Urban Wastewater Treatment in Greece

Although Greece has accomplished the wastewater infrastructure construction in a large extent, as 91% of the country's population is already connected to urban wastewater treatment plants (WWTPs), many problems still need to be faced, such as the limited reuse of treated wastewater and of the surplus sludge (biosolids) produced, the relative higher energy consumption in the existing rather aged WWTPs infrastructure and the proper management of failing or inadequately designed septic tank/soil absorption systems, still in use in several (mostly rural) areas, lacking sewerage systems. Moreover, the wastewater treatment sector should be examined in the general framework of sustainable environmental development; therefore, Greece's future challenges in this sector ought to be reconsidered. Thus, the review of Greece's urban wastewater history, even from the ancient times, up to current developments and trends, will be shortly addressed. Noting also that the remaining challenges should be analyzed in respect to the country's specific needs (e.g. interaction with the extensive tourism sector), as well as to the European Union's relevant framework policies and to the respective international technological trends, aiming to consider the wastewater treatment plants (WWTPs) not only as sites for the treatment/removal of pollutants to prevent environmental pollution, but also as industrial places where energy is efficiently used (or even produced), resources' content can be potentially recovered and reused (e.g. nutrients, treated water, biosolids) and the environmental sustainability is being overall practiced.

1. Introduction

Greece is located in the southern end of the Balkan Peninsula, bordering the Ionian, Aegean, and the Mediterranean Seas. The country has a total area of 131,940 km^2 with a population of (around) 11 million, according to the last official census of 2011. Greece consists of a large mainland and extensive archipelagos of around 3000 islands, has almost 18,000 km of coastline and is 80% mountainous with the highest peak of 2919 m in Olympus[1].

The climate in Greece is predominantly classical Mediterranean (mild, wet winters and hot, dry summers). However, due to the country's geography, a range of micro-climates and local variations can be found[2]. Annual rainfall ranges from 300 to 500 mm in southeastern Greece and from 800 to 1200 mm in the northwestern parts of the mainland, but may exceed 2000 mm in some mountainous areas. Greece is expected to have an 18% precipitation decrease by midcentury, and 22% by the end of the century. Considering an expected modest population decline, Greece's per capita water resources are also expected to decline by midcentury[3][4]. These perspectives are likely to necessitate the implication of appropriate changes to Greece's water resources management and, consequently, changes to the respective ways urban wastewater management is commonly practiced.

Even though Greece is among the very few ancient civilizations, where hygienic technologies and wastewater management were practiced as early as 400 BC[5], the wastewater management history of the country has followed similar development paths as to other nations in Europe, namely Britain, France, and Germany, i.e., for centuries wastewater management was not given much, if any, attention[6]. Although in some ancient cities there were existing sewerage systems, wastewaters were usually disposed of in the streets and near the city centers, creating serious impacts on public health and the environment. The industrialization and urbanization during the second half of the 19th century shifted interest towards better wastewater management practices, while the development of the wastewater management in Greece began around the early 1980s, when the country entered the European Union (EU) and as a member state had to comply with the respective EU policies for proper urban wastewater treatment and thus, created its first urban wastewater treatment plants (WWTPs)[7].

Today, Greece's urban wastewater sector presents significant achievements, but also failures, as well as numerous future challenges. Even though the understanding of the various wastewater treatment processes is important, it is not within this paper's intentions to provide here the in-depth explanations, which can be found elsewhere. This mini-review intends to highlight the major aspects of Greece's urban wastewater treatment history, its recent developments, and present

situation, as well as to identify the remaining challenges, in respect to the country's specifications, regarding the European Union's policies and the international technological trends, so as WWTPs to be seen not only as sites for the treatment/removal of pollutants, but also as "industrial" places, where energy can be efficiently used (and produced), and new products (recovery of resources' content) and business opportunities would be created.

We believe the readership of the Journal's Special Issue would be interested in this mini-review, as it highlights not only municipal wastewater management of a particular country, but addresses a country's own wastewater management path in respect to the global thinking of sustainable environmental development.

2. The Past of Urban Wastewater Treatment in Greece

2.1. Historical Development

Historical findings in palaces and cities on the island of Crete, as well as in other Aegean Islands, declare the presence of quite sophisticated sewage systems since the early Minoan civilization, which is considered as Europe's first advanced civilization, flourishing from 2700 to 1450 BC[5]. Sewage systems were found also in residencies in Delos Island (as early as 400 BC) and later, around 300 BC, in the ancient Pella, a city located in northern Greece, best known as the historical capital of the ancient Macedonian kingdom. However, during the same ancient times, open combined sewerage networks of wastewater and storm waters run-off were found also in several other ancient cities, causing quite frequent dispersion of serious water-borne diseases, such as cholera, plague, etc.[8].

