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NON-CONVENTIONAL WATER USE IN GREECE

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INTRODUCTION

In Greece, the total annual precipitation is estimated to be 116,689 Mm^3 and the total water potential is estimated to be 70,276 hm^3, including water transported from neighbouring countries from the north (Hellenic Ministry of Development, 2002). The total water consumption was estimated at 5,500 hm^3/year, while by the end of the last decade, it was increased by about 30%. It is estimated that the water consumption in Greece increases by more than 3% annually.

The major water use in Greece is for agricultural purposes (85%). The relevant figures for domestic and industrial uses are 11% and 4% respectively. The increased demand for water, either for urban or agricultural use, cannot always be met despite adequate precipitation. Water imbalance is often experienced, especially in the coastal and south-eastern regions, due to the temporal and spatial variations of the precipitation, as a result of the increased water demand during the summer months, and the difficulty of transporting water due to the mountainous terrain.

An alternative plan for water resources management could include non-conventional water resources such as the reclaimed wastewater originating from the wastewater treatment plants. These alternative water resources may provide sufficient water for irrigation to avoid severe water shortage, while at the same time the pollution loads entering the sea, rivers and lakes will be reduced.

WASTEWATER TREATMENT STATUS IN GREECE

Greece must comply with the EU 271/91 directive on urban wastewater treatment. Thus, today 350 Municipal Wastewater Treatment Plants (MWTP) can serve about 65% of the country's permanent population (Angelakis *et al*., 2002). For the 21% of the remaining population, it is estimated that 1,800 MWTP will be needed. The remaining 14% of the population is in small villages and remote areas for which on site sanitation technologies should be used. However, Greece as a member of the EU, is required to connect all agglomerations at sensitive areas to sewerage networks with population equivalent ≥ 2,000 to MWTP by the end of 2005 (Tsagarakis *et al*., 2004).

Tsagarakis (1999) has classified the MWTP in operation according to their performance, taking into account effluent qualitative parameters and effluent quality requirements. Of the existing MWTPs, 42% were operating properly, 41% moderately and 17% poorly. In general, the large plants tend to operate well.

In Greece several attempts have been made to use specific technologies for municipal wastewater treatment. Among these, 88% are activated sludge systems, 10% are natural systems and 2% are attached growth systems. Among the activated sludge systems, 85% are extended aeration systems, 10% are conventional systems and 5% are sequencing batch reactors. Extended aeration is the dominant system as it provides additional advantages for the Mediterranean climatic conditions (Tsagarakis *et al*., 2001).

Some decades ago, Greece had not developed its own local knowledge. Sea outfalls were used mostly at MWTPs near the sea for discharging treated effluent. Plants away from the sea usually discharge to permanent or ephemeral rivers. Other disposal areas are agricultural lands, forest lands, lakes and land applications.

Many experimental attempts have been made to reuse the treated olive mill wastewater (Neskakis *et al*., 2002) and swine effluents for irrigation.

QUALITY OF TREATED WASTEWATER

The quality of the effluent in most of the MWTPs is considered to be satisfactory. In most cases, the concentration of the water quality parameters in the effluent appears to be on appropriate limits. Electrical conductivity (EC) is maintained at values less than 2.7 dS/m. This means that none severe potential irrigation problems could exist. Furthermore, inorganic constituents and especially heavy metals are in the range recommended for irrigation waters. Tchobanoglous *et al*. (2003) consider that these concentrations do not create problems as the most of the greek soils are calcareous.

WASTEWATER RECLAMATION AND REUSE

An analysis of the data concerning the water balance of the areas of the treatment plants demonstrated that more than 83% of the treated effluents are produced in regions with a deficient water balance. Therefore, water reuse in these areas would satisfy the existing water demand. Several research and pilot projects dealing with wastewater recycling and reuse are currently under way in Greece (Angelakis *et al*., 2002).

A recent study showed that by reusing the effluent of the existing MWTPs, the reused water, particularly for irrigation, can be increased by 242 Mm^3/year or 3.2% of the current total use of freshwater. Thus the freshwater that is currently used for irrigation can be saved (Tsagarakis *et al*., 2001).

Regarding the cost of recycling, data from the water recycling and reuse practice at Grecotel Hotels showed that reuse of the treated effluents is economically feasible. In particular, the total cost for treating wastewater ranges between 0.44 and 0.59 €/m^3. Additional costs concerning the filtration and irrigation network will be not exceeding 15% on top of the total costs (Valerga *et al*., 2002).

There is no regulation for wastewater reuse on European level. In Greece, criteria for wastewater reuse have not yet been taken. Note that secondary effluent quality criteria are used for discharging purposes with a Health Arrangement Action of 1965 and are independent of the reclamation and reuse applications.

