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Promotion of environmental projects to conform with UWWTD and integrated water management

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ABSTRACT

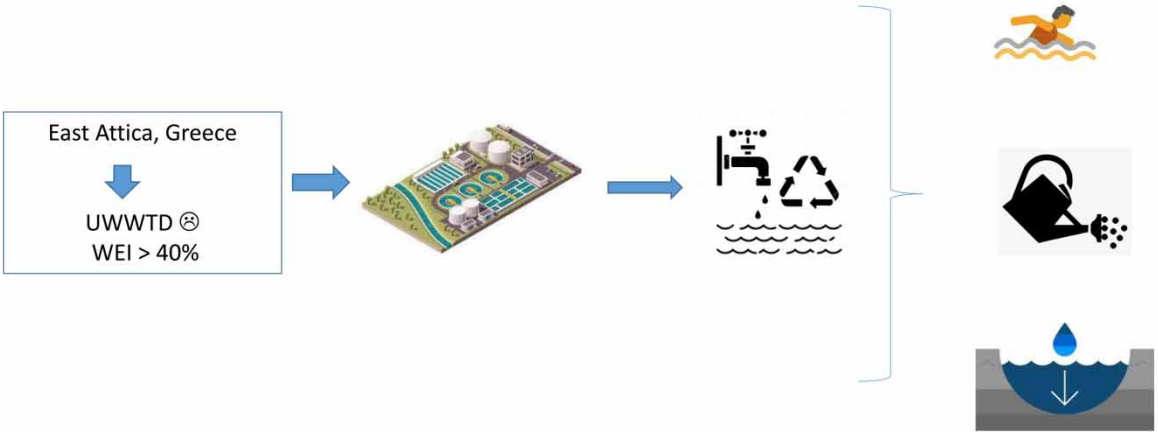
The region of East Attica in Greece faces stress on its water supply, caused mainly by agricultural activities and tourism in the summer. It is therefore imperative for the region to integrate water reuse in its water resources management plan. To this end, a project was conceived that accommodated stakeholder management practices to ensure public acceptance with the challenge to transform potential project risks to opportunities. In particular, two major wastewater projects in the region were approved for co-financing by the European Union (EU) Cohesion funds and implementation by the Athens Water Supply and Sewerage Company (EYDAP S.A.) for agglomerations in East Attica (Rafina/Artemida & Marathon agglomerations). Both projects aim to achieving compliance with 91/271/E.E.C, Urban Wastewater Treatment Directive (UWWTD) and producing treated effluent wastewater that complies with the national standards for unlimited irrigation and urban reuse. Furthermore, another wastewater scheme, co-financed by EU funds with the beneficiary being the Prefecture of Attica, involves the agglomerations of Koropi and Paiania respectively, which are also currently non-compliant. The aforementioned scheme is presently under development after upgrading with advanced tertiary treatment will also produce quantity of reclaimed water suitable for aquifer recharge to restore the water quality of groundwater bodies.

Key words: EU Cohesion funds, joint assistance to support projects in European regions (Jaspers), project management, water reuse, wastewater management, Urban Wastewater Treatment Directive

HIGHLIGHTS

- Conformity to UWWTD.
- Approval of major environmental projects by European Commission.
- Advanced wastewater treatment for wastewater reuse.
- Promotion of reuse in water-stressed areas.
- Sustainability of water reuse schemes.

GRAPHICAL ABSTRACT



INTRODUCTION

As wastewater management in Greece is being regulated by the Urban Wastewater Treatment Directive (UWWTD), compliance to the UWWTD effluent standards for biochemical oxygen demand (BOD_5), chemical oxygen demand (COD) and Suspended Solids (SS) are being achieved in more than 90% of the wastewater treatment plants (WWTPs), while in terms of nutrients, 80% of the WWTPs efficiently remove nitrogen and approximately 45% of the WWTPs remove phosphorus (Gavalaki *et al.* 2017). Although large cities and agglomerations with more than 25,000 population equivalent (p.e.) have practically complied with the UWWTD, there is a significant percentage of agglomerations that is not connected, which is related to areas in the Northern and East Attica Region. The estimated current generated load in those areas corresponds to a not negligible population figure of around 210,000 p.e. (Greek Ministry of the Environment & Energy 2020).

In particular, Attica region has a current population of around 3.9 million people (Greek Statistical Authority 2012), which constitutes almost 40% of the total population of Greece (Greek Ministry of Environment & Energy 2017). Most of the population in the Attica region is concentrated at the capital city of Athens. The Greater Athens area is currently served according to the Greek National Database (http://astikalimata.ypeka.gr/), by three biological nutrient removal (BNR) activated sludge plants in operation: Psyttalia WWTP (3,500,000 p.e., design capacity), Metamorphosi WWTP in the northwest (500,000 p.e.) and Thriasio WWTP in the west with a design capacity of 117,000 p.e. (Figure 1).

