RESEARCH ARTICLE

Water supply of Greek cities: the WFD and the Principles of Integrated Water Resources Management

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Abstract

In this paper the water supply conditions in the major Greek cities have been investigated and a comprehensive description is provided. It has occurred that the choice of the catchment area as the administrative unit for water management purposes is rather adapted to urban water management in Western Europe, than in Greece. In fact, while the major cities in France, Spain and the UK can be mainly supplied by water issued from the catchment area in which they are located, interbasin water transfer is necessary in Greece. The reasons are both hydrological, with the typical catchment area size in Greece being rather small, and socioeconomic, because the economic activities of the Greek cities are not linked to rivers, so that only a few of them are built on large watersheds. The reduction of water losses due to network leakage is suggested as a method for the decrease of interbasin transfer volumes.

Keywords: Greek cities; Integrated Water Resources Management; interbasin water transfer; Water Framework Directive

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# 1. Introduction

Although worldwide urban water supply is smaller than agricultural water use, its management is of importance for social, economic and political reasons. Therefore urban water management policy has been recently intensively investigated (Bithas, 2008; Rygaard, Binning, & Albrechtsen, 2011). In this paper we will focus on strategies to meet drinking water demand in Greek cities.

A survey of the water demand and water pricing policy in Greek urban centres has been undertaken by Mylopoulos, Kolokytha and Tolikas (2003), who concluded that water pricing policies were designed to cover only a part of the direct costs.

Karavitis (1998) has investigated the water management conditions in the city of Athens, and has suggested that the introduction of both structural and non-structural measures is necessary in order to prevent droughts.

Investigations of water demand management and willingness to pay aspects in the cities of Heraklion and Volos were conducted by Genius and Tsagarakis (2006) and Kolokytha and Mylopoulos (2004) respectively.

Kanakoudis and Tsitsifli (2010) demonstrated that water losses in the city of Larissa could be reduced by adequate pressure management of the network.

However, in the aforementioned studies, neither the water supply conditions in Greek cities were extensively presented, nor the interactions between urban water management and geographic, engineering, legal, economic and legal issues were thoroughly investigated.

In the presented study, an in-depth analysis of the interactions above is provided, In particularly, a comparison between economic historical and cultural characteristics related to urban water management in Western Europe and Greece was undertaken.

Interestingly enough, the names of several cities and urban towns in Western Europe are associated with the names of rivers: e.g. Stoke on Trent, Newcastle upon Tyne, Frankfurt am Main, and Neuilly-sur-Seine. Such collocations do not apply to Greek cities. Moreover in Greece prefecture’s names are used for disambiguation purposes between cities or towns bearing the same name (Trikala of Imathia/Trikala of Korinthia) while in Central Europe river names are used for this purpose (Frankfurt am Main, Frankfurt an der Oder).

As it will be presented in this paper the reasons for the facts presented above are that while in Western Europe economic activities, in particularly those connected with cities, are strongly related to the rivers and the spatial entities which contribute to their creation, the rivers basins (RBs), which are also called watersheds or catchment areas, such interactions do not exist in Greece. Subsequently, as it will be explicitly presented in this study, since the 18th century, planning of water resources in Western Europe has considered the RBs. This management practice has been recently incorporated in the Water Framework Directive (WFD) which imposes the RB as the planning unit for water resources management purposes. We will demonstrate that the above principle of the WFD is rather adequate for Western Europe than in Greece, where no such pronounced interactions between rivers and economic activities, especially urban development, exist. The adequacy of the WFD for urban water supply in Greece will be further investigated, and it will be presented which provisions of the WFD would be beneficial for Greece but have been not applied yet. Also, it will be discussed which provisions are not compatible with the principles of Integrated Water Resources Management (IWRM).

# 2. The Water Framework Directive (WFD)

According to Bithas (2008) the WFD, the targets and guidelines of which are incorporated in the legislation of most countries of the European Union, is one of the most elaborate documents concerning water policy worldwide. Some characteristics of this framework are demand management, the public and stakeholder participation in the management process (Kallis & Butler 2001; Sofios, Arabatzis, & Baltas, 2008), providing the public with proper information, (Gupta & van der Zaag, 2008), full cost pricing of water use (Kallis & Butler, 2001), and the choice of the RB as the planning unit for water resources management purposes (Molle, 2009).

In this paper we will focus on the last issue.

