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# Planned industrial estates under law 2545/97: an empirical analysis of wastewater treatment systems

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**ABSTRACT**

This paper refers generally to the Planned Industrial Estates (PIEs) established under Greek Law 2545/97. A number of key features of PIEs are discussed here, including the prefectures in which the estates are established, the Greek Official Gazettes in which the establishment acts were published, the surface area in acres to be covered by the estates, the years of completion of the infrastructure, and the numbers of established businesses involved. The paper also refers to the infrastructure that should exist in a PIE and, in particular, to the wastewater collection network and the wastewater treatment plants (WTPs). The key features of the wastewater treatment systems of all Planned Industrial Estates in Greece established under Law 2545/97 (14 case studies) are presented in the form of a table and are analysed using economical, environmental, and operational criteria. The analysis shows that for the small Planned Industrial Estates (i.e., industrial parks—IPs—and light industry parks—LIPs), it is economically, environmentally, and operationally preferable for industrial wastewater to be disposed of into large operating municipal wastewater treatment plants, rather than into decentralised systems within IPs and LIPs, given that the municipal plants have excess capacity, are at a relatively small distance from the PIEs, and are compatible with the required treatment. The analysis highlights the need to initiate an integrated techno-economic study in view of the new Operational Programme, "Competitiveness and Entrepreneurship", of the Greek Ministry of Economy for the period from 2007 to 2013, which was co-financed by the European Union, and will include actions related to the development of new PIEs.

*Keywords:* Industrial wastewater; Wastewater treatment systems; Law 2545/97; Industrial park (IP); Light industry park (LIP)

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## 1. Introduction

### 1.1. Planned Industrial Estates under Law 2545/97

Over the years, the definition of Planned Industrial Estates (PIEs) has changed somewhat. However, the following definition summarises the key features of PIEs [1]:

"A Planned Industrial Estate (PIE) is an estate that is acquired by a Development Institution, organised under a town plan, provided with the necessary infrastructure networks, and available in the form of plots for the establishment of industrial businesses, which are additionally provided with different services and incentives."

The establishment of PIEs in Greece was initiated in 1962 by the Industrial Development Organisation (OBA), which was merged for this purpose in 1964 with two other financial institutions to found the Hellenic Industrial Development Bank (ETBA) – a governmental organisation.

The legal framework under which the first 35 PIEs were founded in Greece by the ETBA was Law 4458/65, "Industrial Districts" (Official Gazette 33/A/27-2-65), which was subsequently amended and supplemented by Law 742/77. This Law was replaced in 1997 by Law 2545/97, "Industrial and Business Estates" (Official Gazette 254/A/15-12-97). The main differences between Law 2545/97 and Law 4458/65 are as follows:

- Instead of Industrial Districts, Industrial and Business Estates were established, which are divided into the following categories: industrial districts (ID), industrial parks (IP), light industry parks (LIP) and Technopolises (TECHN). Later, two other categories of Industrial and Business Estates were institutionalised.

The main characteristics and differences between the categories of Industrial and Business Estates are presented in Table 1.

The categorisation of industrial and business estates in other countries can be different and can be categorised by distinctive functions or design characteristics, product types or their tenants. In the United States, these estates are categorised as follows (Table 2):

- The exclusive right of the governmental institution, ETBA, to establish and operate PIEs was abolished. Today, such estates can be established either by various governmental institutions, private entities or combinations of the two (public sector plus private sector), but the establishing institution must have the form of a public limited company.

Under the institutional framework of Law 2545/97, 14 PIEs have been built to date, while 5 (LIP of Ormenio, LIP of Litohoro, TECHN Acropolis, IP of Farkadona, and LIP of Ptolemaida) have been established but, for various reasons, have not yet been built.

The Planned Industrial Estates established under Law 2545/97 and their key features are presented in Table 3. The classification is arranged in chronological order.

Note that the country's total number of Planned Industrial Estates is 54.