This practice has continued for almost the next 15 centuries, before being replaced by the use of absorbing septic tanks. After saturation of the septic tank, either a new tank was built nearby, or the waste was collected and discharged untreated into open streams or into the sea. Athens, the present capital of Greece, was first declared the capital of the newly established Greek State on September 18, 1834. Six years later, the first combined flow sewerage system for the collection of both wastewaters and storm waters run-off was constructed for the first time in the modern history of Greece, noting, however, that Athens at that time was a small city with only 7000 residents.

During the years 1834–1980, the sewerage infrastructure was progressively enlarged in scale. Already in 1950, the preliminary design of the Athens Sewerage System began covering an area of around 200,000 hectares. This design was used as the basis for the development of the city's networks during the 1960s and 1970s. During the same period, similar infrastructures were built also in other large cities of Greece, e.g., in Thessaloniki (the 2nd largest city of Greece), where the first combined sewer overflow pipe was built in 1938, while the basis for the present sewerage system network was set up in 1977[9].

Entering into the 1980s, the situation started to improve, as Greece joined the EU in 1981. The issue of the treatment of the collected sewage that up to this point was discharged without any treatment to nearby streams, rivers, or to the sea, started to gain particular attention.

2.2. Development over the Past 40 Years

As a member state of the EU, Greece had to comply with the respective EU policies for wastewater treatment. The development of urban WWTPs followed the developments of the relevant EU directives, as well as the available funding from various EU framework programs. Thus, the first modern WWTPs in Greece started their operation around the beginning of 1990s, as a consequence of the respective EU Directive 91/271/EEC[10] "on urban wastewater treatment and disposal" and its amendments, defined by the subsequent Directive 98/15/EEC[11].

The wastewater treatment plant of Thessaloniki started to fully operate in 1992. This plant is situated 7 km southwest of the city, currently serving about 1 million residents of the greater Metropolitan area, by treating daily around 160,000 m^3 with the schedule future capacity (after extension) to be able to treat around 300,000 m^3/day. The treatment process includes screening, grid removal, primary sedimentation (without use of chemical coagulants), conventional activated sludge treatment with nitrogen removal, and effluent disinfection using chlorine gas (Cl_2). The treated effluent is mainly discharged to the nearby Thermaikos gulf, which is characterized as a sensitive area. However, some efforts of effluent reuse in irrigation were started for the first time in Greece in 1993. Approximately 2225 m^3/year of WWTP effluent is being regularly reused, after mixing with freshwater from the nearby Axios River at 1:5 ratio irrigating approximately 2500 ha of spring crops in the nearby Halastra-Kalohori agricultural area[12]. Sewage sludge (i.e., the primary plus the excess activated) is anaerobically digested, thickened, and dewatered and dried (succeeding substantial volume reduction). The greatest amount of this sludge was deposited in an urban landfill, until few years ago when this practice was prohibited, and currently, this is being commonly used as soil amendment after the appropriate control[7].

▌3. Recent Developments and Current Situation

Today, Greece has a population of approximately 11 million inhabitants, according to the last official census of 2011. The main management model for water and wastewater services in Greece is delegated public management, although more recently some public-private management schemes have been also started to be implemented. In the two biggest cities of Greece (Athens and Thessaloniki), the Greek state delegated two public companies (by a majority) named E.YD.A.P for Athens and E.Y.A.TH. for Thessaloniki. These companies have been listed also in the Greek stock market already for more than 15 years and the Greek state is the main shareholder and, therefore, the President of the Board of Directors and the CEO of both companies are appointed by the government. For cities with more than 10,000 inhabitants, the national law regulating the role and the foundation of Municipal Water and Sewerage Companies was published in 1980. Currently, there are 130 municipality-owned companies, named D.E.Y.A. In cities with fewer than 10,000 inhabitants, the management model is usually the direct urbanity public management[13].

According to article 17 of the Urban Wastewater Treatment Directive 91/271/EEC[10], each member state has to prepare every two years the respective Implementation Report, describing the collection, treatment, and disposal of the relevant wastewater data. Based on the most recent report of 2017, which refers to the year 2014, 91% of the country's population is connected to 254 urban wastewater treatment plants, treating almost 1.74×10^6 m^3/day. These plants provide secondary biological treatment, with 83% providing biological nitrogen removal, 57% providing (additionally) biological phosphorus removal, and 93% providing (tertiary) wastewater disinfection[14].

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