As it has been pointed out by Graefe (2011), the choice of the river basin might be considered as a naturally given region which is “*scientifically justified area based on rationality of natural science*”.

Historical details about the concept of river basin as the planning unit are provided by Molle (2009): This concept has been developed in Western Europe in the 18th Century. In the 1930–1960 period it was linked to the construction and management of multiple purpose dams, and in the 1990’s it re-emerged as a cornerstone of IWRM, as it is related to both catchment and ecological management strategies. Nowadays, it is criticized because of the catchment areas might not be in some cases not the adequate scale for water resources management (Graefe, 2011; Molle, 2009).

We will demonstrate in this study that the concept of the catchment area as the planning unit is more adapted to urban water management in West European Cities (i.e. in the region of the world in which it has been originally developed and applied).

# 3. Urban water resources management in France, Spain and the United Kingdom

According to Molle (2009), the concept of the catchment area as the planning unit has been first developed and adapted, besides the US, in Western Europe- mainly in France, Spain and the United Kingdom. Therefore, we will analyse in this section some features of urban water management in these countries. We think that the concept mentioned above makes sense, at least partially, in Western Europe, because large cities have been developed in the vicinity of major rivers (see also our Table 1), and there is a significant interdependence of water consumption by city dwellers, economic activities and water use for irrigation, energy production and other industrial activities in the limits of the same RB.

The interdependence between urban development and water bodies in the RB of the Seine river has been presented by Billen, Garnier, Mouchel, and Silvestre (2007), who stated that Paris is built at the centre of a dense hydrographic network, where large tributaries facilitate the long-distance transport of food, timber and construction material. Therefore, the population is mostly concentrated in the middle of the river basin. Subsequently, management of the Seine River involves various tasks as flood control, low flow regime regulation, irrigation, hydropower production and water supply (Moulin, Perrin, Michel, & Andréassian, 2005).

The conclusions above are also valid for the catchment area of the Thames River and the water supply of the city of London. The River Thames, which is one of the major rivers in the United Kingdom, satisfies about two-thirds of London’s demand (Matrosov, Harou, & Loucks, 2011).

Madrid (the capital of Spain) depends heavily on the Tagus River, one of the major rivers of the Iberian Peninsula, on whose catchment area it has been built. The Tagus provides water for urban supply, irrigation purposes, and industrial uses, including cooling of nuclear and thermal plants (López‐Moreno et al., 2009). Interestingly enough, Lisbon (the capital of Portugal) lies also in the catchment area of the Tagus River, and subsequently is influenced by water management upstream. Lisbon is being supplied with water directly from the Tagus River and also from the Zêzere River, a tributary of Tagus (Saraiva, Schmidt &, Pato 2014). Therefore, the water resources management can be conducted within the catchment limits of Tagus.

Counterexamples exist where water for domestic supply is transferred from outside the RB, as in the case of domestic water supply of Birmingham (Midlands, England), where water is being transferred by an over 10- km-long aqueduct from the Elan and Claerwen Valleys' Reservoirs in Mid Wales to the city of Birmingham in Western Central England (Elan Valey Organization, 2016).

Nevertheless, for several additional cases the river basin as a management unit makes sense, as we will demonstrate below.

Most water for the city of Lyon is issued from the Crépieux-Charmy wellfield which lies in the vicinity of the city, from which 1,280,000 inhabitants are supplied. Infiltration basins are used for aquifer recharge with surface water pumped from a channel of the Rhône River (Gette-Bouvarot et al., 2015). By this process the quality of the river water is being improved.

Drinking water for Toulouse is issued from the catchment area of the Garonne River, either from the river itself or from its tributaries (Communauté Urbaine Toulouse Métropole, 2012).

Barcelona is built near the deltaic region of the Llobregat River. Although the basin is stressed by the increasing water demands (Saurí, 2003), the drinking water needs of the capital of Catalonia are covered by water stored in dams of the Llobregat River or withdrawals from numerous nearby the city wells.

All the data above are summarized in Table 1.

# 4. Description of the water resources status and policy in Greece

Greece is located in Southeastern Europe. Its terrain is mostly mountainous. Its climate is warm Mediterranean (Csa).

According to the UN’s classification, which considers the annual renewable freshwater availability, Greece possesses 5,840 m3/person/year of freshwater, and is in an advantaged position compared to other Mediterranean countries like Italy (3,243 m3/ person/year), Spain (2,849 m3/person/year), and Israel (461 m3/person/year) (Mylopoulos et al., 2003). Similar data are provided by Sofios et al. (2008).