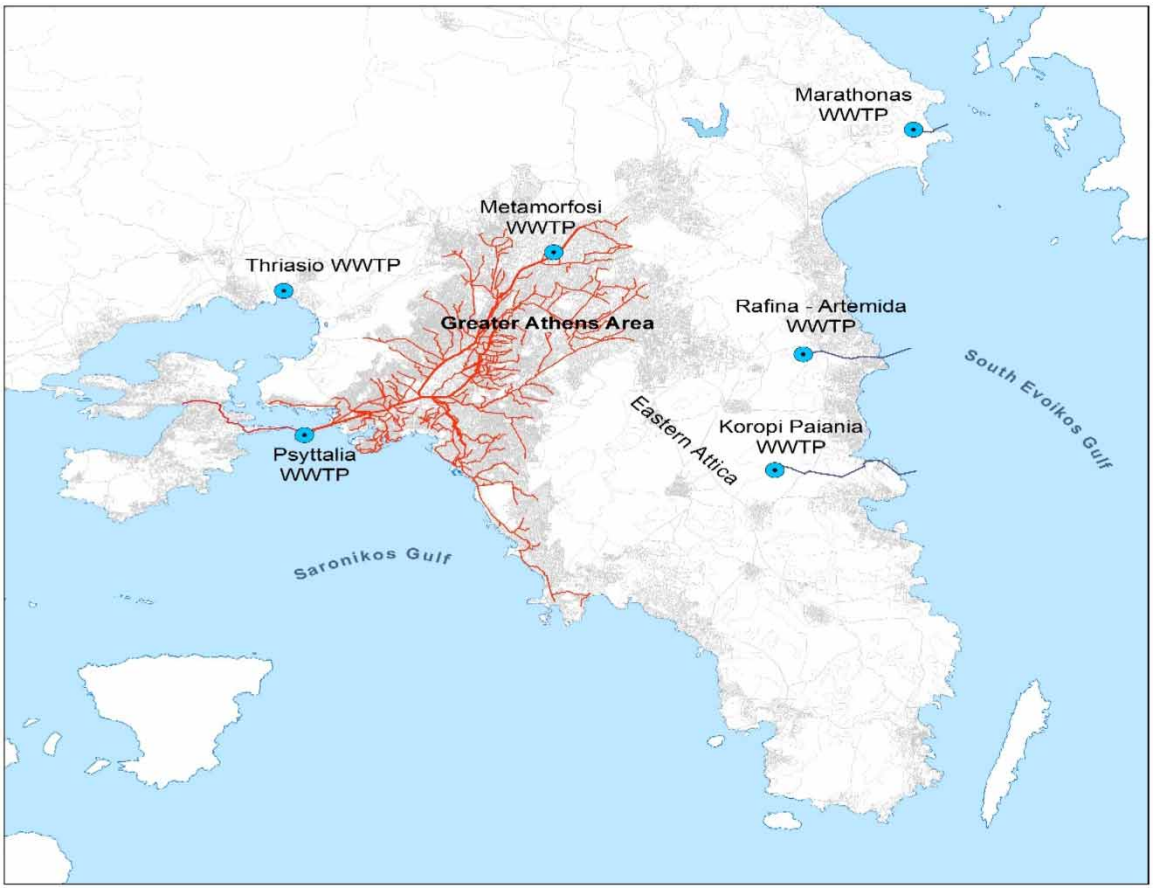


Figure 1 | Existing WWTPs with sewerage network of the Greater Athens area and future WWTPs in East Attica.

There is currently no urban wastewater management infrastructure in most settlements of East Attica Region. The existing wastewater management is restricted mostly to cesspools/soil absorption systems and transportation of this septage to Metamorphosis WWTP, which receives both domestic wastewater and septage for treatment. The years of practice have led toma burden on groundwater and surface water bodies in the region, with clear deterioration of water quality where groundwater tables are coloured red in the River Basin Management Plan

(RBMP) indicating poor water quality/chemical status (Figure 2). Moreover, overflows from cesspools are problematic in terms of environmental and public health protection.

