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WASTEWATER REUSE IN FRANCE: WATER QUALITY STANDARDS AND WASTEWATER TREATMENT TECHNOLOGIES

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ABSTRACT

Wastewater reuse is not widely applied in France, because water resources match most of the needs. Only 6 projects were in operation in 1989. But more than 15 new projects were found to have been set up 7 years later. In the meantime, the Ministry of Health issued a provisional regulation on the reuse of wastewater for irrigation purposes and the Ministry of Environment a Water Law and application decrees acknowledging wastewater reuse as a means of disposal for treated wastewater, which is recommended to be implemented along the coastline. Actually, most of the projects are located in Atlantic islands and on the Atlantic coast. They were developed not only to face the limitation of water resources but also as a means of protecting bathing waters and shellfish farming areas. Most hinterland projects were driven by the rehabilitation of rivers threatened by eutrophication. The inforcement of the recommendations of the Ministry of Health resulted in a slowing down of the development of wastewater reuse and the implementation of wastewater treatments - long residence time lagooning or chlorination and ultra violet radiations - providing water quality higher than required by the standards.

KEYWORDS

Irrigation; regulations; wastewater reuse; wastewater treatment; water quality.

INTRODUCTION

Rain hardly falls below 600 millimetres per year on the least watered parts of France,. Most of these areas, located along the edge of the Mediterranean coast, are served by major hydraulic constructions such as the Durance canal and the lower Rhône canal. Only ten per cent of the capacity of the lower Rhône canal, constructed 40 years ago for irrigation purposes, is utilized. Therefore, there is no real scarcity of water, except for local or exceptional situations, and wastewater reuse is not widely applied. In the late 1980's wastewater reuse was limited to sewage farms of Achères and Reims, relics of the treatment practices of the last century, and to 4 recently set up small projects, 3 of which are located on islands off the Atlantic and Mediterranean coasts (Rodier and Brissaud, 1989).

Despite the very slow development of wastewater reuse, the Ministry of Health (MoH) started the elaboration of regulations in 1989. Guidelines issued in 1991 (CSHPF, 1991) are currently used as a provisional regulation. Wastewater reuse was acknowledged as a means of disposal of treated wastewater and a recommended approach to serve small communities along the coastline in the Water Law and application decrees released by the Ministry of Environment (MoE) in 1992 and 1994.

A survey ordered by the Ministry of Health showed that more than 15 new projects were in operation in 1996 (Figure 1). This provides evidence of the development of wastewater reuse in France. The characteristics of these new projects, i.e. locations, goals, irrigated area, irrigated crops and wastewater treatments before reuse, are valuable information which should help forecasting the future of wastewater reuse in France and neighbouring countries. The aim of this paper is to look for the relationships between the French legal framework of wastewater reuse and the characteristics of the new projects, while putting the emphasis on the wastewater treatment. This investigation is made to contribute to the forthcoming assessment of the MoH's guidelines which has to be delivered before the drawing up of the final regulation of the use of wastewater for irrigation.