Nevertheless, water shortages in urban areas have occurred (Genius & Tsagarakis, 2006; Mylopoulos et al., 2003), and environmental issues like depletion and negative water balances in the catchment areas, salinization of coastal aquifers, and catchment pollution have also been reported (Mylopoulos et al., 2003; Sofios et al., 2008). As noted by Karavitis (1998), the reasons for the problems above are uneven distribution of water resources through time (most of the precipitation occurring during the winter months) and across space (while water is most abundant in the Western part of the country, most population lives in the East), and sheer mismanagement.

The characteristics of the major RBs are presented in Table 2. As is also mentioned by Sofios et al. (2008), the catchment areas of these basins are relatively small. By comparing the data of Tables 1 and 2 one can conclude that the size of the major river basins in Greece is smaller than the typical size of the major river basins in Western Europe.

In order to conform to the WFD, Greek Authorities have merged several catchment areas to build units that have a sufficiently large scale, so that they are adequate units for water resources management. However, we want to point out that this is a more or less arbitrary process, and these “artificial” units, are mistakenly called above River Basin Districts (RBDs). These RBDs are not naturally given and therefore not based on the rationality of natural science. This is one of the reasons, as we have presented in Section 2, why the WFD suggests that the catchment area should be used as the management unit.

In compliance with the WFD, 14 Water Districts (WDs) or Hydrological Prefectures have been assigned in Greece. For each of these WDs, a River Basin Management Plan (RBMP) has been developed. Baltas and Mimikou (2005) have proposed that the number should be reduced to 7, for better organization and flexibility claiming that EU Members States (MSs) with a larger surface area have a similar amount of WDs.

As already stated we will focus on the management of mainly domestic urban water demand, which represents approx. 13-15% of the total consumption, while the share of agriculture and industry (including power production) are about 80-84% and 2.5-4% respectively (Karavitis, 1998). In Greece, drinking water is being supplied by Municipal Enterprises, except for the cities of Athens and Thessaloniki, where the Water Utilities are private enterprises where the State holds 51% of the shares.

In the next section we will provide details regarding water supply of the 20 largest cities in Greece.

# 5. Description of water supply conditions of Greek cities

In this Section the water supply conditions of the 20 largest cities in Greece are presented. Some relevant data are presented in Table 3, while a more detailed description is presented below.

## 5.1 Water supply of the urban area of Athens

The urban area of Athens - which includes the cities of Athens (the capital of Greece), and Piraeus - is the largest in Greece. Approx. 3,000,000 inhabitants live in this area which is the centre of the administration, economy and culture of the country (Karavitis, 1998). Athens lies mainly in the RB of Kephisos which has a catchment area of 380 km2 and is roughly equal to the surface of the city itself (Koutsoyiannis, 2009). Nowadays, water does not flow in Kephisos over the whole year, and as pointed out by Koutsoyiannis (2009) it serves rather as a sewer due to large wastewater injections.

The aforementioned urban area lies in the WD of Attiki, which is the smallest in Greece. Surface water is mainly used for water supply purposes, chiefly from the rivers Evinos and Mornos, both lying in the West of Athens. Smaller quantities from the Yliki lake and the Marathon dam are also being used (Kallis, 2010).

Not one of the above-mentioned water supply sources lies in the same RB (hydrological catchment area) as the urban area of Athens, except for the dam of Marathon, which lies in the same WD (WD of Attiki). While the River Mornos and lake Yliki lie in adjacent WDs, (WD of West Sterea and East Sterea respectively), the River Evinos lies in a non-adjacent water department (WD of Epirus). The transfer distance from Evinos dam, Mornos reservoir, Yliki lake and Marathon dam is 221.5 km, 192 km, 85 km and 21.5 km respectively (Kallis, 2010).

An extensive description of the water supply conditions of the city of Athens is provided by Karavitis (1998), Kaika (2003) and Kallis (2010). An economic analysis of water supply of Athens is provided by Kallis and Coccossis (2003), who pointed out that heavy subsidization of dams and pipelines for the transfer of raw water to Athens by the European Union, may be the reason that an extensive detection and reduction of leakage in the water network of the metropolitan area of Athens has not been conducted.

## 5.2 Water supply of the urban area of Thessaloniki

Thessaloniki is the capital of the District of Macedonia in the North of Greece. It is the second largest city in Greece and an important economic, industrial and cultural centre.

