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Using Water Smarter

Economy of Freshwater Resources and Potential for Wastewater Reuse in France

Tiphaine JABET

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SYNTHESIS

Using Water Smarter

Economy of Freshwater Resources and Potential for Wastewater Reuse in France

Tiphaine JABET

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AgroParisTech
Centre de Montpellier
648 rue Jean-François Breton – BP 44494
34093 MONTPELLIER CEDEX 5
Tél. : (33) 4 67 04 71 00
Fax : (33) 4 67 04 71 01
www.agroparistech.fr

Office International de l'Eau
Service gestion et valorisation de l'information et des données
15 rue Edouard Chamberland
87 065 LIMOGES CEDEX
Tél : (33) 5 55 11 47 74
www.oieau.org

ABSTRACT

Wastewater Reuse is an innovative practice which may become increasingly important in a context of global warming and water scarcity. Development opportunities of wastewater reuse in the French context draw our attention, especially for agricultural uses. We conducted our analysis through a multidisciplinary analysis including economic, social, institutional, legal, environmental and technical driving forces. Such projects are complex and they have to target a special need, in a specific context. However, wastewater reuse is not a widespread practice so far. Indeed, it is facing regulatory obstacles, it cost can be prohibitive and the social acceptability can be affected. Public and private stakeholders are working for a better knowledge of technical and sanitary issues, in order to lift barriers towards the development of this adaptive approach, especially for critical areas sensitive to water shortages. Among pilot projects that have emerged at the national scale, use of wastewater in forestry caught our attention because of its technical, economic and sanitary interests.

KEYWORDS

Wastewater Reuse, water treatment plant, agriculture, irrigation, multidisciplinary approach, forestry.

RESUME

La réutilisation des eaux usées, plus communément désignée par le terme de REUSE, est une pratique innovante amenée à se développer dans un contexte de changement climatique et de pression sur la ressource en eau douce. Dans le cadre d’un travail de synthèse, nous avons voulu étudier le potentiel de développement de cette pratique dans le secteur agricole, à travers le contexte français. Nous avons mesuré tout l’intérêt de procéder à une analyse multidisciplinaire des différents paramètres gravitant autour d’un projet de REUSE. Un tel projet est complexe puisqu’il dépend intégralement du contexte dans lequel il est mis en place et il doit répondre à un besoin bien ciblé. Encore peu développée, cette pratique fait face à certains freins, que ce soit au niveau de la règlementation, de son coût ou de son acceptabilité sociale. Aujourd’hui, le monde professionnel se mobilise pour lever ces obstacles et pour développer cette solution d’adaptation, notamment dans les régions sensibles à des pénuries en eau. Parmi les projets pilotes qui ont vu le jour, un système précurseur de REUSE en sylviculture a particulièrement retenu notre attention en raison de ses intérêts techniques, économiques et sanitaires.

MOTS CLES

Réutilisation des Eaux Usées Traitées, station d’épuration, agriculture, irrigation, approche multidisciplinaire, sylviculture.

SUMMARY

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LIST OF ABREVIATIONS

ANSES: French Agency for Food, Environmental and Occupational Health Safety
CBA: Cost-Benefits Analysis
CCTVA: Community of communes in Terrasses and Vallée de l'Aveyron
CGDD: Commissioner-General for Sustainable Development
COD: Chemical Oxygen Demand
DALY: Disability-Adjusted Life Years
DBO5: Biochimical Oxygen Demand
FCBA : Forêt Cellulose Bois-construction Ameublement
GIEC (or IPCC): Intergovernmental Panel on Climate Change
REUSE: Reuse of treated wastewater
SM : Suspended Matter
UV: Ultra-Violets
WFD: Water Framework Directive
WWTP: Wastewater Treatment Plant
WHO: World Health Organization

INTRODUCTION

In a global context of climate change and because of the increasing pressure on water resources, it is necessary to move towards new strategies of adaptation in order to meet our future needs. Wastewater reuse appears as an opportunity to anticipate the lack of water and to preserve freshwater resource. Indeed, valorisation of treated wastewater is particularly strategic in water stressed areas, where there is a critical need to save freshwater.

At the global scale, reuse of treated wastewater is estimated around 20 million m^3/day. Users sectors are wide and concern notably irrigation (for agriculture, golf courses, green areas) but also the industrial sector, the environment (for recharge of groundwater, restoration of aquatic environment) or even the production of drinking water. Reuse of wastewater in agriculture is the most widespread practice and covers around 10% of irrigated areas worldwide, which represent 1.7% of world (CGDD, 2014).

The implementation of a reuse project is singular and adapted to its specific context. Its establishment is complex because it incorporates an integrated approach including regulatory, technical, environmental, economic, health, sociological and institutional aspects. Reliable reuse projects can generate a sustainable economic value and fits perfectly into a circular economy pattern. Indeed, effluents leaving wastewater treatment plant (WWTP) return as an input into another system, which generates a real value added.

Regarding current challenges of reuse in agriculture, this study aims at analysing the situation of projects in France but also brakes and opportunities to its development. After a study of the global issues of wastewater reuse in agriculture from domestic origin, this technical synthesis will focus on a multidisciplinary analysis of initiatives in the French context. Then, a specific case study will introduce opportunities for Reuse in forestry.