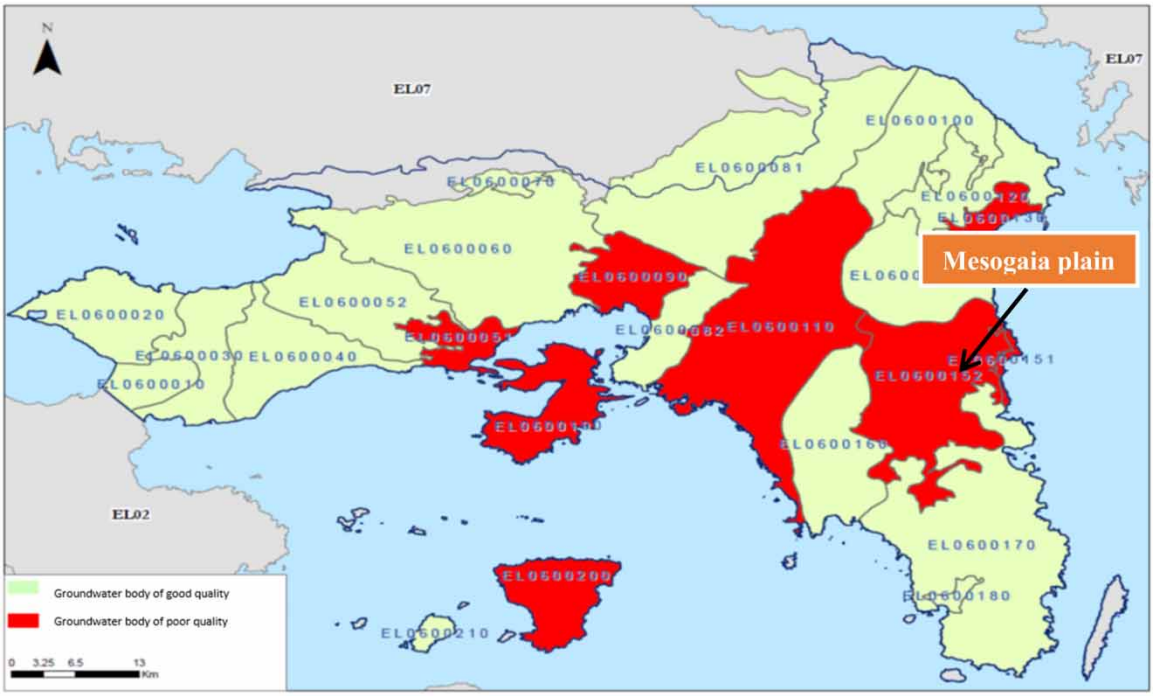


Figure 2 | Groundwater bodies in East Attica (first Revision of RBMP for Attica River Basin District, EL 06: 2017).

Hence, compliance with the UWWTD (91/271/EEC) is imperative and urgent in the area by the implementation of comprehensive sewer collection networks and WWTPs.

On the other hand by considering the whole water cycle, according to the RBMP for Attica, the region and particularly Eastern Attica is characterised as a severely water-stressed region with a high water exploitation index (WEI), well above 40%, especially during summer periods due to tourism and agricultural activities (Greek Ministry of Environment & Energy 2017). This region along with the Aegean Islands & Thessalia River Basin Districts (RBDs) are the most water-stressed districts in Greece, are also considered among the 20 most water-stressed river basin districts (RBDs) in Europe (European Commission 2016).

The WEI, as provided by Eurostat (ESTAT), compares the percentage of total freshwater with the total renewable freshwater resources available. A WEI above 20% implies that a water resource is under stress, and over 40% implies that the water resource is under severe stress indicating unsustainable water use.

These findings justify the need of developing water reuse schemes in the area to alleviate water stresses on one side and restore water quality at surface/groundwater bodies on the other side. This challenge is of great importance, by considering that Greece has an overall bad record on water reuse, i.e. less than 1% of total water use and less than 5% of total treated effluent from WWTPs is reused (European Commission 2016). Besides, water reuse has a critical role to play as a significant part of an integrated water management with respect also to climate change, especially in Mediterranean countries of Europe (Lazarova *et al.* 2001).

Both conformity to UWWTD and promotion of water reuse in East Attica are in line with the provisions of Directive, where in Article 12 of UWWTD is pointed out: *'Treated waste water shall be reused whenever appropriate. Disposal routes shall minimize the adverse effects on the environment.'* (European Council 1991a).

In addition, the recently issued EU 2020/741 Regulation of the European Parliament and of the Council on minimum requirements for water reuse that will come into force from Member States on 26 June 2023 (EC 2020), points out:

'The Union's ability to respond to the increasing pressures on water resources could be improved by wider reuse of treated waste water, limiting extraction from surface water bodies and groundwater bodies, reducing the impact of discharge of treated waste water into water bodies, and promoting water savings through multiple uses for urban waste water, while ensuring a high level of environmental protection.'

This is indeed a great challenge since all southern European countries, and among them Greece, are expected to face decreasing water availability in coming years.

CONFORMITY TO UWWTD IN EASTERN ATTICA

According to the characterisation of UWWTD agglomerations in Greece, priority B agglomerations are those with >15,000 p.e., whereas priority C agglomerations are those with p.e. between 2,000 and 15,000. For both priority agglomerations compliance deadlines according to UWWTD provisions were passed, 31-12-2000 was the compliance deadline for priority B agglomerations and 31-12-2005 for priority C agglomerations.

Following the update of the Master Plan for wastewater infrastructure in East Attica (EYDAP S.A 2016), two major wastewater projects were approved to be co-financed by EU/Cohesion funds for implementation by EYDAP S.A. in order to achieve conformity to UWWTD for priority B & C agglomerations in East Attica (i.e., agglomerations in Rafina, Artemida & Marathon Municipalities).

In particular, the Rafina-Artemida and Marathon wastewater schemes involve the construction of WWTPs (135,000 p.e. and 51,400 p.e respectively) and associated infrastructure for served agglomerations (sewerage networks & effluent disposal works) were approved for co-financing by the C (2020) 4877/15-7-2020 and C (2021) 3150/3-5-2021 Implementing Decisions of the European Commission respectively (European Commission, 2020 & 2021).

Both above projects are ongoing and the beneficiary is EYDAP S.A.

Furthermore, another wastewater scheme that its implementation had been approved to be co-financed by EU Cohesion funds in the previous programming period 2007–2013 is the Koropi-Paiania wastewater scheme. Its implementation is continuing in the current programming period 2014–2020 and the whole scheme is near completion. The beneficiary of the project is the Prefecture of Attica and after its commissioning will be handed over to EYDAP S.A. for operation. The Koropi-Paiania wastewater scheme involves the construction of the WWTP for served agglomerations (93,000 p.e.) and associated infrastructure (sewerage networks & effluent disposal works).

The locations of the new WWTPs that will be developed in Eastern Attica are presented in Figure 1. A brief overview of their main characteristics is given below.