Although several small rivers and torrents existed in the urban area of Thessaloniki (Moutsopoulos, 1980; Yannopoulos, Kaiafa-Saropoulou, & Angelakis, 2015), nowadays they have been covered over by urban development in order to maximize usable land (Yannopoulos et al., 2015).

Water for the supply of the urban area of Thessaloniki is being conveyed from the springs of Aravissos, from the Aliakmon River and from wells in the vicinity of Axios River (Spahos, Voudouris, Drosos, & Dimopoulos, 2006). No one of these water sources is situated in the same RB or the same RBD as the city of Thessaloniki. While the springs of Aravissos and the wellfield near Axios River lies in the same WD as the city of Thessaloniki (the WD Department of Central Macedonia), Aliakmon dam lies in the WD of Western Macedonia.

Water is being transferred by gravity from the springs of Aravissos through a closed pipeline and from the Aliakmon dam through an open channel to a pumping station near the Axios River (Michoudi, 2002), from where it is being lifted to the water treatment plant in Sindos and then it is pumped to city of Thessaloniki.

## 5.3 Water supply of the city of Patras

The city of Patras (also known as Patra), which is located at the South of the country, in the north of Peloponnese peninsula is the third largest city of Greece, the largest city in Peloponnese and the regional capital of Western Greece. Its harbour is a nodal point for trade with Italy and the rest of Western Europe.

The city is being provided by water from the Glafkos catchment area (30.9%), by wells in the vicinity of the city (57.9%) and by the Haradros catchment area (11.2%) (L. Tsatsos, personal communication, December 29, 2015). The RBs of Glafkos and Haradros lie in the same RB as the city of Patras, although they form a different unit. Both surface water from a dam and groundwater from wells are being conveyed from the Glafkos river basin to the city of Patras, while water which is being conveyed to Patras from the Haradros basin is being issued from wells.

Precipitation decrease and an increase of water pumping during the last decades have resulted in a lowering of the head of the aquifers (Lambrakis, Voudouris, Tiniakos, & Kallergis, 1997). Therefore, the increasing needs for drinking water can hardly be covered by the existing resources. Two dams have been constructed in the Peiros-Parapeiros drainage area. The construction of the largest one, namely the Asterios dam, which is situated at a distance of approx. 32 km from the city of Patras, is almost completed. Nevertheless the question of sharing the water resources of these dams, between the city of Patras, the nearby industries, and the Municipalities of Erymanthos and Westerns Achaia is still open (Podimata & Yannopoulos, 2015). We want to point out that the Peiros-Parapeiros drainage area is located neither in the same RB nor in the same RBD as the city of Patras.

## 5.4 Water supply of the city of Heraklion

The city of Heraklion is the fourth largest city in Greece, and the largest in the island of Crete. It is the administrative centre of the island and of economic importance. Water transferred from the Aposselemis dam has given a solution to water shortage problems (Giakoumakis, 2013) which until recently have caused periodic water supply interruptions (Genius & Tsagarakis, 2006).

The Aposselemis dam is not located in the same RB as the city of Heraklion, nevertheless it is situated in the same RBD (administrative river basin).

## 5.5 Water supply of the city of Larissa

Larissa is the largest city in the Thessaly region of Greece and capital of the Thessaly region and the Larissa regional unit. It is located in the middle of the Thessalian Plain, which is the largest in Greece. It is major agricultural, commercial and industrial centre. Until the 1990s drinking water was provided by the Pinios River, but due to pollution problems afterwards water is being transferred from three major wellfields (Larissa Water Utility, http://www.deyal.gr/ydreusi/ydreysi.html).

## 5.6 Water supply of the urban area of Volos

Volos is a coastal port city in the central part of Greece (Thessaly region), and also an important industrial centre.

Nowadays drinking water for the city of Volos is provided from water wells inside and outside the city’s boundaries, where the outside water wells are located 20 km at the West, and also from 5 springs of the Pelion Mount located in the north of the city (Kolokytha and Mylopoulos, 2004; Volos Water Utility, http://www.deyamv.gr/m1.html).

In order to obtain sufficient water for the city inhabitants, water will be transferred from wells which are going to be drilled in the Karla lake basin (Volos Water Utility, http://www.deyamv.gr/m1.html). In order to ensure sustainability of water resources management strategies in the Karla Lake catchment a simulation model has been developed (Loukas, Mylopoulos, & Vasiliades, 2007).