CHALLENGES RELATED TO WASTEWATER REUSE IN AGRICULTURE

DEFINITION AND USES

Wastewater reuse is an old practice which has been developed since the late 19th century in countries such as Australia, France, Germany, India, Britain and the United States. For decades, many Reuse projects have been developed, especially in areas where freshwater resources suffer from great strain. The Mediterranean area, due to its vulnerability to climate change, concentrates the highest rate of initiatives turned towards wastewater Reuse to face water scarcity.

Reuse is a process whereby domestic wastewater, instead of being discharged into watercourses after passing through WWTP, is subject to another treatment in order to be recovered. Treated wastewater can be distributed according different practices, including flood irrigation, spraying, sprinkling, drip irrigation and micro-irrigation (WHO, 2006).
Uses of wastewater can be more or less stringent at the world scale. They are depending on the local and regulatory context where the project is developed. In developing countries, uses are mostly informal and wastewater doesn't receive an additional treatment.

WHO HEALTH RECOMMENDATIONS

Informal uses of wastewater can generate public health issues regarding their high concentration rate of pathogens such as viruses, bacteria, nematodes, protozoa…Poor sanitary quality of water is causing around 2 million deaths a year, mostly in developing countries. In order to improve epidemiological knowledge and define microbiological quality standards, WHO has settled guidelines concerning health aspects linked with Reuse in agriculture. Those directives has been developed in 1989 and revised in 2006 and 2012.

The implementation of irrigation programs with wastewater has to follow an overall management strategy, with a special consideration of health risks. Desirous of ensuring a sanitary level of protection, WHO has set a risk threshold with pathogenic microorganisms of 10^{-6} DALY per person per year. The DALY unit reflects impacts of Reuse in irrigation on the life time lost because of diseases, compared with an ideal healthy life (WHO, 2012).
As a first step, any proposed Reuse installation has to validate the compliance of local health goals. Then, an efficient operational monitoring network and water quality controls should support the project, in order to ensure a robust prevention of health risks of different users, such as farmers, local residents and consumers.

AN INTERESTING RESOURCE WITH HIGH NUTRIENT CONCENTRATION

Valorisation of mineral resources represent today a major issue in agriculture. First, nitrogen represents 25 to 45% of the carbon footprint from agricultural production. Then, phosphorus is facing an unprecedented crisis as its reserves are estimated around 70-75 years (Molle, 2012). According to the World Health Organization, intakes from wastewater reuse in agriculture could allow a reduction of 30% of mineral amendments in the world (Condom, 2014). For the record, treated wastewater are concentrated approximately of 50mg/l of nitrogen, 10mg/l of phosphorus and 30 mg/l of Potassium (WHO, 2012).
Treated wastewater has significant interests as it contributes to nutrient fertilization and maintenance of soil organic matter. It provides micro and macro elements to agricultural production and offers a greater variety of nutrients compared to commercial fertilizer (Lenica, 2013).

WHICH TREATMENTS FOR WASTEWATER REUSE?

Methods of treatment of wastewater are defined according different issues:
- What are the water requirements and which treatment capacity is required;
- What are the development strategies of Reuse to meet the different uses;
- What are the quality needs. Quality of treated wastewater determines its potential for a new use. Depending on its sanitary characteristics (proportions of pathogens, pollutants) and its concentration of minerals, wastewater will be affected to different agricultural purposes (Synteau, 2012). Appendix 1 illustrates possible treatment methods related to the desired agricultural uses.

WASTEWATER REUSE IN FRANCE

THE FRENCH CONTEXT

Despite a good availability of water resources at the national scale, France has to face numerous regional disparities. Indeed, some localized areas face chronic water stress situations, usually coupled with a significant water demand (irrigation requirements at peak periods for example). Among them, island regions, Mediterranean coastal areas or also agricultural scarce areas can be mentioned. Shortage periods are steadily increasing the vulnerability of these regions towards climate change (IPCC, 2014).

In France, domestic sewage transiting treatment plants are estimated around 5 billion m^3/year (Loubier, 2014). Nowadays, Reuse represents barely 1% of volumes from the treatment plants. In this context, this alternative to freshwater resources could represent a significant lever for agriculture for the coming years.

REUSE projects in France are quite marginal. They are mostly part of long-term approach to secure water supplies, in periods of peak demand or shortage. Projects holders are coming from the public sphere but also from the private sector for well-identified uses (irrigation of golf courses).

To date, bibliographic resources do not yet provide a numerical, localized and updated representation of existing Reuse projects. While some projects are established for several years (Ile de Noirmoutier, the ASA Limagne Clermont Ferrand ...), many local initiatives and pilot projects are emerging in recent years.

MULTIDISCIPLINARY ANALYSIS OF REUSE PROJECTS FOR IRRIGATION

First of all, deployment of Reuse projects for agricultural purpose needs to determine what are sources and uses, in terms of quantitative and qualitative needs. The development strategy combines both driving forces (increased water demand due to urbanization and tourism, water deficit areas, development of peri-urban agriculture), contextual aspects (socio-economic frame, status of the resource, climatic and physical constraints, infrastructures) and the objectives defined by the different stakeholders (Condom, 2012)

Figure 1 Sustainability criterias related to the deployment of REUSE projects

Driving forces associated to the development of REUSE projects are depending on the area considered. For example, on coastal issues, REUSE projects of the Atlantic coast are mostly emerging due to environmental and tourism purposes in order to protect the bathing areas; while on the Mediterranean coast, the main drivers of these projects will be water deficit and over-exploitation of water resources (Declercq, 2016). As illustrated in Figure 1, the sustainability of wastewater reuse projects in agriculture must be assessed globally, in an integrated way. In the frame of this study, it could be interesting to point that each REUSE system is complex has to be part of a multidisciplinary analysis.