### 1.2. Infrastructure of the Planned Industrial Estates

The above-mentioned Laws—4458/65, 742/77 and 2545/97—place great emphasis on the communal technical infrastructure in Planned Industrial Estates. This infrastructure strongly affects the proper operation

Table 1
Main characteristics and differences between the categories of Industrial and Business Estates according to Law 2545/97

| | Category of estate | Allowed industrial activities[a] |
|---|---|---|
| 1 | Industrial district | Up to high-impact industry |
| 2 | Industrial park | Up to medium-impact industry |
| 3 | Light industry park | Only low-impact industry |
| 4 | Technopolis | High-technology activities |

[a]According Decision No. 13727/724/2003 of the Ministry of Environment (Official Gazette 1087/B/5-8-03), the environmental category that an activity falls into (high, medium or low impact), is a reflection of the production capacity and the degree of potential off-site environmental impacts generated by the activity.

Table 2
Main characteristics and differences between the categories of industrial and business estates in the U.S., according to [2]

| o. n. | Category of estate | Allowed activities |
|---|---|---|
| 1 | Industrial park | Large-scale manufacturing and warehouse facilities |
| 2 | Warehouse/ distribution park | Large storage facilities |
| 3 | Logistics park | Logistics and processingfacilities, showrooms |
| 4 | Research park | Wet and dry labs, offices, light manufacturing |
| 5 | Technology park | High-tech companies |
| 6 | Incubator park | Small start-up businesses |
| 7 | Corporate park | Research labs, light manufacturing, shopping centres |

Table 3
Key features of the Planned Industrial Estates that were established under Law 2545/97 [3]

| o.n. | Name of the Planned Industrial Estate | Prefecture | Greek Official Gazette with the establishment act | Surface area (in acres) | Year of completion | No. of establ. busin.[a] |
|---|---|---|---|---|---|---|
| 1 | LIP of Thesprotia | Thesprotia | 304/B/5-4-99 | 120 | 2009 | 8 |
| 2 | LIP of Rethimno | Rethimno | 304/B/5-4-99 | 285 | 2009 | – |
| 3 | LIP of Ag.Nikolaos | Lasithi | 977/B/26-5-99 | 250 | 2009 | – |
| 4 | LIP of Kozani | Kozani | 1635/B/20-8-99 | 55 | 2007 | – |
| 5 | LIP of Anopoli | Iraklio | 1919/B/25-10-99 | 71 | 2007 | 15 |
| 6 | LIP of Zervohoria | Halkidiki | 449/B/4-4-00 | 106 | 2009 | 3 |
| 7 | IP of Thessaloniki | Thessaloniki | 462/B/5-4-00 | 1,022 | 2009 | 2 |
| 8 | LIP of Keratea | Attiki | 695/B/3-6-03 | 1,100 | 2009 | 15 |
| 9 | IP of Koufalia | Thessaloniki | 695/B/3-6-03 | 113 | 2009 | 2 |
| 10 | TECHN of Thessaloniki | Thessaloniki | 430/B/2-3-04 | 94 | 2009 | 2 |
| 11 | LIP of Serres | Serres | 1110/B/5-8-05 | 122 | 2009 | – |
| 12 | IP of Kastoria | Kastoria | 1465/B/24-10-05 | 302 | 2009 | – |
| 13 | LIP of Kavala | Kavala | 1466/B/24-10-05 | 130 | 2009 | – |
| 14 | LIP of Patra | Ahaia | 1857/B/29-12-05 | 596 | 2009 | 35[b] |
| 15 | LIP of Ormenio | Evros | 449/B/4-4-00 | 632 | – | – |
| 16 | LIP of Litohoro | Pieria | 1431/B/14-11-02 | 1,005 | – | – |
| 17 | TECHN Acropolis | Attiki | 1848/B/13-12-04 | 225 | – | – |
| 18 | IP of Farkadona | Trikala | 255/B/25-2-05 | 902 | – | – |
| 19 | LIP Ptolemaida | Kozani | 1464/B/24-10-05 | 505 | – | – |

[a]The number of established businesses refers to those established as of 2009.
[b]The 35 businesses listed for the LIP of Patra were settled there before the establishment of the Planned Industrial Estate.

of the established in PIE businesses and is one of the attractions for businesses to become established in a PIE. According to article 17 of Law 2545/97, the technical infrastructure of a PIE includes the following: roads, sewerage drainage networks, surface water drainage networks, water supply systems and networks, wastewater treatment plants, road lighting, telecommunication networks, building infrastructure, different electromechanical facilities, electricity supply networks, fire networks, gas networks, railways, port infrastructure and, generally, every type of infrastructure required for communal services of PIEs.

