

TREATED WASTEWATER REUSE IN THE WATER MANAGEMENT PLAN OF LESVOS ISLAND, GREECE

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EXTENDED ABSTRACT

The island of Lesvos – Greece was a study area for the preparation of a pilot "Water Supply Master Plan" decided by the Ministry of Environment, Planning and Public Works". From the management simulation, that took place after the determination of future needs, resulted that a significant deterioration of water deficits in a horizon of 40 years is expected, particularly in the municipality of Mytilene, which consumes about half the water sources of the island. Even if measures are taken to reduce network losses and water consumption the deficit is expected to be twice the current one for all municipalities and three times for the municipality of Mytilene by 2048.

In order to cover the expected water deficits the following specific steps were suggested:

- ◆ To promote the basic measures for conservation and rational use of water.
- ◆ To build the reservoir in Tsiknias in the predicted from the existing studies, position and size, with a priority on serving the needs of drinking water and secondary irrigation. At the same time to revise and supplement the technical and environmental studies in order to ensure the desired conditions for the wetland protection of the bay of Kalloni. The construction project will not remove the existing sources of water supply, instead it will complement them.
- ◆ To build the reservoir of Polihnitos in order to serve the needs of drinking water and irrigation, along with the related water transport projects. The work can be connected with Tsiknias aqueduct in a technically effective way.
- ◆ To study and construct smaller dams and reservoirs in areas that cannot be served by the projects Tsiknias and Polihnitos. Also, the construction of water transport is proposed.

The reuse of treated wastewater should be considered in the Water Resources Management Studies. In Lesvos there are six wastewater treatment plants (WWTP) in operation today while by 2020 36 WWTPs are planned to operate on the island. Of these, 26 plants provide secondary treatment and disinfection of water, as presented in the corresponding studies of environmental terms. Therefore, their effluents can be used to irrigate crops. In this way, a significant amount of water saving is achieved estimated to about 3.5×10^6 m³ annually. The amount of fertilizer saved is also important since the treated water of all WWTPs contains nitrogen, the concentration of which is within the limits of the relevant legislation, but it still remains high, reducing this way the use of fertilizers. In the same way enrichment of the soil in phosphorus is also achieved as the effluent of the WWTPs contains phosphorus. Similarly the reduction in fertilizer phosphorus that occurs by the use of treated wastewater in these areas is calculated.

From the above it becomes clear that the parallel use of the treated wastewater in those areas that are going to be served by the reservoir of Tsiknias contributes to both the reinforcing the reserves of underground aquifers and the reduce of the reservoir volume.

Keywords: water resources management, wastewater reuse, Lesvos Island.

1. INTRODUCTION

Nowadays the continuous increase of population, the pollution of surface and underground waters, the unequal distribution of water rainfall and the periodical droughts, have led the water supply companies to search of new water resources. The use of the sufficiently treated domestic sewage, which is discharged in the environment, attracts more and more interest as a viable solution to the lack of water.

After a decision of the Ministry of Environment, Planning and Public Works a private company worked out a "Water Supply General Master Plan for Lesvos Island" (YPEXODE, 2008). In this study the availability of water in all its forms, the development prospects of the island, the estimation of the future needs and the level of water sufficiency were thoroughly examined. An investigation of the probable solutions followed evaluating the efficiency of each one. The different scenarios were analyzed through suitable mathematic simulations in order to assess the future water sufficiency and the level of cover of needs.

However the Master Plan does not include the reuse of the treated wastewater from the treatment plants of the island as it is suggested from the Water Framework Directive 2000/60 and the Directive 91/271. The aim of the present study is to incorporate the treated wastewater reuse in the water supply system of Lesvos as it is proposed from the Master Plan.

2. RESULTS OF THE MASTER PLAN STUDY AND WASTEWATER REUSE

From the simulation resulted that the current (2008) deficit of water amounts to $1.5 \times 10^6 \text{ m}^3$ of water, which is expected to increase largely in 40 years, particularly for the Municipality of Mytilene, which consumes about half the water supply of the island. As a result the doubling of current deficits for all municipalities and the triplication for the Municipality Mytilene up to 2048 at minimal is expected, under the condition that measures of restriction of consumption and losses of networks will be taken.

Consequently, in order to cover the predicted water deficits concrete preventive actions were proposed (YPEXODE, 2008).