Regulatory aspects

At the European level, wastewater Reuse is part of the deployment of the Water Framework Directive (Directive 2000/60/EC) for the sustainable management of the resource. Article 12 of Directive 91/271/EC specifies conditions and restrictions associated to Reuse. Then, each European country imposes its own recommendations and guidelines, which can be more or less restrictive and adapted to different uses.

At the national scale, the regulation in the Environmental Code (R. 211-23) has been imprecise for a long time. Before the publication of the sanitary and technical Decree of August 2010 about Reuse for irrigation (single use authorized to date), the project had been studied and redesigned for fifteen years. French standards for Reuse are much more stringent than those recommended by WHO. French regulations have the particularity to frame effluent quality, but also spreading practices of treated wastewater.

The decree of 2010 blocked the emergence of new projects Reuse because only gravity irrigation techniques or localized (drip irrigation) were allowed. However, sprinkle irrigation is the most suitable technology in France for agricultural irrigation, green areas or golf courses. To develop a project with this practice, a six-month phase of testing had to be conducted beforehand, at an average cost estimated at 200 000€ (Declercq, 2016).

Anses has brought its support to the government by piloting a risk assessment study of aerosols in some treated wastewater sprayed (Anses, 2012). This study found that the concentrations of chemical contaminants in treated wastewater were far below the maximum concentrations fixed (102 to 107 times lower) (Condom, 2013). The microbiological risk still remains a major risk factor because of the lack of epidemiological data enabling to associate an intensity of exposure to a risk of contamination. Recommendations about the risk of exposure have been elaborated: they concern water quality, irrigation practices (network management, scope sprinklers, safety distances) and information to residents (awareness, prevention, access restrictions) (Abs, 2012). Annex 2 illustrates those “vigilance points”.

In 2014, the decree of 2010 has been revised: experimental constraints for sprinkler irrigation have been removed and replaced by technical requirements. Since then, more research pilot projects have become possible. The regulation should be reviewed by 2016 but no significant changes in the evolution of practices are expected (Declercq, 2016).

The installation of an experimental irrigation project involves today:

- The implementation of a regulatory folder with technical, health and agronomic justification to support of the project;
- A validation by official authorization;
- An analysis of technical feasibility of the pilot project;
- An evaluation of the effectiveness of the sector.

Sanitary aspects

Wastewater can contain microbiological contaminants (which are causing infections, diarrhea, and allergies) and physicochemical (factors of poisoning and cancer). The health impact should be evaluated in advance in order to associate an appropriate treatment. Reuse projects must be compatible with the basic need to protect public health and environment. Health risks must be studied according to the contaminant concentration of the treated wastewater and the level of exposure of users and residents.

Depending on the type of desired agricultural use, water quality values are defined by the Code of the Environment. As we can see from the chart below, four categories are thus selected, from the more rigorous frame A to the less D.

Figure 2 Table representing wastewater quality standards for different agricultural uses (Lazarova et al, 2007 ; Legifrance, 2014)

		Quality levels			
		A	**B**	**C**	**D**
Type of use		- Vegetable crops consumed raw, unprocessed by a suitable industrial processing - Tree Fruits and pastures irrigated by sprinkling - Green spaces	- Vegetable crops consumed after cooking or transformed by industrial processing - Cut flowers sold (with drip irrigation) - Fresh grazing	- Cereal crops, - Nurseries, bushes and other flower crops with drip irrigation (not sprinkling)	- Forest with public controlled access
Quality caracteristics	MS (mg/L)	< 15	35 Conforms to the regulation of discharges from wastewater to the outlet from the station, out of the irrigation period		
	COD (mg/L)	< 60	125 Conforms to the regulation of discharges from wastewater to the outlet from the station, out of the irrigation period		
	E.Coll (UFC/100 ml)	≤ 250	≤ 10.000	≤ 100.000	-
	Fecal enterococci (reduction in log)	≥ 4	≥ 3	≥ 2	
	Phages F-specific RNA (reduction in log)	≥ 4	≥ 3	≥ 2	
	Spores of sulfite-reducing anaerobic bacteria (reduction In log)	≥ 4	≥ 3	≥ 2	
Distance restrictions for the protection of activities (m)	Waterhole	20	50	100	
	Pond aquaculture, fish farming, recreational fishing	20	50	100	
	Conchyliculture	50	200	300	
	Swimming and water activities	50	100	200	
	Livestock watering	50	200	300	

From a technical perspective, the health risk must be assessed in two distinct stages: the distribution of water and its absorption by the soil.
By air, inhalation of aerosols may represent an important public health problem. Scientific studies are trying to analyse sanitary inhalation risks with sprinkler irrigation. Concerning epidemiologic issues, only legionella contamination risks have been identified to date. It is therefore necessary to make appropriate treatment (UV, oxygen, pressure variation ...) to reduce the overall risk of microbiological contamination (Condom, 2013).
Established by the decree of the Environmental Code (2014), constraints associated to the distribution of treated wastewater (wind, terrain, distance, irrigation equipment) are causing technical problems in windy areas, such as coastal areas. Indeed, these parameters are difficult to assess: a wind speed greater than 15 km/h during 10 min led to the automatic shutdown of sprinkler irrigation (Nedey, 2015). Moreover, sharp monitoring materials can be very expensive (Lazarova, 2016).