To reduce losses caused by leaks part of the water supply network is being replaced. The goal of the Municipal Company is to reduce water losses from 40% to 25%.

## 5.7 Water supply of the urban area of Ioannina

The city of Ioannina is the capital of Epirus region, in north-western Greece.

It is located on the shore of the Pamvotis lake.

Water of excellent quality, from the springs of Krya (which are located about 8 km north of the city) is used for the supply of the city dwellers (Karakitsios, 2010). According to Karakitsios (2010), the springs of Krya have sufficient quantity of water to supply Ioannina for the next decades.

## 5.8 Water supply of the city of Trikala

The city of Trikala is located in the regional unit of Thessaly. It has been built on the banks of the Lithaios River, which is a tributary of the Pinios River.

The city of Trikala is supplied by 14 wells which are situated in its vicinity, most of them are located west of the city.

## 5.9 Water supply of the city of Chalkis

Chalkis is the largest city on the island of Euboea. It is situated on the Euripus Strait and is connected to the Greek mainland by a bridge.

Water for the dwellers of the city of Chalkis is being provided by water wells in the vicinity of the Paralimni Lake located in the mainland. Water being issued from Eria springs, which are located in the eastern part of Euboea Island, is also being used for the same purpose.

## 5.10 Water supply of the city of Serres

Serres is the second largest city in the Central Macedonia Region, after Thessaloniki, and it is the capital of Serres Regional Unit. The city is located in a fertile plain, northeast of the Strymonas River, and is built on the bank of one of its tributaries.

Drinking water for the dwellers of the city of Serres is mainly provided by wells situated in the plain of Serres. Several soaking pit tanks are positioned in this area, which form a health hazard for the inhabitants, so that measures for the protection of the inhabitants’ health should be undertaken (Special Secretariat for Water, 2013).

## 5.11 Water supply of the city of Alexandroupoli

Alexandroupoli is positioned in the East Macedonia and Thrace Region, near the Evros River and the Turkish border. It is the capital of the Evros regional unit and an important commercial center of northeastern Greece.

The drinking water for the city of Alexandroupoli is provided by the Dipotamos dam, situated in the catchment area of Loutros torrent (194 km2), a sub-basin of the Evros River (Vogiatzi, 2015). The water from the dam is transferred to the city of Alexandroupoli through a 36-km- long cast iron pipe of 600 mm diameter. The dam of Dipotamos serves also to the water supply of the city of Trainoupoli (Vogiatzi, 2015).

## 5.12 Water supply of the city of Xanthi

Xanthi is situated in North Eastern Greece and is the capital of the prefecture bearing the same name. The city lies on the banks of Kossynthos River.

Drinking water for the city of Xanthi is provided both by karst springs near the Nestos River at a distance of 16-km from the city and also by a wellfield which is situated inside the city borders, in the Drossero district. The former water springs are not located either in the same RB or administrative RBD. No measures are taken to protect the water extracted from the wells in Drossero. Small industries and soaking pits are situated near the wells, and also uncontrolled waste disposal takes place (Thomas, 2003). Papadopoulos et al. (2006) stated that microbial contamination of the wells in Drossero was possibly the cause of the gastroenteritis outbreak which was observed on January 28th, 2005.

## 5.13 Water supply of the city of Katerini

The city of Katerini is the capital of Pieria regional unit. It lies on a Plain between Mount Olympus and the Thermaikos Gulf.

The city of Katerini is being supplied with water from wells located in the vicinity of the city. Water management has to be carefully planned, because sea water intrusion problems may occur in the future due to the proximity of the aquifer to the sea.

## 5.14 Water supply of the city of Agrinio

Agrinio is the largest city of the Aetolia-Acarnania Regional Unit of Greece and is situated at a distance of approx. 275 km at the west of the city of Athens.

The water supply for the city of Agrinio is ensured by the Kastraki dam, which is built on the Acheloos River (Special Secretariat for Water, 2014). The dam is also being used to generate hydroelectric power.

## 5.15 Water supply of the city of Kalamata

The city of Kalamata is the second largest city in the Peloponnese peninsula.

Water for the supply of the city is being provided from the springs of Hagios Floros- Pidima (the mean flow-rate of the springs is 4.5 m3/s), which lay in the catchment area of the Pamisos River (728 km2), while Kalamata is located in the catchment area of the Nedas River (278 km2) (PEP, 2014). Nevertheless both the Pamisos River and the Nedas River are situated on the same administrative catchment area (RBD).