ESTABLISHING CRITERIA

In Greece, a preliminary study for establishing quality criteria in water recycling area has been undertaken. A summary of those criteria are given in Table 1 (Tsagarakis *et al*., 2004). The application of these criteria should be associated with the following comments:

1. A minimum of four samples should be considered.
2. Student's *t*-test should be met.
3. Values for the criteria indicated must be conformed with the values of the 80% of the samples per month, based on average values.
4. Control of odour is required in cases of application on soil surface in and/or close to residential areas.
5. The criteria for irrigation are not applicable in the case of subsurface irrigation.
6. For irrigation purposes, disinfection with Cl^- should be avoided. In addition, the following should be considered: (i) integrated management of water resources; (ii) seasonal storage which improves water quality and availability, and (iii) quality supervision of the sampling methods, the frequency of sampling and the reliability of analyses.
7. According to the Greek legislation, recycled wastewater can be reused for irrigation except for the irrigation of edible plants.

Table 1. Proposed minimal microbiological and physical criteria for reusing of reclaimed wastewater in Greece

No	Water quality criteria	Recommended uses
1st	I.N.[a] ≤ 0.1 eggs/l FC[b] ≤ 10 cfu/100 ml TSS[c] ≤ 10 mg/l	1.Residential areas with high public contacts 2.Toilet flushing and air conditioning 3.Car washing
2nd	I.N. ≤ 1 eggs/l FC ≤ 100 cfu/100 ml TSS ≤ 20 mg/l	1.Ponds, bodies of water, and streams with high public contact[d] 2.Fountains and other recreation places 3.Streets cleaning and fire-fighting
3rd	I.N. ≤ 1 eggs/l FC ≤ 1000 cfu/100 ml TSS ≤ 35 mg/l	1.Irrigation of fodder crops for livestock[e], of crops for canning, of vegetables to be eaten cooked, of plant nurseries, etc. 2.Aquaculture
4th	I.N. ≤ 1 eggs/l FC ≤ 10,000 cfu/100 ml TSS ≤ 35 mg/l	1.Irrigation of wooden areas, industrial wood areas, greenbelts and areas 2.where the public is not allowed to enter 3.Industrial use (except for the food industry)[f] 4.Ponds, bodies of water and streams where public contact is not allowed
5th	I.N. ≤ 1 eggs/l FC ≤ 100 cfu/100 ml TSS ≤ 10 mg/l	1.Groundwater recharge (direct injection and/or surface spreading)[d,g,h]

[a]I.N.: Intestinal nematodes including the following families: *Strongyloides*, *Trichostrongylus*, *Toxacara*, *Enterobius*, and *Capillaria*. Limits are not applicable for most of the uses.
[b]FC: Faecal Coliform.
[c]TSS: Total suspended solids.
[d]Limits for NO^{3-} should be required, such as TN < 15 and <50 mg/l for groundwater recharge (direct injection and surface spreading, respectively) and NO^{3-}–N < 100 mg/l for ponds and water streams.
[e]Limits for *Taenia* sp. (<1 eggs/l) should be required.
[f]Limits for industrial cooling for *Legionella phennophila* should be required.
[g]A minimal depth for the groundwater table of 5m is required.
[h]In the case of direct injection particularly to a potable groundwater aquifer, the criteria for potable water should be applied.

The proposed minimal criteria for municipal wastewater recycling and reuse for Greece are focused on microbiological hazards. The quality criteria should reflect the regional variations in climate and effluent characteristics to protect individuals against realistic maximum exposures. Intestinal nematodes should be of major concern. Additional proposed criteria should be: a) realistic in relation to local conditions (epidemiological, socio-cultural, and environmental factors), b) economically feasible, c) practical, d) simple, e) flexible, and f) enforceable.

AGENCIES INVOLVED IN THE WASTEWATER SECTOR

The agencies involved in the wastewater sector in Greece have two major duties: these related to the construction and those related to the operation-management of MWTP. Some of these agencies are engaged in the construction, some in the operation of MWTP and some in both. The agencies, depending on the level of their authorities, are:

1. At local municipality level:
   - Communal enterprises for water supply and sewerage.
   - The Athens water and sewerage company.
   - Municipality and community.
   - Municipal enterprises for water supply and sewerage.
   - Municipal technical services.
   - The Thessaloniki water and sewerage company.
2. At wider local level:
   - Prefecture technical services.
   - Prefecture technical services for municipalities and communities.
   - The Athens water and sewerage company.

- The Thessaloniki water and sewerage company.

