: farmers have access to a cheap resource and helped to reduce the pressure on drinking water resources, while discharges of water into the natural marine environment have decreased.

An evaluation study of water resources management scenarios in Noirmoutier revealed that the RTWW for crop irrigation is more advantageous than other practices. The cost of recycled water for agricultural irrigation varies from 0.46 to 0.70 € / m^3 against 0.96 €/ m^3 for irrigation of green areas and 1.29 €/ m^3 for non-potable domestic uses.

Treated wastewater by Salaisière and Casie stations are pumped out of lagoons to irrigate crops.

Tableau 1: Water quality levels treated in 2011 at the Salaisière station

La Salaisière	Conditions à respecter du 1 / 1 au 31 / 12 sur le milieu récepteur n°2 (rejet lagunage dans fossés de marais)	2011	Conformité
Escherichia Coli	80% des échantillons présentent une teneur inférieur à 1000 E.Coli/100ml	100%	OUI
Streptocoques fécaux	80% des échantillons présentent une teneur inférieur ou égale à 1000 Strep. fécaux/100ml	100%	OUI
Oeufs d'Helminthes	80% des échantillons présentent une teneur inférieur à 1 oeuf d'helminthe / litre	100%	OUI
NH4+	80% des échantillons présentent une teneur inférieur ou égale à 5 mg/l de NH4+	100%	OUI

In 2011, the thresholds were generally respected. The non-compliance observed in summer is due to duck droppings present on the lagoons which decreased the quality of the lagoon and strengthened the impact of the concentration of Escherichia coli.

3. Assessment of experiences

We can therefore summarize the main factors that encourage and those that constrain a RTWW project in the following table (Condom et al., 2012)

Main constraints	Success factors
- Regulations not adapted to the local context; - Competition with other water resources (including conventional); - Sanitation sectors inadequate or incomplete; - The risk of soil salinization and water pollution; - The lack of analytical ability or control procedures; - Inadequate pricing policy (with strong subsidy of conventional water resources) and limited financial capacity; - A lack of knowledge and technical skills; - A perception by the people who, in different contexts, can be highly negative and lead to rejection.	- An integrated, multidisciplinary and multisectoral approach, concerted between the stakeholders and coordinated in institutional level; - Taking into account, from the initial stages of the project design, the potential uses with regard to quantitative and qualitative aspects of the resource in waste water; - An integration of this practice in a broader context of integrated management policy of water resources.

The outcome of a RTWW project therefore involves the existence of the following elements (Agence Française de Développement, 2011):

- Verification of a political will
- Confirm the actual existence of a demand for reused water: Analysis of the reuse market should not be limited to finding a need, but should lead to confirm the existence of a sustainable and effective demand for this unconventional resource
- Establish health standards adapted to the use of reused water and health monitoring
- Determine the treatment technique according to the sanitary quality required for the end use.
- Check the reliability of the production line of TWW and provide a rapid response system for processing incidents
- Find the conditions of the economic and financial balance of the reuse.

Conclusion

Recent technological advances, in the field of rustic solutions, such as lagoons or filtration membranes make treatment easier and less expensive. It is certain that this new resource will increase considerably in the near future in all areas where water supply of "first hand" is insufficient or random. The environmental benefits arising from the use of this new resource is significant.

So far, due to its climate, France has little exploited this possibility, although the specialized French companies have implemented outstanding facilities abroad. The new technical possibilities, regular and general increase in prices of drinking water, disparity of resource distribution and environmental requirements, also the recent administrative clarifications should accelerate the use of waste water not only for the irrigation but also for leisure spaces and urban uses.

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Annexes

Annex 1: Examples of hazards associated with wastewater use in agriculture (Organisation mondiale de la Santé, 2006)