Technical aspects

For each Reuse project, the main challenge is to optimize technical aspects with the objective of developing a sustainable system. For this, consideration of usages, practices and equipment is required:

▪ Optimization of uses

Reuse enables the provision of a reliable water resource as the volume is assumed to be constant throughout the year and independent of climatic events. To cope with the seasonality

of demand for irrigation (which reprensents few months a year), strategies has to be found to combine different uses or find optimal storage means.
To date, the diversification of uses in France is restricted to agriculture, irrigation of green spaces and golf courses. Many opportunities may emerge such as the washing of roads, cars, or feeding the fire terminals in urban areas. The removal of these regulatory locks could help improve the economic viability of projects Reuse (Lazarova, 2016).

▪ Optimization of practices and equipment management
The potential evolution of treated wastewater quality has to be supervised. For this purpose, control techniques are set up upstream and downstream the chain.
In treated wastewater, loaded elements have an effect on premature aging irrigation equipment. It is due to clogging phenomena, and its causes can be wide (Molle et al, 2014):
- Sedimentation of aggregated particles in traps areas;
- Formation of biofilms slowing down the fluid velocity. They are caused by the aggregation of microorganisms such as bacteria, fungi and algae;
- Chemical precipitation of minerals creating deposits which can clog the system;
- Creation of "plugs" at the distributor level watering.

Therefore, equipment management requires regular maintenance and frequent controls to prevent damage to equipment.
The research coupled with technologies and irrigation techniques represent a big potential for Reuse development in agriculture. Nevertheless, technologies must meet a very targeted and adapted application (Savary, 2016).

Economic aspects

Quality standards are rigorous and associated treatments are complex. The profitability of a project can be affected in case of overtreatments associated to uses requiring a lower water quality. The quality of treated wastewater has to be adapted to the purpose, without compromising social, sanitary and environmental aspects. A larger French experience should contribute to reduce treatment costs in the coming years.
Because of the cost of distribution networks, we also measure the importance of the proximity of the request and the demand of treated wastewater. The distance between WWTP and the irrigated plots can be an important obstacle to the deployment of a Reuse project. Regarding this limiting factor, Reuse initiatives are usually developed in the framework of renovations (networks), expansion of WWTP or new projects if the context is favourable (Declercq, 2016).

The Cost-Benefit Analysis (CBA) is a method to assess the profitability of long-term projects for the collectivity (project developers, users, funders, state). It analyses the relationship between costs and profits generated for all users (integrating environmental and social externalities), compared to a baseline. The CBA is used to highlight the distribution and the equity of benefit between the different stakeholders (Loubier et al, 2015).
CBA coupled with a financial analysis (which studies the profitability only to the project developer) allows to analyse the feasibility and sustainability of projects in the territory. It also assess whether compensation measures have to be settled to achieve a situation of "win-win" (Condom et al, 2012).

Many economic analyses have pointed out that the emergence of Reuse projects have been possible thanks to a combination of three factors (Loubier et al, 2015):
- Technical opportunities;
- A favorable territorial context;
- Social ties between the economic or privileged users and providers of the resource.

Social aspects

Wastewater Reuse impacts positively on the quality of life, by maintaining green areas for example, and tourism services (Irrigation of golf courses in dry areas, reducing discharges into the ocean and the sea). Reuse contributes to boost agriculture in peri-urban areas and secure resources. Then, this concentrated water has an impact on the profitability of production. Generally, Reuse has a role to play in maintaining or creating jobs (Molle, 2012)

The General Commission for Sustainable Development (CGDD) conducted a study on a sample of 4000 individuals, representative of the population in France. This study aimed at analysing the social acceptability of alternatives solutions for water management in the frame of the adaptation to climate change. According to the study, 68% of French people would be willing to consume vegetable products from the irrigation of treated wastewater (Appendix 4). Paradoxically, the available water is generally seen as sufficient and people living in areas with higher water pressures do not seem more sensitized to this problem (CGDD, 2014). The social acceptability of Reuse programs seems quite moderate, whereas many people are not aware that imported fruits and vegetables are coming from countries where irrigation with wastewater is common (it is the case of Spain for example).

Acceptance of projects is depending on the intended use of the treated wastewater and the proximity to irrigated plot (Charland, 2014). At the stage of project planning, it is essential to take into account the socio-cultural framework to assess the acceptability of the establishment of Reuse system. These practices are not well known by farmers, consumers and local residents: the psychological barriers can be important and it raises concerns or questions. It is essential to communicate around the subject and accompany the different actors to change their perception of this kind of practices. It can be possible by agricultural extension activities, by communication tools, but also by training sessions adapted to the needs of farmers, irrigators, policy makers. Tools recommended by WHO are presented in Appendix 5.

Environmental aspects

Reuse allows a significant saving of clear water resources and limit pollution of the environment. When treated wastewater is applied at the right dose, the soil plays its purifying role and releases into the environment are very low.
In case of overexploitation of natural water resource, this technique avoids tap into aquifers or surface watercourses. In agriculture, it can be a way to overcome the water use restrictions in summer (Molle, 2014).