The current legislation does not define the minimum technical infrastructure that must be included in a PIE. However the experience gained by the Directorate of Industrial Location and Environment of the General Secretariat of Industry from the implementation of such projects shows that the minimum technical infrastructure of a PIE should include the following: roads, sewerage drainage networks, surface water drainage networks, water supply systems and networks, wastewater treatment plants (inside or outside the PIE), road lighting, and building infrastructure.

Among the aforementioned elements of technical infrastructure, wastewater treatment plants play a critical role because they serve one of the main purposes of creating the PIEs, which is the protection of the environment from industrial activities.

### *1.3. Brief literature review of Planned Industrial Estates' WTPs*

Decentralised, on-site common wastewater treatment systems have been generally accepted as a solution for the collecting, conveying, treating, and disposing of wastewater from Planned Industrial Estates [4–6].

However, some references discourage the installation of on-site common wastewater treatment systems for Planned Industrial Estates for different reasons and encourage the use of municipal or regional wastewater treatment facilities. Use of these facilities can occur either when a local jurisdiction gives the responsibility for the sewerage maintenance and sewage disposal to local water authorities, as, for example, in England and Wales, or because the treatment and disposal of wastewater on-site by a common wastewater treatment system may create various problems [2,7].

Industrial wastewater from high-tech and other high-impact activities that are different from those affecting residential wastewater must be pre-treated on site by the tenant prior to normal treatment at the municipal or decentralised on-site, common wastewater treatment plant [7]. Labour costs account for the majority of operating costs, while electricity and the cost of chemicals are relatively minor. Generally, according to ref. [8], the operating cost per $m^3$ of flow decreases when the nominal flow increases. According to ref. [9], the total operating cost of WTPs in Greece is essentially lower than in the U.S. (by up to 70%).

## 2. Wastewater treatment systems in Planned Industrial Estates

### *2.1. General remarks*

During the operation of a PIE, two main types of liquid waste are generated: residential type sewage generated in sanitary installations of businesses (toilets, canteens, etc.) and industrial wastewater generated during the construction of businesses. The treatment of the first type of waste requires the implementation of biological methods, similar to those used for residential sewage. In treating the second type of waste, two methods can be implemented: if the wastewater comes from businesses processing agricultural products, then the aforementioned biological methods can be implemented; if, however, the wastewater comes from high-tech and other businesses with high environmental impacts, then combined biological and chemical methods can be implemented.

The wastewater treatment systems of PIEs can be used for all of these waste streams [4–6]. Biological treatment usually works in aerobic conditions. In any case, the operator of the PIE, using the proper regulations, defines the standards that have to be met by the wastewater from businesses to the communal wastewater treatment systems of the PIE. These standards define the physicochemical and biological characteristics of the waste and may include the banning of certain substances from the waste, such as fluids with a flashpoint ≤25°C, liquids with pH <6.0 or pH >9.5, and other parameters.

A major problem for the operation of the decentralised wastewater treatment systems of PIEs is finding the proper receiving body of water for the wastewater treatment system's final effluent. Usually, this effluent is discharged into surface recipients such as the sea, a creek or a river. However, if a surface recipient is not available, the establishment and operation of a decentralised wastewater treatment system of a PIE is not possible, and the wastewater of the PIE must be discharged for processing into the wastewater treatment system of the nearest municipality, provided that the municipalities facility has available capacity and treatment compatibility to accept it. In small PIEs, the final effluent may be discharged on land through a disposal field [4].

In relation to the wastewater treatment systems of municipalities, the on-site decentralised wastewater treatment systems of PIEs have another major problem. Operation for an extended time—in some cases, for several years after their establishment—at low capacity, due to the gradual occupancy of PIE with businesses, can cause environmental and operational problems. Such problems are usually solved through the installation of an additional balancing reservoir at the entrance of the WTP with a capacity capable of ensuring a sufficient flow into the WTP during the slow period or through the disposal of the industrial wastewater during the slow period to a WTP outside the PIE using tanker trucks. These problems can also be solved by using modular WTPs.