Marathon WWTP scheme

The study area covers the region of the municipality of Marathon in the region of East Attica. The total population of the area is 33,423 inhabitants according to National Statistics Records with a summer peak population of around 72,000 people due to tourism and population shift from the city of Athens. Currently, Nea Makri and Marathon agglomerations of the Marathon Municipality, which are priority B & C settlements respectively in the project area, are reported as non-compliant with the UWWTD.

The investment measures include the construction of about 188 km sewer network (175 km gravity pipes and 13 km pressure pipes), 15 pumping stations, one wastewater treatment plant 51,400 p.e., and 2.2 km of effluent pipeline discharging in the South Evoikos Gulf at 15 m depth. The project has a total eligible cost of around 113,5 million Euros plus VAT with the financial contribution by EU/Cohesion Fund to be almost 91,3 million Euros (around 90% of the total eligible cost).

Applied WWTP technology consists of a conventional biological nutrient removal (BNR) activated sludge plant with part of the effluent to undergo conventional tertiary treatment (coagulation, disk filtration and ultraviolet disinfection) to render it suitable for unrestricted irrigation in neighbouring agricultural areas. Produced sludge after thickening/dewatering will be transported to Psyttalia WWTP for drying.

Rafina-Artemida WWTP scheme

The study area covers the area of the municipalities Rafina-Pikermi and Artemida-Spata in the region of East Attica. The total permanent population of the area is 55,334 inhabitants according to National Statistics Records (Greek Statistical Authority 2012), where the summer peak population arises to 86,000 inhabitants. Currently, Artemida and Rafina (priority B agglomerations) & Pikermi/Spata (priority C agglomerations) in the project area are reported as non-compliant with UWWTD.

The investment measures include the construction of about 430 km sewer network, 23 pumping stations, one WWTP for 135,000 p.e. and 2 km off-shore effluent pipeline discharging in the South Evoikos Gulf at around 50 m depth. Besides, the project will also provide a facility for the promotion of reuse of effluent water by the construction of a Centre for Environmental Awareness and Information (CEAI) at Rafina-Artemida WWTP.

The project has a total cost of 237.7 million Euros without VAT of which the approved eligible cost by the Cohesion Fund for co-funding is 229.9 million Euros (around 90% of the total eligible cost).

Applied WWTP technology consists of a BNR-activated sludge plant coupled with an advanced tertiary treatment step (membrane biological reactors (MBRs) and UV disinfection) to render effluent suitable for urban/suburban reuse and unrestricted irrigation in neighbouring areas. Produced sludge after thickening, anaerobic digestion and dewatering will be transported to Psyttalia WWTP for drying.

Koropi-Paiania WWTP scheme

The study area covers the area of the municipalities Koropi and Paiania in the region of East Attica. The today permanent population of the area is around 60,000 inhabitants (Greek Statistical Authority 2012), which presents no fluctuation in the summer period. Currently, Koropi (priority B agglomeration) and Paiania (priority C agglomeration) in the project area are reported as non-compliant with the UWWTD 91/271/EEC.

This wastewater scheme includes about 156 km sewer network, one WWTP for 93,000 p.e. and 1 km length offshore effluent pipeline discharging in the South Evoikos Gulf. The project is near completion with the WWTP expected to enter trial operation in the last quarter of 2022.

Applied WWTP technology consists of a conventional BNR-activated sludge plant with part of the effluent to undergo conventional tertiary treatment (coagulation, disk filtration, and U disinfection). Produced sludge after thickening/anaerobic digestion and dewatering will be transported to Psyttalia WWTP for drying.

A study to upgrade Koropi-Paiania WWTP with an advanced tertiary treatment step (i.e., membrane ultrafiltration) following conventional filtration is ongoing, to render effluent suitable for aquifer recharge in Mesogaia plain and unrestricted irrigation in neighbouring agricultural areas. Besides, a future extension of Koropi-Paiania WWTP will be required to accommodate additional domestic wastewater load arising from the seaside areas of Koropi and Saronikos Municipalities, which are priority C settlements non-compliant at present with UWWTD.

The project management aspect – The initial challenges

For the above Rafina-Artemida and Marathon major wastewater projects to be implemented by EYDAP S.A. a specialized Jaspers (Joint Assistance to Support Projects in European Regions) team was specifically involved, to promote concise projects' preparation hence rendering them suitable for co-financing by EU funds. To this respect, initial project perception accommodated appropriate stakeholder management practices to ensure public acceptance with an extra challenge to transform potential project risks to opportunities.

This approach was critical for the successful projects' preparation, as both projects have been under negotiations for many years. Finding suitable locations for implementation as well as reaching agreements with the relevant Municipalities and reaching for public acceptance combined with existing spatial planning restrictions has complicated the planning process and created long delays. In this context, Jaspers contribution was critical to provide a sound and robust documentation for both projects.

From early design stages the following challenges were faced;

The administrative/project management aspect

The issue: Construction responsibility lies with many parties. According to the legal framework in Greece, the responsibility of construction of the primary sewerage network (pipes with a diameter $D > 315$ mm), the WWTPs, and the disposal of treated effluents projects lies with EYDAP S.A. The responsibility for construction of the secondary network of sewerage pipes (pipes with diameter $D \leq 315$ mm), and the construction of the connection of the sewerage network to the each property belongs to the municipalities. Moreover, the municipality implements the latter after a relevant application by the property owner, which results in construction works that are scattered in time.