The environmental impact of the Reuse is lower than other alternative techniques such as water desalination or interregional water transfers. In France, Reuse initiatives haven't caused major environmental issues so far. However, regarding characteristics of the environment, a special attention should be paid to the risk of eutrophication, groundwater pollution and how are valued co-products of the treatment. The concentration of salts in water can be harmful to the soil structure and agricultural productivity, we must ensure through regular analyses that wastewater is not too loaded (Charland, 2014).
Furthermore, we must ensure that the uses of the wastewater do not affect rivers in periods of low freshwater flows, because sewage water outlets are additional resources discharged into watercourses. It is not possible to withdraw the releases of WWTP in conditions where the flow of low water goal is difficult to achieve (Loubier et al, 2014).

Institutional aspects

The sector of wastewater reuse is still very little institutionalized. Associating uses and resources while involving multiple stakeholders is a key challenge for the development of Reuse in France. Many national and foreign examples have shown that the political will of elected representatives has a strong influence in supporting and boosting the projects. In fact, Reuse is a lever for an integrated approach to land and resource (Charland, 2014).
Actors in the water sector have a major role to play for the coming years in France. Combining their technical expertise and the innovation potential in wastewater treatment processes could enhance the treatment and control of the quality of treated wastewater.

Many collaborative initiatives are emerging to promote Reuse pilot projects at different scales. Experience feedbacks are essential to promote projects upon elected representatives and users still unfamiliar with these practices. This could also contribute to initiate consultations intended to soften regulatory constraints.
Among the initiatives that have been developed, here are some notable examples:
- Reuse HotSpot is a collaborative platform developed by Ecofilae. It aims to share expertise, decision-support tools and study the different opportunities of Reuse.
- Nowmma (supported by Pôle-Eau) is a research and development project concerning Reuse across Mediterranean basin. It follows a multi-player partnership, associating public and private stakeholders. Nowmma studies all sources of wastewater and diversification of uses (Jauzein et al, 2014).
- ALERA: This new project gathers 4 French and Spanish Pyrenean-Mediterranean regions. The purpose of this cooperative framework is to promote knowledge sharing. This project is supported by the Granollers area, the municipality of Migjorn Gran (Spain), Ecofilae and the Communauté de Communes Terrasses et Vallées de l'Aveyron (CCTVA). The Reuse project of CCTVA particularly caught our attention as it reflects a promising initiative in the forestry sector. That is the subject of our third part.

CASE STUDY – WASTEWATER REUSE APPLIED IN FORESTRY

BENEFITS OF REUSE IN FORESTRY

Among the variety of Reuse initiatives that can be developed in France, the valuation of the wastewater in forestry production with short rotation coppice (SRC) appears as an attractive option because of its combined benefits:
- Reuse in forest areas is developed in closed and controlled plots, allowing a good control of health risks;
- Forests are described as "green filter" because of their natural Purification function. As the forest soil can degrade wastewater, this practice allows good control of environmental issues by approaching a “zero discharge” into the environment (Fraysse, 2016).
- Inputs and nutrients contained in wastewater enhance tree growth and biomass production;
- This solution is simple, easy to implement and quite cost saving as it doesn't require large infrastructures.

Adapted to temperate countries, this solution is interesting for small-medium sized wastewater treatment plants in rural areas (Declercq, 2016). Outlets of this production can be found in biomass production (production of wood energy and fiber), the paper industry and the wood industry. This production is advantageous as supply is inferior to demand (CCTVA, 2016).

FEEDBACK FROM TREATMENT UNIT OF NEGREPELISSE (TARN-ET-GARONNE)

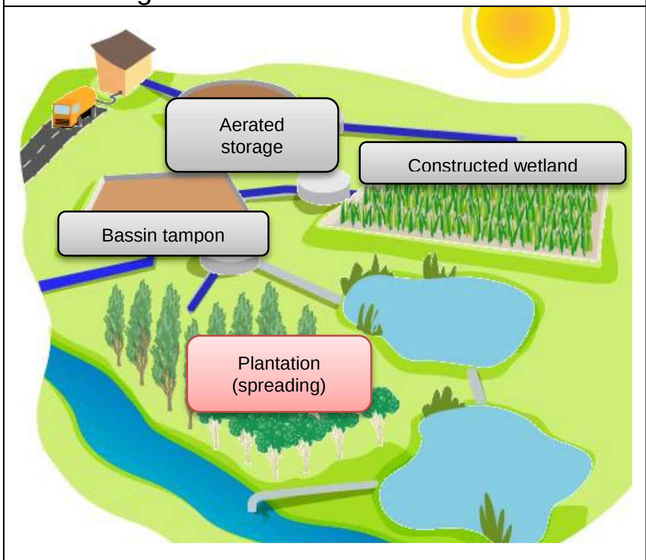
The Wastewater Treatment Plant of Negrepelisse faces two major issues: it is located within an agricultural region suffering from chronic water stress in summer; and the city is facing a demographic growth. Climate, agriculture and urbanization have an important impact on water resources.
This WWTP has a classical treatment chain connected to the network, running on extensive processes (population equivalent of 4000). In a context of local deficit of sanitation infrastructures, an annex was built with an extensive treatment of discharge from non-collective sanitation. This system is unique in France as it is unusual to use wastewater in forest production (SRC derived from eucalyptus and poplar trees). Biomass created will be valued in the production of energy to power municipal wood boilers of the municipality (Astee, 2013).
This Reuse project was boosted by elected representatives, eager to develop a project involving plant engineering and innovation (Bel, 2016). Many stakeholders are gathered around this project such as the research (Cemagref), the SATESE and technological institute FCBA. Still at an experimental stage, this initiative is part of a sustainable and integrated management of resources (Fraysse, 2016).