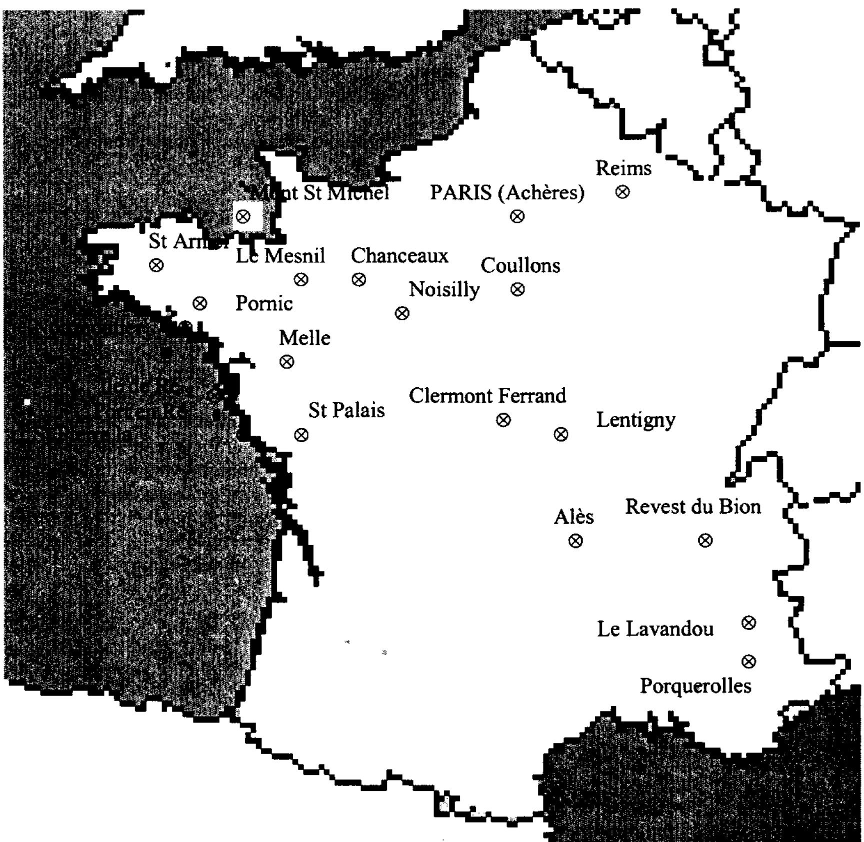

Figure 1. Agricultural reuse projects in operation in 1997.

LEGAL FRAMEWORK

January 3, 1992 France's water law required each city to define the zones to be served by public municipal sewerage, storage, treatment and disposal or *reuse of wastewater*. This was the first time wastewater reuse appeared in a French regulation. Wastewater reuse was thus aknowledged not as a marginal water supply but as an alternate solution to wastewater discharge. A June 3, 1994 decree provided the basis for water reuse rules in France. First, it clearly stated that treated effluents can be used for agricultural purposes, but only if water reuse projects are operated without any risk for the environment and public health. Second, wastewater treatment requirements, irrigation modalities and monitoring programs must be defined after an order of the Ministries of Health, Environment and Agriculture. This order will be prepared by the Interminister Water Mission and the National Council for Public Health (CSHPF).

The idea that water reuse can be a viable alternative to the disposal of treated effluents in rivers and coastal waters was repeated in a May 12, 1995 order of the MoE. It encouraged the use of alternative solutions to the discharge of wastewater in sensitive areas, where advanced tertiary treatments are not affordable; in those cases the order recommends that cities evaluate other alternatives, such as, among others, land application. The reuse of the treated wastewater of small seaside resorts is also recommended, together with infiltration and other appropriate solutions, in order to put an end to the disposal of wastewater in bathing waters, shellfish breeding areas and other receiving waters, the quality of which must comply with stringent sanitary regulations.

The order to be prepared by the Interminister Water Mission and the CSHPF will slightly differ from the *Recommendations about the use, after treatment, of municipal wastewater for the irrigation of crops and landscape areas* drawn up by the CSHPF (1991). These recommendations serve until now as a provisional regulation. They refer to the A (nematode egg content < 1/l, faecal coliform content <1000/100 ml), B (nematode egg content < 1/l, no bacteriological criterion) and C (no microbiological criterion) categories of water reuse defined by the World Health Organisation guidelines (WHO, 1994). But, as stressed by Bontoux and Courtois (1996), additional requirements on irrigation management and the prevention of health risks related to human exposure made the French recommendations more stringent than the WHO's guidelines.

For instance, irrigation of vegetables to be eaten raw with quality A water is allowed, but methods that reduce the direct contact of irrigation water with vegetables and fruits are highly recommended. Irrigation of public green spaces with the same quality of water is tolerated, provided it is done by short range sprinklers outside opening hours. Also, sprinklers should be more than 100 m from houses, sports and recreational areas. This last requirement applies also to aspersion of cereal, fodder crops, nurseries, ... with B quality water. The most prominent restrictions added to the WHO's guidelines are mainly aimed at protecting people from aerosol risks. Reuse of C quality water by drip or underground irrigation is limited to areas closed to public access.

Moreover, each new wastewater reuse project must be authorized by the representatives of the MoH and monitored on a permanent basis. The effect of this provisional regulation can be seen in the 16 wastewater irrigation projects worked out during the 1990's.

PROJECTS DEVELOPPED FROM 1981 TO 1997

Location

Among the 19 projects developed since 1981, six are located on the Atlantic coast, five in three islands off the same coast (Figure 1), only one on the Mediterranean coast (a golf course irrigation), and another one on the Porquerolles island and six are scattered in the hinterland. As expected from the MoE's recommendations, most projects serve communities and touristic resorts situated along the coastline of Vendée, Britany and Normandy. In the south of the Gironde mouth, wastewaters of touristic resorts are not reused but infiltrated into a 5 km wide sand dune string stretched along the shore line.