The above said framework, the number of parties involved puts at risk the projects' functionality in the desired time. Such situations appeared in the past in similar projects in the region of Attica (i.e., having a WWTP with limited incoming wastewater flow far below the design level, due to difficulty in properties' connection to the system/considerable time delays in the construction of the different project parts by different coordinators).

The adopted approach: Project holistic approach. Aiming at the best possible cooperation and coordination of the involved parties, EYDAP S.A promoted a holistic approach to the construction process adopting widely known appropriate project management stakeholder practices (PMI 2017a, 2017b). Via an agreement between

EYDAP S.A and the municipalities, the responsibility for construction of all of the network parts was transferred from the municipalities to EYDAP S.A.

Environmental project in areas with significant archaeological interest

The issue: Extensive archaeological findings are expected during the project's construction. The project areas are of high archeological interest and many archaeological findings are expected during project excavation. During the procedures of the projects' Environmental Approval, the responsible Archaeological Division of the Ministry of Culture and Sports identified areas of increased archaeological interest and proposed appropriate changes to pipeline routes. Final project designs have been updated accordingly.

The adopted approach: Environmental protection aligned with preservation of cultural heritage. Aiming at the best possible cooperation and coordination of the involved parties by adopting appropriate project management practices, memorandums of understanding (MoUs) have been signed for both projects between EYDAP S.A and the Ministry of Culture. In MoUs all identified aspects of coordinating the projects' construction towards rescuing any archaeological finding have been described. Indicative actions include the involvement of Archaeological Division in the planning process and especially in the development of the detailed project schedule (baseline and all necessary updates) and the establishment of a subproject to address the requirements of archaeological findings necessary work and budget. The subproject work and budget (5% of total project cost) has been fully incorporated in the project.

Achieving public acceptance

The difficulty: WWTP locations have been a matter of dispute for over twenty years. For both the Rafina-Artemida and Marathon major projects, public acceptance of the WWTP location was the main reason for the delay of projects' implementation, which also led to the imposed fines for non-compliance with 91/271/EEC Directive. This is a widely known attitude referred to as the 'Not in my back yard' (NIMBY) attitude, which is very common in Greece. Area residents have blocked the environmental approval with legal appeals for many years based on the false perception that a WWTP comes with noise, bad odour and area degradation.

The adopted approach: Turning threats into opportunities. A crucial challenge of appropriate project management practices is to transform potential threats to opportunities. To this respect, for Rafina-Artemida wastewater project EYDAP S.A in cooperation with the two involved municipalities designed the surrounding area of the WWTP as a recreational area where residents and visitors can enjoy walking and bicycling and have the opportunity to witness the reclaimed water (WWTP effluent) being used in artificial ponds and also for the park's irrigation. An environmental centre will operate within the administration building of WWTP and environmental awareness activities will take place for the public and also for specific potential users of the reclaimed water (e.g, farmers).

The approach led to the initiation of a new environmental project as presented below, aiming to promote the use of the reclaimed water for various reuse practices (i.e. *unrestricted irrigation, urban/suburban reuse, aquifer recharge*). This new project that involves a feasibility study to address the sustainability for reuse is currently under design phase. Jaspers' contribution to this approach has so far been crucial and is ongoing to address new challenges.

POTENTIAL REUSE OF RECLAIMED WATER

The reuse of treated wastewater for supplementary uses is a measure proposed in the RBMP of Attica Region (EL06) for the achievement of the objectives of the Water Framework Directive (WFD) 2000/60/EC (Greek Ministry of Environment & Energy 2017).

This supplementary measure is termed in the RBMP as '*Preparation of water reuse studies of the reclaimed water from tertiary WWTPs*' (i.e., measure code: M06S1001). In these studies – although no specific reference is made for the water reuse schemes described in this article – it is proposed that agricultural irrigation may be a preferable reuse practice and/or alternative reuse practices could be implemented (i.e., urban/suburban reuse, aquifer recharge).

Therefore, the challenge of water reuse of the reclaimed water from the WWTPs to be developed in East Attica forms a fundamental part of an integrated water resources management in the area.

A recent Master Plan for Effluent Reuse from Eastern Attica WWTPs was carried out by EYDAP S.A. (EYDAP 2017). The master plan had a twofold purpose: to identify the best practices of the reclaimed water produced by WWTPs and to define the areas where reclaimed water may be applied.

To this respect, three water reuse practices were identified: *unrestricted irrigation*, *urban/suburban reuse* and *aquifer recharge* to alleviate water stresses in the area and to restore the effects of overexploitation of groundwater bodies/continuous water quality deterioration of groundwater tables. The appropriate reuse practices and the required quality of reclaimed water to be produced from each WWTP are given in Figure 3.

The strategic choice taken for future reuse of the effluent water produced from WWTPs when the required quantities/quality of the reclaimed water will be available has an impact on the selection of the fit-for-purpose WWTP technology.