To solve these problems for its PIEs, ETBA used multi-function reservoirs (a form of the above-mentioned modularity). With this technique, some of reservoirs of the WTP during the period of low wastewater flow are not used at all, while others are used for a function other than the one they were designed for at full-load operation of the WTP. Thus, during the period of the low wastewater flow, the WTP has substantially lower capacity than that for which it was designed.

### *2.2. Analysis of wastewater treatment systems of PIEs under Law 2545/97*

Table 4 presents the key features of the wastewater treatment systems of all 14 PIEs established under Law 2545/97. As the table shows, 5 out of 14 PIEs have decentralised WTPs, while the remaining 9 discharge their wastewater to the WTP of the nearest municipality.

Most of the five PIEs with decentralised on-site WTPs have a balancing reservoir at the entrance to the unit with enough capacity to ensure a sufficient flow into the WTP during the period of operation at reduced load.

For three of the PIEs, the final effluent is planned to be discharged on land through a disposal field, while for the other two, the final effluent is planned to be discharged into surface recipients (the sea in the region of the Thermaikos Gulf and the Axios River).

Of the nine PIEs that discharge their wastewater to the WTP of the nearest municipality, two have a pre-treatment plant on site.

According to the files of the Ministry of Economy (2010), the system operating cost in the case of discharge to the municipal WTP ranges from 0.23 to 0.87 €/$m^3$ of wastewater. There are noticeable differences in operating costs between PIEs.

Table 4
Key features of the wastewater treatment systems of PIEs established under Law 2545/97 (Files of the Ministry of Economy 2010)

| o. n. | Name of the Planned Industrial Estate | Treatment in a decentralised WTP | | | Treatment in a municipality's WTP | | Nominal wastewater flow[a] ($m^3$/day) | Estimated operating cost of the system[b] (€/$m^3$ wastewater) |
|---|---|---|---|---|---|---|---|---|
| | | | Method of the final effluent discharge | | | On site pre-treatment plant | | |
| | | | Disposal field (acres) | Surface recipient | | | | |
| 1 | LIP of Thesprotia | Yes | 11 | – | No | – | 50 | 2.73 |
| 2 | LIP of Rethimno | No | – | – | Yes | YES | 500 | 1.68[c] |
| 3 | LIP of Ag.Nikolaos | No | – | – | Yes | YES | 300 | 1.74[c] |
| 4 | LIP of Kozani | No | – | – | Yes | – | 30 | 0.62 |
| 5 | LIP of Anopoli | Yes | 3.5 | – | No | – | 25 | –[d] |
| 6 | LIP of Zervohoria | Yes | 30 | – | No | – | 60 | –[e] |
| 7 | IP of Thessaloniki | Yes | – | Thermaikos Gulf | No | – | 640 | 0.51 |
| 8 | LIP of Keratea | No | – | – | Yes | – | 360 | 0.29 |
| 9 | IP of Koufalia | Yes | – | Axios River | No | – | 139 | 2.36 |
| 10 | TECHN of Thessaloniki | No | – | – | Yes | – | 178 | 0.75 |
| 11 | LIP of Serres | No | – | – | Yes | – | 780 | 0.65 |
| 12 | IP of Kastoria | No | – | – | Yes | – | 600 | 0.61 |
| 13 | LIP of Kavala | No | – | – | Yes | – | 490 | 0.23 |
| 14 | LIP of Patra | No | – | – | Yes | – | 86 | 0.87 |

[a]The nominal wastewater flows were obtained from existing studies and questionnaires sent to the PIEs' establishing institutions.
[b]The estimated operating costs of the systems were obtained from questionnaires sent to the PIEs' establishing institutions and are based on 100% occupancy of a PIE by businesses.
[c]In the LIPs of Rethimno and of Ag.Nikolaos, the operating costs include operating costs of the pre-treatment plant and the costs paid to the municipality.
[d]The cost obtained for the LIP of Anopoli is not comparable with those of other PIEs because LIP's WTP is a compact type (needs low maintenance) and therefore is not included in the table.
[e]The cost obtained for the LIP of Zervohoria was based on the operation of WTP in its current (low) occupancy of the PIE and therefore was not included in the table because it is not comparable to those of other PIEs.