Objectives

Every island off the French coast is experiencing water shortage, which is mainly due to increasing tourism. In several cases, water is supplied from the mainland and its marginal cost is soaring. The first objective of wastewater reuse is to provide water for the irrigation of food crops and maize, thus allowing maintenance of profitable agricultural activity and a permanent population in these islands (Noirmoutier, Ré, Porquerolles). Treated wastewater is also supplied to golf courses (Oléron) that are part of the touristic economy. The second objective is to prevent the pollution of bathing water, shellfish breeding areas (Noirmoutier, Ré, Oléron) and aquaculture water (Noirmoutier, Ré). At Porquerolles, wastewater is entirely reused. In several other cases where the amount of wastewater exceeds the irrigation needs, disposal to the sea is interrupted during the touristic season and wastewater is stored in reservoirs (Ré, Noirmoutier). Moreover, the treatment performed to match the water quality standards required for agricultural reuse allows compliance with the current microbiological criteria of bathing and shellfish breeding waters.

Most projects set up in the mainland along the Atlantic coast have the same two objectives. Supplying conventional water to Pornic golf course would have cost 9 $/m^3 instead of only 2 $/m^3 for tertiary treated urban wastewater. During the irrigation season, effluents of the Pornic treatment plant are no longer disposed of in the pretty old harbour. Thus the aesthetics of the very heart of the resort are greatly improved. The reuse of the wastewater of Le Mont Saint Michel and neighbouring villages halted the disposal of wastewater in the bay, which is one of the most popular French tourist places and an area devoted to the breeding of mussels and oysters. Wastewater, stored during the rainy season, allows increase of crop production of a polder zone.

Most hinterland projects were driven by the rehabilitation of rivers threatened by eutrophication. Effluents of the Clermont Ferrand wastewater treatment plant used to be disposed of in a nearby small river, and thus heavily polluted it. Moreover, farmers used to pump from the river to irrigate hundreds of hectares of maize plantation. This resulted in a large flow rate reduction and in further degradation of the river water quality. Reusing the effluents, which will be achieved in summer 1998, will dramatically improve the river quality and provide a reliable water resource to the farmers. The main goal of the Melle project was the rehabilitation of the stream which used to be a receiving body for treatment plant effluents. Projects in Le Mesnil en Vallée and Le Fuilet were mainly driven by the absence of streams capable of receiving secondary treated wastewater. Reusing wastewater was found to be a cheaper solution than sophisticated tertiary treatments; it allowed development of irrigated agriculture and increased a few farmers' incomes.

Irrigated crops

Most of the 17 projects set up since 1981 are small scale projects. The largest irrigated area will be 600 hectares at Clermont Ferrand. The mean irrigated surface is just over 100 ha. Only 4 projects have an irrigated surface of more than 100 ha and 9 less than or equal to 50 ha.

In tourist areas located along the Mediterranean and Atlantic coastlines, the irrigated crops are:

- market gardening (potatoes, cabbages, carrots, onions, ..), orchards, meadows and maize,
- or lawns of golf courses.

According to CSHPF's recommendations, irrigation of meadows, maize and vegetables to be eaten cooked requires B quality water. A quality water is required for the irrigation of vegetables to be eaten raw (aspersion of this category of vegetables is prohibited) and the aspersion of golf course lawns. Orchards can be irrigated with water of quality A, B or C, depending on the irrigation system.

Maize is the most frequent crop irrigated in hinterland projects. Alfalfa and nursery are exceptions and require water quality B and B or C respectively, depending on the irrigation technique.

Wastewater treatment

In nearly every project, wastewater is secondary treated through a biological process: activated sludges or aerated lagooning. An additional treatment is necessary to reach A quality and, even, B quality. It can be seen from Table 1 that the tertiary treatment applied to the secondary effluents mainly depends on the cultivated crops.

When wastewater is used for market gardening irrigation, tertiary treatments are performed in series of 3 to 4 maturation ponds or in a stabilization reservoir. Chlorination is used in only one case (Ars en Ré). The relatively high number of ponds is intended to assure an appropriate disinfection level during the irrigation season. Monitoring of several projects has shown that the bacteriological quality of the irrigation water easily complies with the A category standard of the WHO's guidelines. The geometric mean of faecal coliform contents measured twice a month during one year at the outlet of the Noirmoutier lagooning system is 40/100 ml. The highest concentration, 710/100 ml, occurred in January. At the outlet of Mont Saint Michel lagoons, the maximum faecal coliform content was found to be 20/100 ml and no helminth egg was detected. Carrots irrigated with reused water had a lower faecal coliform content (<10/ml) than those irrigated with conventional water (90/ml). At the outlet of Porquerolles lagoons, where the water residence time is one month, faecal coliform contents are currently ranging from 100 to 1000 /100 ml. Performances were significantly higher 10 years ago.

Lagoons are also used as storage facilities. Then, water depth ranges between less than 1 m and 3 m from one lagoon to another. Water depth may also vary throughout the year according to the irrigation needs (Mont Saint Michel, Murviel Les Montpellier).