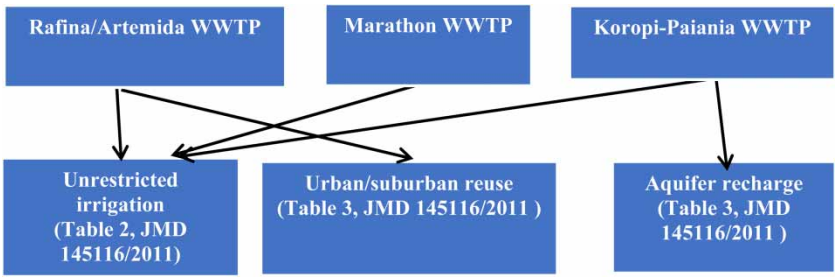


Figure 3 | Quality of reclaimed water from Eastern Attica WWTPs.

For *unrestricted irrigation,* which requires reclaimed water quality with chemical/microbiological permissible concentrations according to national standards (Joint Ministerial Decision 145116/2011, Table 2 of Annex I) as given in Table 1 below, a BNR-activated sludge treatment scheme coupled with a conventional tertiary treatment step (coagulation/gravity or disc filtration etc. and U disinfection) is required.

Table 1 | Effluent criteria for water reuse according to Joint Ministerial Decision 145116/2011

Parameter	Maximum permissible concentration (Table 3, Annex I, JMD 145116/2011)	Maximum permissible concentration (Table 2, Annex I, JMD 145116/2011)	Percentage of samples' compliance
BOD	10 mg/l	10 mg/l	80%
COD	60 mg/l	60 mg/l	80%
TSS	2 mg/l	10 mg/l	80%
Total Nitrogen, TN	$\leq$ 15 mg/l	$\leq$ 15 mg/l[a]	mean annual value
Turbidity	2 NTU	2 NTU	median
E. coli	<2 cfu/100 ml	<5 cfu/100 ml	80%
	<20 cfu/100 ml	<50 cfu/100 ml	95%

[a]for unrestricted irrigation in nitrate vulnerable zones (NVZ), according to 91/676/EEC Directive (EC 1991b).

For *urban-suburban reuse* and *aquifer recharge* which requires reclaimed water quality with chemical/microbiological permissible concentrations according to national standards (JMD 145116/2011, Table 3 of Annex I) as given in Table 1 below, it is necessary to include a more advanced tertiary treatment scheme along with BNR activated sludge treatment. To this respect, advanced tertiary treatment may be accomplished with microfiltration/ultrafiltration schemes with MBRs/ultrafiltration membrane modules or more energy intensive schemes (e.g., reverse osmosis).

In general, national reuse standards as given in Table 1 are stricter from the standards adopted in the EU 2020/741 Regulation (EC 2020). However, it should be stressed that EU 2020/741 Regulation covers only the application of treated urban wastewater for agricultural irrigation and not for aquifer recharge.

More specifically, regarding the application of *unrestricted irrigation* in Eastern Attica (i.e., class A of water quality in EU 2020/741), national reuse standards are the same in terms of BOD_5, total suspended solids (TSS) parameters for reclaimed water ($\leq$ 10 mg/l). Regarding the turbidity of reclaimed water, national reuse

standards are stricter (≤ 2 NTU instead of ≤5 NTU in EU 2020/741: Annex I, Table 2). As far as microbiological parameters are concerned, national reuse standards are again generally stricter (*Escherichia coli* number ≤5/100 ml instead of ≤10/100 in EU 2020/741: Annex I, Table 2). However, EU 2020/741 Regulation entails more microbiological parameters to be monitored to ensure appropriate water quality for public health (i.e., *Legionella sp.*< 1,000 cfu/l, intestinal nematodes/helminth eggs ≤1 egg for irrigation of pastures or forage). These paramaters have not been tackled in national reuse standards.

In addition, a crucial component that is addressed in EU 2020/741 Regulation is risk analysis to identify and manage risks in a proactive way for the whole water reuse system (from the entry of wastewater to WWTP reclamation facility to the supply, distribution and storage infrastructure etc.). Risk management is critical to ensure that reclaimed water is properly and safely managed for the protection of the environment and for human/animal health. This requirement is currently missing in national reuse standards. However, it is envisaged that risk management will be incorporated in national reuse standards in due course, considering the fact that EU 2020/741 Regulation will come into force for Member States to apply from 26 June 2023.

On the other hand, EU 2020/741 Regulation has no provisions for the maximum permissible concentrations of selected heavy metals and metalloids, as well as for certain agronomic characteristics of the reclaimed water for agricultural irrigation, provided by JMD 145116/2011.

The main characteristics of the reuse schemes proposed from each WWTP to be developed in East Attica are overviewed below and in Table 2.

Table 2 | Preliminary estimation of capital expenditure (CAPEX[a]) in M€ of effluent reuse schemes in East Attica

WWTP	P.E. (Initial phase/extension)	Irrigated area, ha (Phase A')	Irrigated area, ha (Phase B')	CAPEX[a], M€ (Phase A)	CAPEX[a], M€ (Phase B)	CAPEX[a], M€ (Aquifer recharge: Phase A')
Rafina-Artemida	135,000/180,000	840	200	6.4	1.5	–
Koropi-Paiania	93,000/132,000	1,200	400	23.6	7.9	9.2 (12.3 Phase B')
Marathon	51,400/85,000	410	250	2.7	1.6	–
TOTAL	**279,400/397,000**	**2,450**	**850**	**32.7**	**11.0**	**9.2**

[a]not including general expenses and overheads (18%), contingencies, revision costs, and VAT.