- Promotion of basic measures of saving and rational use of water.
- Construction of the reservoir in Tsiknias in the suggested from the existing studies place and size, mainly for domestic water supply and secondly for irrigation. At the same time the technical and environmental studies should be updated to ensure the desirable conditions for protection of the wetland of Kalloni. Construction of the necessary substructure for the treatment and the transfer of the water to the served communities without dispensing with the old sources but in supplementary operation with them.
- Construction of the reservoir in Polichnitos for the needs of water supply and irrigation of the nearby area with the relevant works of water transfer. Investigation of the likely combination with the reservoir of Tsiknias in a beneficial technoeconomical way.
- Study and construction of smaller reservoirs and lagoons in regions that cannot be served from the above reservoirs, with parallel construction of the corresponding water transfer works.

Nevertheless the possibility of reuse of the treated wastewater for irrigation should be evaluated. The treated wastewater can be used in agriculture (for irrigation), in industry, to the recharge of ground water resources contributing in this way to the development of new water resources, to the protection from the phenomenon of saltwater intrusion and finally to the reduction of the water cost. The methods that are used for irrigation include:

- Surface application systems

- Sprinkler systems
- Drip or trickle application systems
- Subsurface irrigation network

With the ground water recharge we achieve:

- Decrease of the groundwater table drop because of over pumping
- Protection of the aquifers in coastal areas from the sea water intrusion
- Water storage for future use

3. WASTEWATER REUSE SUGGESTIONS IN LESVOS ISLAND

In the island of Lesvos Greece there are currently in operation six wastewater treatment plants while thirty more are anticipated to operate by the end of 2020 (Fig. 1). According to the approved Environmental Impact Statements twenty six plants include secondary treatment followed by disinfection. The quality characteristics of the effluent were determined according to the requirements of each recipient, (Nikolakopoulos, 2009, Paraskevas *et. al.*, 2001).

The evaluation of the appropriateness of the treated domestic wastewater for reuse depends on the criteria of salinity, infiltration, toxicity, the presence of trace elements and nutritional elements. Because of the lack of data the necessary area for irrigation has been estimated only with the degree of nutrients (nitrogen and phosphorus) removal taking into consideration the harvested part of the various cultures (Table 1).

Table 1. Nitrogen and phosphorus requirements from representative crops harvest in relation to the yield and the harvested product, (Broadbent and Reisenauer, 1985)

Cultivations	Harvested plants part	Yield in kg/10 ³ m ³	N removal in Kg/tn of product	P removal in Kg/tn of product
Olive tree	Fruit	519	1.80	-
Vine	Fruit	2472	0.90	-
Wheat	Seed	494	17.70	3.60
	Hay	865	8.20	0.90
Orange tree	Fruit	1977	2.30	-
Trefoil	Hay	1434	29.50	2.40
Potatoes	Nodule	4943	3.60	-

Regarding the microbiological load and particularly the TC and FC of the disinfected effluent of the plants the evaluation was based on the criteria suggested by the WHO guidelines and Cyprus legislation, (WHO, 1989). The average values of the effluent of the plants are much smaller than the above criteria.

The treated wastewater reuse is realized during the summer months and specifically the period from April 15 to October 15 (six months). The rest of the year the storage of the water in appropriately built tanks is suggested in order to use the water during the summer.

Regarding the choice of the irrigation system it would be advisable the use of water ditches for olive and citrus trees, over land flow for cereals and trefoil, while for vegetables, vines, potatoes and legumes a dripping irrigation system is suggested.



Figure 1. WWTPs in the island of Lesbos

The island was divided with administrative criteria (borders of the municipalities) in order to study and evaluate the results. In every municipality all the data relative with the size of the cultivated areas and the kind of the cultivations were taken. The size of the areas that can be irrigated were calculated considering the relief of the ground, the distance of the WWTP (usually in a circle of 5 km), the kind and the size of the cultivations, the nitrogen and phosphorus requirements of every cultivation and the necessary quantity of water for irrigation according to Table 2.

Table 2. Water need for various cultivations, (CMD Φ16/663/1-6-1989)

Cultivations	Quantity of water (m ³ /10 ³ m ³ /year)
Arable crops	622
Orchards	578
Olive trees	481
Vines	481
Wheat	667
Trefoil	755

Then the connection of the scenarios of the treated wastewater from the local WWTPs reusing with the proposals of the water supply Master Plan of the island was evaluated, (Nikolakopoulos, 2009).

Municipality of Agiasos:

Irrigation of 120,000 m² of olive trees is suggested. The rest quantity of water, about 180,000 m³ /year, cannot be used because of the high relief of the ground so the construction of a water tank for fire fighting is proposed.

Municipality of Gera:

Water saving of about 265,000 m³ /year is achieved if the total amount of the treated wastewater is disposed for irrigation. About 242,000 m³ can be used right after the construction of the plant while the rest quantity, about 23,000 m³, can be used in the future as long as it is feasible from an economic point of view. Consequently the reduction of the proposed by the Master Plant water tank for about 242,000 m³ is achieved.