## 5.16 Water supply of the city of Kavala

The city of Kavala is situated in northern Greece, it is the principal seaport of eastern Macedonia and the capital of Kavala regional unit.

Water for the inhabitants of the city of Kavala is being provided by the spring of Voirani (mean flow-rate 1650 m3/h) and also from the Amissiana wellfield (mean flow-rate700 m3/h). Water flows by gravity from Voirani through a 16.3-km-long pipe to a pumping station near Amissiana, and is lifted subsequently to the city of Kavala (Galazoula, 2006). The Voirani spring is situated inside the catchment area of Strymonas River, but not in the same aquifer as the city of Kavala.

The water losses due to leaks of the pipe network are high, and may represent half the total flow-rate of the city of Kavala (Galazoula, 2006).

## 5.17 Water supply of the city of Chania

The city of Chania is situated on the north-west coast of the Crete Island and is its second largest city, and the capital of the Chania Perfecture.

The urban water demand of the city of Chania is covered by the Agia springs and several wellfields, including the wellfield of Miloniana (Kalaitzaki, 2010).

## 5.18 Water supply of the city of Lamia

The city of Lamia is the capital of the Regional unit of Sterea Ellada.

Water from the springs of the Gorgopotamos River, which is a tributary of the Sperchios River, is being transferred to the city of Lamia by a 10.4 km-long-pipe (Organisation for Greek Local Self-Governance, 2013).

## 5.19 Water supply of the city of Komotini

Komotini is situated in northeastern Greece in the region of East Macedonia and Thrace. The city has been built in the northern part of the plain bearing the same name, and it is a major agricultural center. The Vosvozis River flows through the city.

While during the wet period (approximately from October to May), water for the inhabitants of Komotini is supplied directly by the Vosvozis River, during the dry period (aprrox. from June to September) water is issued by a wellfield in the alluvial plain of the Vosvozis River, near the city of Komotini (Moutsopoulos, Gemitzi & Tsihrintzis, 2008).

## 5.20 Water supply of the city of Rhodes

The city of Rhodes,also known as Rodos, is the principal town of the Rhodes island. It is one of the most popular tourist destinations in Europe, so that tourism contributes heavily to the local economy.

Due to water problems induced by uncontrolled development, the Gadouras dam has been built in the centre of the island. Water from the dam is being transferred to the north of the city of Rhodes, at a distance of approx. 43.5 km (Manoli, Assimacopoulos, & Karavitis, 2004; Special Secretariat for Water, 2015).

# 6. Discussion

## 6.1 Implementation of the WFD for urban water management purposes

The river basin as management and planning unit has been used in Western Europe for over a century before it was incorporated in the WFD (Water Framework Directive) (Molle, 2009; see the Section ‘*The Water Framework Directive’* of this paper). Although some researchers state that this concept has reached its limits (e.g. Molle, 2009; Graefe, 2011), we think that regarding the urban water management it has to be taken into account, because several major cities in Western Europe lie in large catchment areas, so that most part of their water demand can be covered within their river basin limits. Furthermore there are strong interactions between urban water demand, water use for irrigation, energy production and industrial purposes, and also dam regulation for flood prevention purposes inside a single catchment, as has been presented in the Section *‘Urban water resources management in France, Spain and the United Kingdom’*.

On the contrary, we think that the above-mentioned concept is less adapted to Greece. Due to fragmentation the catchment area size is smaller than in Western Europe, as it is presented in Table 2 and discussed in a previous Section. Additionally urban development in Greece, unlike in France, the UK or Spain has not been linked to any rivers. Therefore, while the major cities in Western Europe are built on the banks of some of the largest rivers, this is not the case in Greece, as from the five largest cities only Larissa is located in the catchment area of one of the largest rivers (see Tables 2 and 3). Therefore, due to the small size of the catchment, the water demand of most of the major cities (e.g. Athens, Thessaloniki, Patras, Volos) cannot be satisfied within the limits of the river basin area in which they are situated. As it is presented in the same Table 3, interbasin water transfer is also necessary to satisfy the water demand of several smaller cities, like Chalkis, Xanthi, Kalamata and the city of Rhodes. Furthermore, there are no such pronounced interactions inside the same river basin in Greece between urban water demand and other uses, as in the case of France, Spain and the UK. Subsequently, there is no such a strong justification to impose the river basin as the planning unit.