Marathon WWTP

According to the Master Plan for Effluent Reuse (EYDAP 2017), an irrigation network can be constructed to serve agricultural land such as greenhouses with vegetables, gardens, etc.

Marathon WWTP (51,400 p.e.), which is expected to be commissioned in the next five years, will have the capacity to provide unrestricted irrigation to an area of 410 ha of agricultural land north of Schinias Olympic rowing centre. Following Marathon WWTP extension (85,000 p.e.) to accommodate flows/loads in a 20-year period (2040), a complementary area of 250 ha can be irrigated (Table 2). Environmental licensing has been obtained for unrestricted irrigation of the produced reclaimed water from Marathon WWTP. However, for its specific application a more detailed technical and environmental study meeting the requirements of JMD 145116/2011 is required.

Rafina-Artemida WWTP

According to the Master Plan, an irrigation network can be constructed to serve agricultural land (vineyards, olive trees, vegetables) in the buffer zone northwest of the Athens International Airport.

Rafina-Artemida WWTP (135,000 p.e.) which is expected to be commissioned in the next five years will have the capacity to irrigate with unrestricted irrigation 840 ha of agricultural land. Following the Rafina-Artemida WWTP extension (180,000 p.e.) to accommodate flows/loads in the 20-year period (2040), a complementary area of 200 ha can be irrigated (Table 2).

Besides, two tapping points on the on shore part of the effluent pipeline for urban and suburban reuse of effluent water have been proposed, that may irrigate around 90 ha of urban/suburban areas in Rafina and Artemida settlements.

Full environmental licensing has been obtained for unrestricted irrigation and urban/suburban reuse of the produced reclaimed water from Rafina-Artemida WWTP, which involves the application of unrestricted irrigation/urban-suburban reuse in the aforementioned areas.

Koropi-Paiania WWTP

To promote sustainable effluent reuse to groundwater bodies in the Mesogaia plain (Figure 2), which are subject to overexploitation by farmers in the summer months, salinity intrusion, and constant water quality deterioration of their tables and to re-evaluate available agricultural areas for *unrestricted irrigation*, the Master Plan for Effluent Reuse has been revised accordingly.

The objective was to re-assess projected reuse areas as a result of the proposed transfer of domestic wastewater arising from seaside areas of Saronikos and Koropi municipalities planned by EYDAP S.A. (EYDAP 2020).

Koropi-Paiania WWTP (93,000 p.e.) following construction of the sewerage network and of private connections to the network will enter a six-month trial operation by the contractor in the coming period. Trial operation of WWTP will have the purpose of testing: (i) installed electromechanical equipment, (ii) instrumentation, control and automation processes, and (iii) selecting best operational treatment scheme by considering/assessing different alternatives.

Following trial operation, the contractor will undertake normal operation of WWTP for an extra period of 15 months. At the end of normal operation, WWTP will be fully commissioned for operation by EYDAP S.A. Therefore, plant commissioning is expected within the next two years. To this respect, an upgrade of WWTP is planned in order to provide the required effluent quality according to national standards for *aquifer recharge/unrestricted irrigation*.

This is certainly necessary since the constructed WWTP is a typical BNR-activated sludge plant with an inadequate tertiary treatment step to produce the required effluent quality for the above reuse purposes.

As a result of this investigation, Koropi-Paiania WWTP (93,000 p.e.) after upgrading may irrigate 1,200 ha of agricultural land mainly of vineyards and vegetables (600 ha in the buffer zone southwest of the Athens International Airport and 600 ha in an area neighbouring to Kalivia settlement).

Besides, the WWTP may provide reclaimed water to aquifers in the Mesogaia plain, which can take up to around 65% of the produced water in winter months for subsequent abstraction for irrigation in the summer, thus minimizing effluent disposal to the sea.

Following WWTP extension (132,000 p.e.) to accommodate additional flows/loads from Saronikos/Koropi seaside settlements, the above share to the total produced water in the winter is expected to be around 50%. Besides, a complementary area of 400 ha can be irrigated (Table 2).

Environmental licensing is in progress through the implementation of a comprehensive environmental impacts assessment (EIA) study that will cover the application of unrestricted irrigation/aquifer recharge in the aforementioned areas.

According to the Master Plan, an initial estimation of the required capital expenditure (CAPEX) for the gradual development of the proposed water reuse schemes in East Attica is given below (Table 2: Phase A: Initial capacity of WWTPs to be constructed, Phase B: Extension of WWTPs for 2040).

As can be seen in Table 2, CAPEX estimate for Koropi-Paiania WWTP reuse scheme is considerably higher than the corresponding estimates for Rafina-Artemida & Marathon WWTPs schemes. This is attributed to the transportation expenses, due to the fact that Koropi-Paiania WWTP is located at a significant distance to the application field (around 10 km) compared with corresponding distances from Rafina/Artemida and Marathon WWTPs (2 km and 1 km respectively).

Operational expenditure (OPEX) estimates for these reuse schemes have not yet been assessed. However, it is planned that these values will be determined in the context of a comprehensive feasibility study (FS), as discussed below. OPEX estimates will include administrative, operational, maintenance, environmental, and risk management costs, according to the provisions of EU 2020/741 Regulation. A major objective of FS will be to select least cost solutions by evaluating alternative construction/operation implementation scenarios. This involves the estimation of net present value (NPV) for each alternative scenario, by considering CAPEX/OPEX estimates.