In the case of on-site decentralised wastewater systems, the cost reached 2.73 €/$m^3$.

The operating costs of two PIEs (the LIP of Ag.Nikolaos and the LIP of Rethimno) with pre-treatment plants on site from which the final effluent is discharged to the WTP of the nearest municipality, are 1.74 and 1.68 €/$m^3$, respectively. In these cases, the cost rates are between the operating costs of discharging wastewater to the WTP of the nearest municipality and the operating costs of decentralised on-site wastewater treatment plants.

According to the files of the Ministry of Economy (2010) for the IP of Thessaloniki's decentralised on-site wastewater treatment plant, the rates of the components of total operating cost are 24.8% for electricity, 20.3% for chemicals and 54.9% for labour, as shown in Fig. 1. These results are similar to those obtained by the research of [9].

Odours around an operating WTP may indicate a malfunctioning of the plant. These odours usually result from anaerobic conditions in WTP. However, spot checks conducted recently on the IP of Thessaloniki, which was established under Law 2545/97 in the area of an older paper industry (MEL) and which is operating at a low capacity, detected a significant odour coming from the wastewater treatment plant.

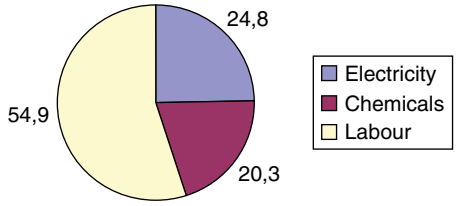


Fig. 1. Rates of the components of total operating cost for the IP of Thessaloniki's WTP (files of the Ministry of Economy 2010).

### 2.3. Results

The operating costs of a WTP with regard to discharge to the municipality WTP is relatively low, apparently because of the economies of scale that are created. The differences in costs among PIEs in this regard are the result of different pricing policies being pursued by each municipality. No relationship was found between the operating cost and the total flow (in $m^3$/day) of wastewater in the PIE.

In the case of on-site, decentralised wastewater systems, the cost appears to be higher. In this case, however, there appears to be an inversely proportional relationship between the operating cost and the total flow of wastewater in the PIE; the operating cost reduces with the growth of the nominal total flow (LIP of Thesprotia—total flow 50 $m^3$/day, operating cost of 2.73 €/$m^3$ versus IP of Thessaloniki—total flow 640 $m^3$/day, operating cost of 0.51 €/$m^3$). A similar conclusion emerges from the survey of ref. [8].

For PIEs with pre-treatment plants and final disposal to a municipal WTP, the operating cost is slightly higher than those with direct discharge to a municipal WTP because of the additional operating costs of pretreatment plants.

The odours detected in the IP of Thessaloniki probably originate from impairment of the wastewater treatment plant.

## 3. Conclusions

The above analysis of decentralised wastewater treatment systems in Planned Industrial Estates under Law 2545/97 shows that for those systems, financial, environmental, and operational issues can be raised.

Regarding financial viability, the operational cost in €/$m^3$ of wastewater in cases of decentralised wastewater treatment plants is higher than that of treatment in WTPs owned by municipalities.

With regard to environmental and operational issues, for decentralised wastewater treatment systems, operation at a low-capacity rate for a long time—several years, in some cases—after their establishment can cause environmental and operational problems.

The analysis shows that it is financially, environmentally, and operationally preferable for wastewater—mainly from small PIEs (IPs and LIPs)—to be disposed into large operating wastewater treatment systems owned by municipalities rather than into on-site decentralised wastewater treatment systems, provided that the municipal WTPs have available capacity and treatment compatibility to accept it.

Additional research on these issues may aid in the search for new technological solutions to ensure sustainable management of wastewater [10].

This report shows the need to initiate an integrated economic and technical study on the development of new PIEs in view of the impending launch of the programs of the National Strategic Reference Framework (NSRF).

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