Although the river basin as the planning unit seem not to be adapted to Greek urban water management, the applications of other guidelines of the WFD would be beneficial. These include requirements for the improvement of surface waters and the establishment of the wellhead protection zones around wells. As it has been presented in the previous section, the lack of wellhead protection in the city of Xanthi has possibly caused severe health problems.

## 6.2 Interbasin water transfer and the principles of integrated water management (IGWM)

As has been presented above, interbasin water transfer for urban water management purposes is inevitable in Greece. For this reason it should be compatible with the principles of integrated water management (IGWM). As it has been pointed out by Gupta and van der Zaag (2008) who reviewed several studies, two major points which should be considered (and are also relevant to urban water management) are whether water is used efficiently by the receptor, and whether alternative water resources in the recipient basin exist and are cost effective.

### 6.2.1 Efficient water use in Greek cities

The efficient use of water in urban centres involves both the reduction of losses due to leaks, and reduction of excessive consumption.

*6.2.1.1 Leakage reduction in water supply networks*. Kanakoudis, Gonelas, and Tolikas (2011), have stated that it is common in Greece that the water loss volumes caused by leakage are more than 50% of the System Input Volume. Reductions can be achieved by repair or replacement of trouble-causing parts of the network or by adequate pressure management. Examples of such water losses management strategies are provided by Kanakoudis and Tsitsifli (2010).

*6.2.1.2 Reduction of urban water consumption by price approaches*. As stated by Mylopoulos et al. (2003), a reduction in water consumption can be achieved by adequate pricing policy which would be also compatible to the WFD guidelines, and it has also been confirmed by a recent survey in the city of Volos (Mylopoulos, 2015).

### 6.2.2 Alternative water resources to interbasin transfer for the Greek cities

According to Rygaard et al. (2011), potential local water resources in urban centers, which offer alternatives to interbasin transfer, which mainly involve:

* Desalination
* Wastewater reuse
* Rainwater harvesting

*6.2.2.1 Desalination* Raw material for desalination is available for many Greek cities, because they have been built on (or near) the sea shore (e.g. Athens, Thessaloniki, Patras, Volos, Heraklion and Chalkis). Nevertheless the specific energy consumption for water desalination in Greece is large, ranging from 3.02 kWh/m3 to 9.38 kWh/m3 (Avlonitis, Kouroumbas, & Vlachakis, 2003), while similar data are reported by Kartalidis,Tzen, Kampragkou and Assimacopoulos (2015). Drinking water is being conveyed to urban centres mainly by gravity, so that typically the energy consumption is relatively low. For example in the city of Patras it is 0.44 kWh/m3 (L. Tsatsos, personal communication, December 29, 2015), while according to Kartalidis et al. (2015) the specific energy consumption in both Athens and Thessaloniki is lower than 2 kWh/m3. We believe that the findings presented above hold for other cities, due to favourable geographic conditions water is being transferred mainly by gravity, as it is the case in Heraklion, Chania, Kavala and Alexandroupoli. Subsequently the use of desalination is currently restricted to the Greek islands, where water resources are scarce (Kartalidis et al., 2015). Therefore, it is doubtful whether in the short term, desalination will offer a sustainable alternative to interbasin water transfer, considering that electricity in Greece is mainly produced by fossil fuels. Thus its use will increase CO2 emissions.

*6.2.2.2 Wastewater reuse*. The outlook for use of treated wastewater in Greek cities is neither particularly good. The use of treated wastewater as treated drinking water requires high operational costs, whereas it is questionable whether the public will accept this solution. To the best of our knowledge no studies on this problem are available in Greece.

*6.2.2.3 Rainwater harvesting*. Research efforts on rainwater harvesting in Greece are relatively sparse, but existing results are rather encouraging. Campaigns undertaken in the city of Xanthi by Melidis, Akratos, Tsihrintzis, and Trikilidou (2007) and also by Gikas and Tsihrintzis, (2012), indicate that rainwater collected by roof drainage can be used as grey water for domestic use.

Nevertheless more research is necessary in order to investigate the potential of rainwater harvesting in Greece. It is expected that this technique is rather adapted to smaller towns and to suburbs, than in urban centers where available space is scarce and atmospheric pollution may have adverse effects on rainwater quality.