Municipality of Evergetoula:

An amount of about 120,000 m³ can be disposed for irrigation of various cultivations. There is also an equal amount of water left unexploited. So it is suggested to construct a small earthen dam on the river Evergetoula just after the disposal point of the treated wastewater. The water of the dam can be used either for future irrigation of the greater area or for fire fighting. Alternatively recharge of the ground aquifers can be achieved since the region borders with the Bay of Gera where problems of sea water intrusion are observed.

Municipality of Eressos-Antissa:

Since there is already in use a reservoir with irrigation water in the area, it is suggested to use a quantity of the treated water for recharge of the ground aquifers to face the sea water intrusion problems in the plain of Eressos.

Municipality of Kalloni:

Water saving of about 512,000 m³ /year can be achieved if the total amount of the treated wastewater is used for irrigation. Consequently the volume of the reservoir of Tsiknias, as it is suggested in the Master Study, can be reduced by the equal volume.

Municipality of Mantamados:

Saving a quantity of water equal to about 102,000 m³ /year can be achieved if the total amount of the treated wastewater is used for irrigation. About 85,000 m³ /year can be disposed for irrigation right after the construction of the plant while the rest of the water can be used in the future if it is decided that the transfer of the water is feasible from a techno economic point of view. Thus an additional reduction of the necessary volume of the reservoir in Tsiknias can be achieved.

Municipality of Mithymna:

A reservoir has already been built for irrigation and drinking water of the towns Petra and Mithymna. However, because of construction problems, the reservoir is not in use yet. After the operation of the WWTP there will be a saving of 256,000 m³ treated water per year. About 103,000 m³ /year can be disposed for irrigation right now while the rest of the water can also be used for future irrigation, if the proper cultivation is planted, or alternatively for ground aquifer recharge.

Municipality of Mytilene:

A small quantity of about 10,000 m³ per year of the treated water from the biggest plant of the island can be used for the irrigation of the various cultures in the area. Ground water recharge is suggested for the rest using overland flow or infiltration basin. In this way saving of about 1,600,000 m³ of treated water per year is achieved supporting the water balance in the region.

Municipality of Petra:

Saving a quantity of water equal to about 350,000 m³ /year can be achieved if the total amount of the treated wastewater is used for irrigation. About 230,000 m³ /year can be disposed for irrigation right after the construction of the plant while the rest of the water can also be used for future irrigation, if the proper cultivation is planted, or alternatively for ground aquifer recharge to face the sea water intrusion, a common problem to the area.

Municipality of Plomari:

Saving a quantity of water equal to about 330,000 m³ /year can be achieved if the total amount of the wastewater from the existing treatment plant is used for irrigation. About

120,000 m³/year can be disposed for irrigation right now while the rest of the water can be used in the future if it is decided that the transfer of the water is feasible from a techno economic point of view. Alternatively groundwater recharge can be applied either by overland flow or infiltration basin. In any case the volume of the reservoir of Sedounta which is planned by the Master Plan can be reduced by about 120,000 m³.

Municipality of Polichnitos:

Saving a quantity of water equal to about 250,000 m³ /year can be achieved if the total amount of the treated wastewater is used for irrigation. About 120,000 m³ /year can be disposed for irrigation right after the operation of the WWTP while the rest of the water can be used in the future if it is decided that the transfer of the water is feasible from a techno economic point of view. Alternatively groundwater recharge can be applied either by overland flow or infiltration basin. Thus an additional reduction of the necessary volume of the reservoir of Tsiknias, which is planned by the Master Plan for the drinking and irrigation water of the greater area, can be achieved.

4. CONCLUSIONS

The reuse of treated wastewater from local WWTPs should be considered in the Study on Water Resources Management of Lesvos, and is an important part of it. By 2028 there will be on the island of Lesvos 36 operating WWTPs. Twenty six of them include secondary treatment and disinfection of water, so their effluent may be used to irrigate selective cultures. With the wastewater reuse the following can be achieved:

- Saving significant amounts of nitrogen (N) for fertilizing. Treated wastewater contains nitrogen with concentration within the permitted limits but enough to reduce the necessary use of fertilizers wherever irrigation with treated wastewater is applied.
- In the same way reduced quantities of phosphorus fertilizers are required if treated wastewater is used for irrigation.
- Saving of a significant amount of water since totally about 3,000,000 m³ per year can be used for irrigation from the effluent of the plants. It means that the reservoirs of Tsiknias and others can be substantially smaller while new areas can be watered and increase the income of the farmers.
- Finally the reserves of the ground aquifers will increase and the sea water intrusion phenomena will be avoided in the future.

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