3. At national level:
   - Ministry of Environment, Physical Planning and Public Works.

CASES OF WASTEWATER REUSE

Agricultural Reuse

There are several MWTPs where effluents are used for direct irrigation of agricultural land (Tsagarakis *et al*., 2001, Tsagarakis *et al*., 2004). These are located:

- At Levadia (Central Greece), 3,500 m^3/d are used to irrigate cotton. Advanced treatment includes nutrients control (N-P). The irrigation system is a closed pipe network.
- At Amfisa (Central Greece), 400 m^3/d are discharged into a 30,000 m^3 reservoir for the irrigation of olive trees.
- At Ko (Aegean Islands), restricted areas of field and tree crops close to the installation are irrigated, but it is in the planning process to extend the irrigated area with the 4,000 m^3/d effluent that can be produced. Advanced treatment includes nutrient control (N-P).
- At Palecastro (Crete), 280 m^3/d are used to irrigate olive trees after loading on a 20 m^3 reservoir. The irrigation method is a closed pipe network.
- At Zakros (Crete), 210 m^3/d are used to irrigate olive trees, without any storage. The irrigation method is trickle irrigation. During the unirrigated period, effluent is diverted to the adjoining ephemeral river.
- At Hersonissos (Crete), treated effluent is stored in two reservoirs of total volume 1,000m^3 . The system provides water for irrigation of olive trees on an area of 2,200 ha. The irrigation method is trickle irrigation. In addition, water for fire protection is provided through the storage tanks used for agricultural irrigation. In these tanks water should always be above 200 m^3 as this quantity is regarded as the minimum needed in case of fire at the area.
- At Archanes (Crete), a 40 m^3/h secondary effluent treated by filtration and UV disinfection is reused it for irrigation originally on about 14 ha of olive trees and vineyards. An irrigation network of 5.1 km length is going to be installed for irrigating two irrigation zones at different elevations. One storage tank is going to be installed in each zone of volume 150 and 100 m^3 respectively.

Effluent from some of the waste stabilization ponds in operation is used for agricultural irrigation by farmers.

It should be noted that there are plants that discharge to ephemeral rivers and after infiltration there is pumping through adjacent wells by farmers for irrigation. This is a way of indirect reuse for irrigation.

Forestry and Landscape Reuse

The effluents from a few plants are used for the irrigation of forestry and other amenity purposes (Gaki *et al*., 2002, Sbiliris and Kanaris, 2002, Tsagarakis *et al*., 2001, Tsagarakis *et al*., 2004):

- At Hersonissos (Crete), two types of landscape irrigation are applied: (a) irrigation of ornamental plants on the side of the new national road Iraklio–Ag. Nikolaos (6–7 km), and (b) irrigation of a land of 5 ha planted with ornamental trees and shrubs in the surrounding areas of two hotels sewerage network.
- At Kentarchos (island of Serifos), 100 m^3/d are used to irrigate trees after applying sand filtration.
- At Agios Konstantinos (island of Samos), 200 m^3/d are used to irrigate trees with a sub-surface system.
- At Karistos (Evia), 1,450 m^3/d are used to irrigate 14,000 trees using nearly all the effluent with a closed pipe network.
- At Ierisos (Central Macedonia), 1,200 m^3/d are discharged into a reservoir before irrigating forested land.

- At Chalkida (Evia), 9,000 m^3/d of tertiary treated water is provided for landscape irrigation and industrial use. Finally, 280 ha with 100,000 trees and shrubs will be irrigated with a closed pipe network using 4,000 m^3/d.
- Creta Farm which is a meat producing, processing and packaging industry located in Rethymno Crete, uses 300 m^3/d, from the produced wastewater, for the irrigation of more than 2,000 eucalyptus, 1,500 tamarix trees and large number of olive trees.

Industrial Reuse

There is no significant industrial reuse of treated effluent except from some installations that use filtration for treating further effluent. Industries that are heavy water consumers, will be interested in using reclaimed wastewater, particularly in areas under water shortage.

An example can be given for a Cement Industry near Chalkis which uses approximately 5,000 m^3/d from the nearby Chalkis MWTP (Sbiliris and Kanaris, 2002).

CONCLUSIONS

Water resources are limited temporally and spatially in Greece. The continued increase of domestic and irrigation water demand can only be met through an integrated water management scheme that includes the use of all sources including non-conventional waters. By reusing the effluent of the existing MWTPs, the reused water, particularly for irrigation of agricultural land, can be increased by 3.2% of the current total use of freshwater. Thus, the freshwater that is currently used for irrigation can be saved. This percentage will be substantially increased as the number of MWTPs increase.

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