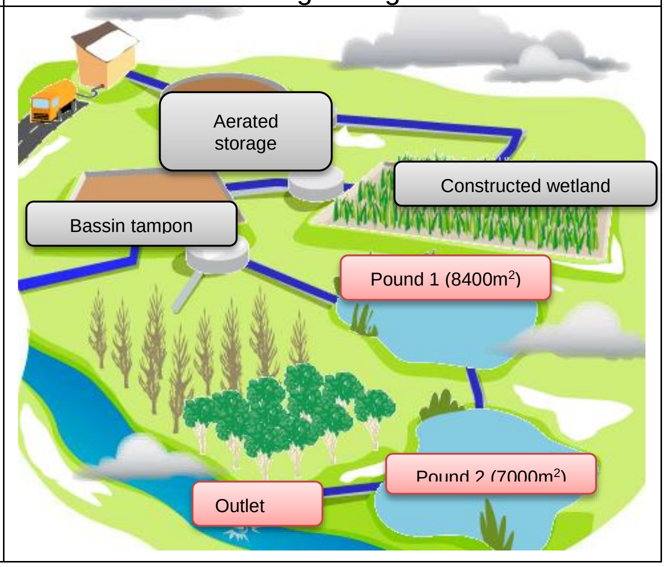
Wastewater treatment: two setups

After a pretreatment, wastewater is routed to a reed bed filter. The destination of the filtrate then depends on the period of the year, according to forestry needs. Two setups have been developed to cope with the seasonal demand (Figure 3):
- A summer setup from March to October. The water filter output is pumped up to the forest plantation for irrigation with a small flow. The load of wastewater is naturally degraded by the soil for planting. A buffer tank also serves as a reserve for irrigation (Astee, 2013).
- A winter setup from October to May. The filtrate is collected in ponds as the plantation doesn't need irrigation during winter dormancy. Lagoons play a buffer role (reduction of N and P) to improve the quality of discharge into the river. The duration of a course in the lagoons is over one year (Bel, 2016).

Figure 3 Diagrams of seasonal operations with wastewater REUSE (CCTVA, 2016)

Summer circuit Irrigation of forest with wastewater	**Winter circuit** Lagooning





Short Rotation Coppice production is located halfway between agriculture and forestry. The species are planted densely on a plot of 5 ha and are harvested every seven years. The plant will grow back at the stump after cutting (similar to a mechanical harvest).
3.2ha of planting are irrigated with wastewater from the WWTP, up to 5000m^3/year. Plantations benefit from a nutrient-rich irrigation, which can cover the minerals and organic elements needs necessary for their growth. The spread is also very water unpolluted (filtered BOD5 <25 mg/l; filtered COD <125 mg/l; MY <150 mg/l) (CCTVA, 2016). Irrigation is done by nozzle for plots near homes and micro-sprinkler for remoted plots (Bel, 2016).

The experimental project

The experimental station project aims to determine the environmental impact of the use of treated wastewater (as well as ash and sludge). To optimize irrigation management and maximize the biomass production, the effect of doses of wastewater and the efficiency of irrigation equipment are tested (Fraysse, 2016).

The experiments will be achieved next year. It will be possible to analyse the stock of biomass produced and to do analysis on the water quality and filtration characteristics. After 4 years, the first results are positive, especially on the production of biomass that would have almost doubled (especially with eucalyptus, well adapted to the soil and climate context). Biomass inputs should cover 1/3 of the annual municipality need to power the wood boilers in 3 years (at the time of the first harvest) (Bel, 2016).

Limitations

Some limitations to Reuse system in forestry could be identified. First, implementation of such projects is not always easy because of land issues: the surfaces should be available nearby, the land prices must be affordable, and housing should be relatively remoted from irrigated plots…

At the social level, the proximity of a station using Reuse techniques does not have a good reputation and can lead to discontent. This factor has been identified as a brake for the Negrepelisse treatment plant, even if the houses are relatively far (over 250m, except one about fifty meters). A public meeting to discuss the project and reassure local residents could be probably considered.

Due to a high content of nutrient in wastewater, one may encounter some technical risks in infrastructure, such as algae blooms in storage ponds or clogging of irrigation networks. Preventive controls and declogging operations are expected as part of the operation. Furthermore, ensure monitoring of irrigation systems (in particular nozzle) is essential because it can sometimes be buried because of its position at the ground level (Bel, 2016).

Finally, in the case of poor management of the SRC system (overloaded effluents, soil not suitable, unadjusted doses needs), problems of nutrient saturation and increasing salinity can be met.

Perspectives

Reuse in forestry applied to Non-collective sanitation has many development chances, either at national or international scale. It is an alternative and extensive solution, which consumes less energy and creates biomass for other uses. The sludge collected on filters may also be used in agriculture. Reuse in forestry fits perfectly in a circular economy pattern.

In addition, these systems don’t need costly infrastructure and operating fees, compared to intensive systems. In difficult economic circumstances, the establishment of these facilities can meet the sanitation needs effectively and affordably.