# 7. Conclusions

A comprehensive description of water supply and management practices in Greek cities has been presented and it has been demonstrated that the principle which is suggested by the WFD, that the RB should be the unit for water resources management is not adequate for urban water resources planning in Greece.

We want to point out that both the motivation and the features of statutory planning, which is being widely used for urban planning purposes, and consists of “*setting clear and enforceable rules*” (Albrechts, 2017a), are very similar to the motivation and the features of imposing the RB as the planning unit for water resources planning purposes (see Molle, 2009 and also the analysis presented in Chapter 2 of this study). The two approaches lead also to a rather rigid planning framework, and therefore have been criticized (Molle, 2009; Albrechts, 2017a, b), since nowadays processes are characterized by growing complexity and are rather dynamic.

We want to further point out, that our findings question the principle of choosing the RB as the planning unit (an approach which is compatible to the statutory planning approach), are also valid for other Eastern Mediterranean countries. In fact, several cities in this part of the world have water supply characteristics similar those of Greek cities, because, unlike in Western Europe, there is a weak or non-existent interdependence between urban development and the rivers features. Subsequently, the size and the water volume of the catchment area inside which most major cities in Eastern Mediterranean are built, is not sufficient to cover their needs.

A characteristic example is the megacity of Istanbul (former Constantinople), the largest city in Eastern Mediterranean, which has been built on the Bosporus straits, due to their strategic significance, rather than on a major river. To satisfy the urban water demand of Istanbul large volumes of water are being transferred from rivers in adjacent catchments (Islar & Boda, 2014).

Interbasin transfer is also necessary for meeting the water supply needs of Ankara in Turkey (Islar & Boda, 2014), and of Nicosia, the capital of Cyprus (Iacovides, 2011).

Correspondingly, to meet the acute water needs (which include domestic use), in Palestine water is being conveyed from the Red and the Dead Sea. Part of the water demand in Israel is also covered from water which is being conveyed from water sources not laying inside the RB, while desalination also plays an important role.

Inter-basin transfer to satisfy urban water demand is also necessary in other parts of the world, except in Eastern Mediterranean countries, namely in RBs in which the population density is high, but rainfall is low and water resources are scarce. Such examples are Lima, Peru and Quito, Ecuador (Vergara et al. 2007, Buytaert & De Bièvre, 2012). Nevertheless it is beyond the scope of this article to analyze these cases further.

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Figure 1 Presentation of the Greek Water Districts and their dependencies (modified from Greek Special Secretariat for Water, http://wfd.ypeka.gr).

**Table 1**. River basin characteristics of the river basins in which some of the major cities in France, Spain and the UK are located.

|  |  |  |
| --- | --- | --- |
| **CITY** | **RIVER** | **SURFACE OF THE CATCHMENT AREA (km2)** |
| London (UK) | The Thames | 16,133 |
| Paris (France) | La Seine | 78,650 |
| Madrid (Spain) | Tagus | 80,100 |
| Lisbon (Portugal) |
| Lyon (France) | Le Rhône | 95,500 |
| Toulouse (France) | La Garonne  | 55,846 |
| Barcelona (Spain) | Llobregat | 4,948 |

**TABLE 2.** Characteristics of the major Greek rivers

|  |  |  |  |
| --- | --- | --- | --- |
| **River** | **Surface of the catchment area [km2]** | **Water District (WD)** | **Major cities located in the river basin of the catchment area (In parenthesis is provided the number of inhabitants)** |
| Evros | 53,000  | Thrace | Alexandroupoli (57,812) |
| Axios | 22,250 | Central Macedonia | (-) |
| Strymonas | 17,150 | Eastern Macedonia | Serres (58,287), Kavala (54,027) |
| Pinios | 9,500 | Thessaly | Larissa (144,651), Trikala (61,653) |
| Aliakmon | 6016 | Central Macedonia | (-) |
| Acheloos | 5,572 | Western Sterea Ellada | Agrinio (55,097) |
| Nestos | 5479  | Thrace | (-) |
| Alfios | 3,810 | Western Peloponnese | (-) |
| Arachtos | 2,000 | Epirus | (-) |
| Sperchios | 1,900.72 | (Eastern Sterea Ellada | Lamia (52,006) |

Ο ΠΙΝΑΚΑΣ 3 ΠΕΡΙΕΧΕΤΑΙ ΣΕ ΧΩΡΙΣΤΟ ΑΡΧΕΙΟ