Hazard	Exposure route	Relative importance	Comments
Excreta-related pathogens			
Bacteria (*E. coli*, *Vibrio cholerae*, *Salmonella* spp., *Shigella* spp.)	Contact Consumption	Low–high	Can survive in the environment long enough to pose health risks. Contamination of crops has led to disease outbreaks. Produce washing/disinfection and cooking reduce the risk. Poor personal hygiene after wastewater contact will increase the risk of infection/disease.
Helminths			
- Soil-transmitted (*Ascaris*, hookworms, *Taenia* spp.)	Contact Consumption	Low–high	Present in areas where sanitation and hygiene standards are low. Risk depends on how wastewater is treated, if shoes are worn, if food is cooked before eating, etc. Eggs can survive for a very long time in the environment.
- Schistosomes (trematode bloodflukes)	Contact	Nil–high	Schistosomes are present only in certain geographic regions and require suitable intermediate hosts. Schistosomiasis is transmitted through contact with contaminated water in endemic areas.
Protozoa (*Giardia intestinalis*, *Cryptosporidium*, *Entamoeba* spp.)	Contact Consumption	Low–medium	Can survive in the environment long enough to pose health risks. Limited evidence of disease outbreaks. Produce washing/disinfection and cooking reduce the risk. Poor personal hygiene after wastewater contact will increase the risk of infection/disease.
Viruses (hepatitis A virus, hepatitis E virus, adenovirus, rotavirus, norovirus)	Contact Consumption	Low– high	Can survive in the environment long enough to pose health risks. Contamination of crops has led to disease outbreaks.

Hazard	Exposure route	Relative importance	Comments
Viruses (hepatitis A virus, hepatitis E virus, adenovirus, rotavirus, norovirus) *(continued)*			Produce washing/disinfection and cooking reduce the risk. Poor personal hygiene after wastewater contact will increase the risk of infection/disease. In areas with poor sanitation and hygiene standards, most people are infected as children and develop immunity. May pose more of a health risk for local people who are not exposed as children or for tourists without immunity to local diseases.
Skin irritants	Contact	Medium–high	Skin diseases such as contact dermatitis (eczema) have been reported after heavy contact with untreated wastewater. Cause has not yet been determined but is likely due to a mixture of microbial and chemical agents. May also be caused by cyanobacterial toxins in some situations.
Vector-borne pathogens (*Plasmodium* spp., dengue virus, *Wuchereria bancrofti*, Japanese encephalitis virus)	Vector contact	Nil–medium	Limited to geographic areas where the pathogen is endemic and suitable vectors are present. Risk is mainly associated with water resource development (i.e. development of reservoirs and irrigation systems) and usually not specifically with wastewater use in agriculture. Lymphatic filariasis is the exception, as its vectors breed in organically polluted water.
Chemicals			
Heavy metals (arsenic, cadmium, lead, mercury)	Consumption	Low	Heavy metals may accumulate in some plants, but rarely to levels considered unsafe.
Halogenated hydrocarbons (dioxins, furans, PCBs)	Consumption	Low	Concentration of these substances is generally low in wastewater (but may be higher in sludge). These substances are usually adsorbed by soil particles and not taken up by plants.
Pesticides (aldrin, DDT)	Contact Consumption	Low	Risk is related to agricultural practices. Wastewater generally does not contain high concentrations of these substances.

Annex 2: Management Strategy to reduce environmental impacts (Organisation mondiale de la Santé, 2006)

Compound	Control measure
Nitrogen in excess	Dilute wastewater with fresh water when possible
	Limit the quantity of wastewater applied
	Remove excess nitrogen from wastewater
Organic matter	Do not continuously apply wastewater, to allow soil to biodegrade it
	Enhance removal of organic matter from wastewater
Salinity	Avoid the use of water with 500–2000 mg TDS/l or 0.8–2.3 dS/m electrical conductivity, depending on the type of soil and land drainage
	Reduce upstream salt use and discharge into wastewater
Chlorides	With sprinklers, only use water with <100 mg/l
	In irrigation by flooding, use water with <350 mg/l
	Irrigate by night to prevent leaf burn
Toxic organic compounds in soil and crops	Pretreat or segregate industrial discharges from sewage
	Promote cleaner production in industries, to avoid using toxic compounds
	Educate society to use less toxic compounds and, when used, dispose of them safely
Metals	Pretreat or segregate industrial discharges from sewage
	Use wastewater only in soils having a pH >6.5
Suspended solids	Use water without solids >2–5 mm
	Remove suspended solids by pretreatment of wastewater
	Plough soils when clogged

TDS, total dissolved solids

Sources: Seabrook (1975); Bole & Bell (1978); Reed, Thomas & Kowal (1980); USEPA (1981); Ayers & Wescot (1985); Phene & Ruskin (1989); Bouwer (1991); Oron et al. (1991, 1992); Pescod (1992); Farid et al. (1993); Chang et al. (1995); National Research Council (1996); Jiménez & Chávez (1997); Strauss (2000); Cornish & Lawrence (2001); AATSE (2004); Ensink, Simmons & van der Hoek (2004); Ensink et al. (2004); Foster et al. (2004).

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