Finally, Reuse can be a support for non-collective sanitation, and its development is expected in Europe and across the world. This expertise can be exported to developing countries (with other species of trees adapted to local contexts) because of its low cost, reliability and its simplicity of operation. Regarding issues revolving around sanitation (latrines, faecal sludge management ...) in developing countries, Reuse can be an interesting solution.

CONCLUSION

Integrating the principle of a circular economy, wastewater Reuse represents a lever to climate and water challenges ahead. It contributes to the development and the security of agriculture in peri-urban or rural areas, and can be developed under construction, renovation or expansion projects of WWTP.

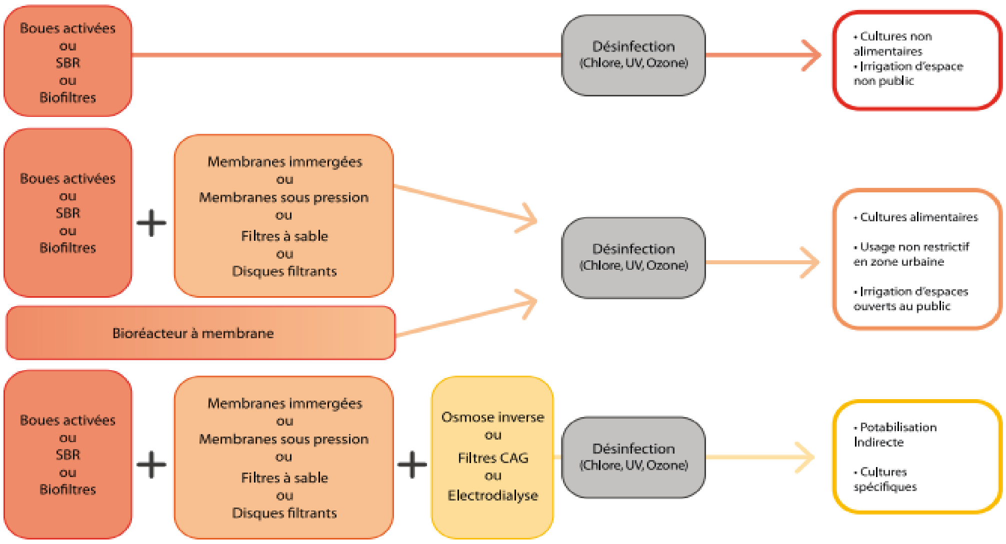
Despite its strong potential across the French territory, Reuse remains an alternative represented by some experimental and pilot projects. The reasons for its moderate expansion can be explained by factors of several origins. First, any project supported by local representatives must respond to a need in a very specific context (durable water scarcity, competition with drinking water needs ...). There is also some reluctance to the financial constraint that imposes Reuse compared to direct sampling in the environment and some opportunities of development may be abandoned due to a lack of projection in the long term. Moreover, the regulation currently represents a major constraint to Reuse development and is the subject of much controversy among experts. While some argue that too strict standards annihilate the feasibility and profitability of projects; others think that those practices must adapt to the legislation because of public health risks they can generate.

Nationally, many public and private actors are mobilizing for a transition towards Reuse. Local initiatives are developed to design innovative projects, multi-stakeholder partnerships arise and flow of information and knowledge arise. We can suppose that feedbacks from pilot projects will probably help to soften the French regulations. They also recommended articulating the "resource-use" approach to the "use-resource" approach. Today, we need to review the final use before sizing a project of recovery of treated wastewater.

Due to its great potential, many experts are led to believe that the Reuse has a bright future. Alternative water resource needs are growing, so a development of this sector is expected in a few years if the knowledge about the health risks and techniques are refined. Our case study in forestry production is an illustration of a sustainable system Reuse, economic, technically simple and whose health and environmental risks are relatively small.
Finally, at the global level, there is reason to believe that Reuse is an opportunity to create wealth in the territories, particularly in countries or areas facing strong water pressure.

ANNEXES

Annex 1 Treatment levels for a given use (Synteau, 2012)