Contrary to vegetable crop irrigation, polishing of secondary effluents before golf course irrigation generally does not rely on extensive technologies but on conventional disinfection treatments: chlorination and ultra-violet irradiation. These treatments can ensure higher bacteriological quality than required by the MoH's recommendations provided they are properly managed and maintained, a task that golf course staff are able to cope with. A conventional disinfection technology is considered necessary by most golf course owners and MoH representatives for public acceptance and to minimize the risks of microbe dissemination in the neighbourhood, often high standing residential areas. Baden golf course is an exception : parts of the lawns, only 7 ha, are irrigated with wastewater treated in 2 lagoons and a storage. Underground irrigation, as practised at Port en Ré, does not require any disinfection treatment.

Table 1. Main wastewater irrigation projects developed in France for the last 20 years

Projects	Irrigated area (ha)	Date	Specific application	Wastewater treatment	Geographic location
Mont Saint Michel	265	1994	meadows and maize	act. sludge + 3 lag.	Atlantic Coast
Saint Armel	120	1997	market gardening	4 lagoons	
Porquerolles	35	1986	mark. gard. + orchar.	act. slud. + 3 lag.	Med. isl.
Noirmoutier - La Salaisière	220	1981	potat., cabb.. maize,	act. sludge + 4 lag.	Atlantic Islands
Noirmoutier - Barbatre	35	1991	potatoes	aer. lag. + stab. res.	
Ars en Ré	90	1985	maize, potatoes	act. slud. + chl. + res.	
Saint Pierre la Cotinière	25	1994	Golf courses	act. sludge + u.v.	
Port en Ré				underground irrigat.	
Pornic	34	1992		act. sludge + chlor.	Atlantic Coast
Baden	7	1989		2 lag. + stab. res.	
Saintes					
Saint Palais	55	1991		act. sludge + chlor.	
Le Lavandou	30	1994		biofiltr. + ground filtr	Med. Coast
Chanceaux sur Choisille	5	1993	sports areas; parks	act. Slud. + lag.	Hinterland
Le Mesnil en Vallée	85	1995	maize, nursery	Aerated lagoon	
Clermont Ferrand	600	1996	maize	act. slud. + lagoon	
Coullons	94	1994	maize	ph.ch + aer. lag + 2 lag	
Melle		1994	maize	act. slud. + 2 lag. + res	
Nouzilly	50	1993	maize, alfalfa	act. slud. + stab. res.	

Secondary effluents are also tertiary treated in lagooning systems or stabilization reservoirs before maize irrigation, thus providing a water quality higher than the B category standard. The reasons for improving the water quality beyond the MoH's guidelines are sometimes related to specific operations, such as in the

Clermont Ferrand project. Workers in charge of maize castration are in direct contact with plants aspersed with wastewater. This was the reason for requiring an A quality irrigation water. The general trend is to consider the MoH's recommendations as minimum requirements to be made more stringent according to local conditions. Lagoons are also used as storage means.

CONCLUSION

Conventional disinfection technologies are generally chosen for golf course irrigation for public acceptance and commercial reasons and also because golf courses are often closely surrounded by residences. When a high microbiological quality must be reached in an urban environment, conventional technologies are taken as more reliable than extensive ones.

On the contrary, lagooning is the most widespread tertiary treatment for other agricultural applications of wastewater, whatever the irrigated crop: vegetables to be eaten raw or cooked, maize, meadows, nurseries, ... Reservoirs, a few metres deep are also used.

Lagooning is very popular in France, where more than 2,000 facilities are operated (Racault *et al.*, 1995). It is a widespread technique in neighbour and Mediterranean countries. It is one of the most appropriate technologies for rural areas. Its advantages are:

- moderate investment costs,
- easy and cost-effective management and maintenance, which should make it the leading technology for developing countries,
- reliability. Average performances are predictable. No electric power failure can drop the treatment efficiency,
- lagoons may serve as temporary storage. Influence of storage on the performances has to be taken into account when designing and operating lagooning systems.

However, lagooning is land consuming; this main drawback prohibits it wherever land is expensive. A second important drawback is that temporary failures of microbiological performances have been often observed. In most cases, preferential pathways related to specific wind conditions can explain lower than expected microbial removal (Frederick and Lloyd, 1996). Though design criteria are well established, the impact of physical design on microorganism removal needs more investigation, as noticed by Pearson et al. (1995). Careful study of the influence of climatic conditions on water residence time distribution should allow to us improve the reliability of disinfection in maturation ponds.

The publication of the MoH's recommendations did not result in an outbreak of projects in France. The effect was more to slow down the development of wastewater reuse (Riou, 1996). Anyway, in the future, new projects are expected to be worked out as alternative solutions to wastewater discharge in sensitive water bodies, as suggested by a 1994 decree of the Ministry of the Environment.

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