FS FOR WATER REUSE

In the context of approval of the two major wastewater projects – Rafina/Artemida and Marathon – to be co-financed for implementation by EU/Cohesion funds, EYDAP S.A. has undertaken the responsibility to develop a Road Map to promote water reuse application in the project areas.

It is expected that following commissioning and operation of the Rafina-Artemida, Marathon and Koropi-Paiania (after upgrading with advanced tertiary treatment) WWTPs, considerable quantities of reclaimed water can be produced. To this respect, EYDAP S.A. will carry out an FS to investigate the sustainability of gradual development of water reuse schemes in East Attica on institutional/technical/environmental/economic and public acceptance grounds. This investigation will be in line with EU Regulation 741/2020 (EC 2020).

Since the gradual implementation of water reuse schemes in East Attica will be the largest implementation of water reuse in the country following the Thessaloniki city case study (Tsagarakis *et al.* 2001; Ilias *et al.* 2014), Jaspers as an experts' team will be involved in the supervision and review of the FS.

Core issues to be addressed are as follows:

- Institutional/administrative and legislative regarding projects' implementation and management bodies;
- Technical/environmental issues regarding review of EYDAP Master Plan/time schedule for gradual implementation of reuse schemes;
- Risk assessment
- Economic issues (cost-benefit analysis, water pricing etc.) and,
- Public acceptance issues

As the development of water reuse schemes has the risk of failure due to potential lack of social support and negative public attitudes such as perception of water quality and willingness to pay, an essential understanding of the social aspects as well as educational/public awareness campaigns are required. Such measures aimed at awareness raising and civil participation in sustainable management of water are proposed in the RBMP for Attica (Greek Ministry of Environment & Energy 2017). In this regard, a Centre for Environmental Awareness and Information (CEAI) at Rafina-Artemida WWTP was approved to be co-financed by EU/Cohesion Funds for construction to play a critical role to ensure the necessary social acceptance, based on actions of public awareness/information and drafting of pilot reuse programs (Figure 4).

Figure 4 | Proposed CEAI to be constructed at Rafina-Artemida WWTP.

More specifically, the aim for the centre is to become an attraction and to provide benefits for the region. The centre will consist of two functional modules, which are the building infrastructure and the surrounding area.

The building infrastructure will include exhibition hall, seminar rooms and offices. The surrounding area of the centre will include areas for pilot projects to support research activities for reuse of effluent waters and sustainable management of water resources. The area will also include vegetable gardens for educational activities with schools and citizens, water surfaces with water lilies and fish with the use of effluent waters.

The centre will be developing/providing environmental education programmes aimed at pupils in primary, secondary, and higher education, seminars and workshops for professional groups related to the management of

water and wastewater (university, manufacturers, suppliers, designers, etc.), and information for the general public (exhibitions and film screenings and presentations on climate change, environmental protection, water, and waste water management).

The actions taking place in the centre will be vital for the acceptance of reuse of recovered water by future users and would contribute substantially to the maturation process of the evolving framework for its implementation.

Regarding the economic analysis, the financial viability of the gradual implementation of water reuse schemes in East Attica should be addressed on the basis of a special cost-benefit analysis to determine the required pricing policy to recover the cost of re-use water in the medium and long term, in accordance with the relevant legislative framework established in the country in line with WFD pricing policies (JMD 135275/22-5-2017).

CONCLUSIONS

1. Although, in general, wastewater management in Greece is regulated by the UWWTD and achieves a high compliance level in large cities and agglomerations with more than 25,000 p.e., there is still a significant percentage of Priority B and C agglomerations, mainly in East Attica, which are currently non-compliant. Among them are the Rafina/Artemida, Marathon, and Koropi/Paiania agglomerations.
2. Two major wastewater projects in the region were approved for co-financing by EU Cohesion funds and implementation by EYDAP S.A. for agglomerations in East Attica (Rafina/Artemida & Marathon agglomerations). Both projects aim to achieving compliance with 91/271/E.E.C. UWWTD and producing treated effluent wastewater that complies with the national standards for unlimited irrigation and urban reuse. Additional to the above, a wastewater scheme was co-financed by EU funds for the agglomerations of Koropi and Paiania in Attica, which are also currently non-compliant. The aforementioned scheme is presently under development and after upgrading with advanced tertiary treatment will also produce quantity of reclaimed water suitable for aquifer recharge to restore the water quality of groundwater bodies.
3. To this respect for the two major projects of Rafina/Artemida and Marathon to be implemented by EYDAP S.A., the initial project perception accommodated appropriate stakeholder management practices to ensure public acceptance with an extra challenge to transform potential project risks to opportunities.
4. Eastern Attica is characterised as a severely water-stressed region with a high WEI, well above 40%, indicating unsustainable water use. Therefore, it is critical that water reuse schemes are gradually developed in the next couple of years in the region so that water stresses can be alleviated in the context of an integrated water resources management. To that end, EYDAP S.A. is on track to carry out an FS for addressing the sustainability for the gradual development of water reuse schemes in East Attica by examining factors such as institutional, technical and environmental risks, managerial and economic resources needed, and the challenge of public acceptance.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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