Annex 2 Pluridisciplinary analysis of wastewater REUSE

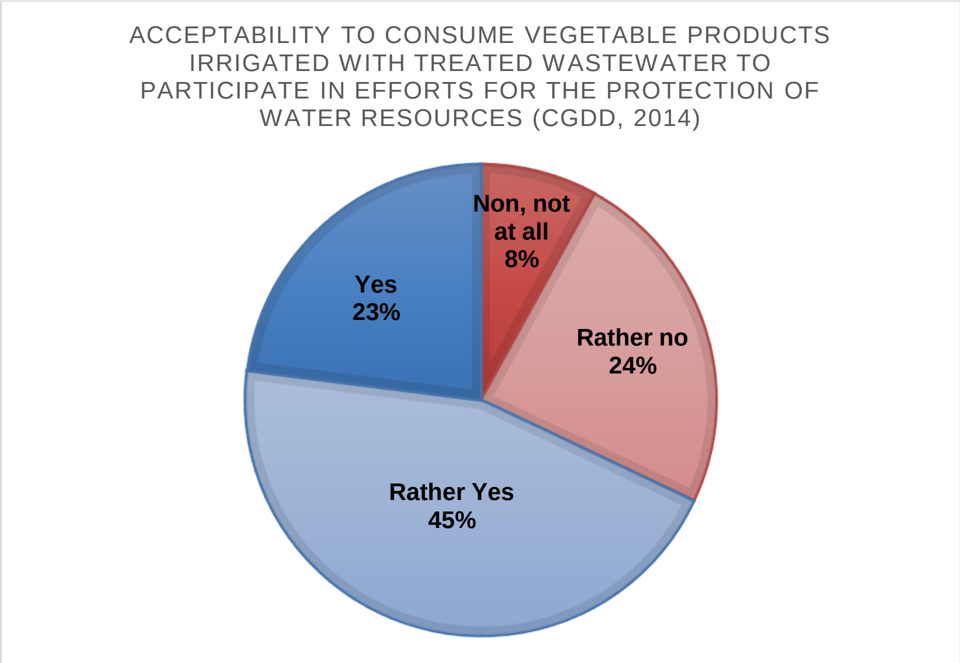
	ADVANTAGES AND PERSPECTIVES	LIMITS AND ISSUES
Global scale	- Integrated managment of the territory	- Difficulty to integrate all the parameters of REUSE to develop a project shaped to the local context - Lack of data for analysis of the sector: methods still not widespread enough (confidential / competitive field)
Regulatory aspects	- WHO standards: use categories more or less demanding in terms of the production reffered - Framing of REUSE by European standards for water treatment - Regulation of the Code of the Environment in 2014 under review	- Strong Regulations that hinders the development of projects - Standards sometimes poorly adapted to different contexts (wind factor too restrictive in coastal areas, for example)
Sanitary aspects	- Possibility to adjust the quality of water for a given use - Areas controlled depending on the quality used - Health campaigns have not raised issues related to the REUSE in France	- Risk of contamination / exposure to pollutants associated with: nitrates, phosphates, heavy metals, organic pollutants (especially Cadium), pathogens (bacteria, viruses, parasites) - Evaluation method of health risk: choice of method may influence the results
Technical aspects	- Specificity if each site: variability of treatment techniques depending on the area, production, context - Provision of reliable water resources, whose volume is constant throughout the year and independent of climatic events - Availability time (and reliable resource available all year - no seasonality) and spatial (essential near the irrigated area) - Natural Pollution treatment by the ground	- Implementation complexity - Accelerated aging problems by clogging distribution networks - Proximity essential supply wastewater to limit investments in distribution networks to optimize costs - Projects related to REUSE depend on the potential evolution of the quality and quality of water available
Economic aspects	- Development of agriculture in sensitive areas (lack of water, isolated or remote areas from water resources) - Cheaper resource than that water from desalination - Revitalization of an agricultural or forestry sector - Additional yield possible thanks to nutritional value of water - Provision of reliable water resources, whose volume is constant throughout the year and independent of climatic events	- Complexes associated treatments, increasing the cost of production of reusable water. - Environmental and social costs and benefits difficult to monetarize - Energy consumption

Social aspects	- Maintenance of urban agriculture, maintaining the landscape	- Different perceptions depending on the context, can be highly negative and be a brake on development projects - Communication campaigns to expand the quantitative issues of resource and reassure the population about such practices
Environmental aspects	- Significant Economy of fresh water resources, reducing its over-exploitation in sensitive areas, reducing waste upstream - Favourable consequences in terms of environmental pollution, reduction of emissions of pollutants, limit pollution in a sensitive receiving environment (reduced eutrophication etc.) - Contribution active management of coastal aquifers to master saline intrusion in some cases - Improvement of living conditions for some uses (watering recreational land, golf courses and green spaces)	- sewage water outlets are additional resources dumped into rivers: this aspect can be problematic during low water episodes - Soil and water: any excess trace element - High concentration of pollutant substances: the ecosystem's natural balance change risks
Institutional aspects	- A concerted approach between different stakeholders - Development of partnerships for the development of knowledge and the development of projects	- Problems of interpretation of the regulations in the services of the state (tendency to minimum health risk taking) - Vision still "down": the downstream has little influence on upstream - need to encourage the sharing and dissemination of knowledge, yet remaining very confidential data. - Encourage multi-stakeholder consultation efforts - Notions of responsibility, education, autonomy to develop these projects

Annex 3 Health aspects: Critical points of REUSE and health recommendations from the ANSES report on crop irrigation and green spaces (2012)

Raw wastewater chemical and microbiological contaminants	
Treatments Storage	The quality of choice (A, B, C or D) as a function of the intended use Origin control quality preselected
Distribution	Design and network management (identifying pipes, drains, maintenance of water quality) Drain at the end of the irrigation season and flushing the system before startup
Irrigation	Choosing the type of sprinkler (low pressure, orientation, etc.) Wind speed and wind direction Quality control of water
Exposure	Barriers to the wind (vegetated fences, walls, etc.) Safety distances Rules for access to irrigated areas Public Information Protective measures for professionals

Annex 4 Social aspects: survey results CGDD / IFOP "Given the risk of decreased water availability, are the French people ready to accept changes in their consumption patterns, including wastewater reuse? "



This analysis is based on a method of quotas on the basis of gender, age, occupation, size of town, region, status of housing, based on the population census of 2010 (INSEE).

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Fax. : (33) 4 67 04 71 01
www.agroparistech.fr

15 rue Edouard Chamberland
87065 Limoges Cedex

Tél. (33) 5 55 11 47 80
Fax. (33) 5 55 11 47 48
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