Chapter 2: Introducing the Case Study, the Asopos River Basin in Greece.

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Abstract The case study area is presented in this chapter. The study area comprises the river and estuary of Asopos and the lagoon of Oropos northeast of Attica. Along the Asopos river human activities, mainly agriculture and industrial take place. Industrial and agricultural effluents pollute the river, the aquifers and the soils of the area, making it a negative example of the impacts to humans and environment that arise from non sustainable use of natural resources. The chapter starts by presenting the geographical distribution of the river system and the water bodies of the catchment. The chapter presents also a review of the related legislation that has contributed to its current situation. Then the current water status of the catchment is described, while the pressures and related impacts in the catchment are examined. Afterwards the focus is on the social and environmental functions and values of Asopos River and Oropos Lagoon. Identifying the main social, economic and environmental impacts of degradation in the area provides the background for the analysis that follows in the subsequent chapters.

Keywords Asopos River Basin, Oropos Lagoon, Institutional framework, Water quality, Waste waters

1. Presentation of the Asopos River Basin

Asopos RB is part of the Water District (07) of East Sterea Ellada (Figure 1). As it has been reported in MoEPPW (2006, p.81): "Water District (07) of East Sterea Ellada occupies a total area of 12.341 km^2 and consists of the Prefecture of Evoia, major parts of the Prefectures of Fthiotida (83.1%), Voiotia (98.5%) and Fokida (41.9%) and smaller parts of the Prefectures of Magnisia (14.9%) and Attica (7.2%). The main river basins of Water District (07) are: River basin of Voiotikos Kifissos River, River basin of Sperchios River and River basin of Asopos River. Furthermore lakes Iliki and Paralimni are significant water bodies located in the Water District (07)."

Figure 1: Water District (07) - East Sterea Ellada
(Source: MoEPPW, 2006)

Asopos RB covers a total surface area of 450 km^2 (East Attica and Viotia Districts), and extends to Evoikos Gulf. Its sources are in Elikona but along its flow other streams from the mountains of Parnitha and Dervenochoria also contribute. Asopos has a total length of 57 km and flows through Asopia, the plain of Thiva, Oinofita, Schimatari, Sikamino and Oropo and it finally reaches North Evoikos Gulf. River's annual runoff is 70 hm^3. Figure 2 shows the distribution of Asopos RB highlighted in blue. A population of approximately 70.575 citizens is residing in the broad river area, which constitutes the largest industrial area in Greece, situated only 60 km north of Athens.

Administratively in that particular RB there are eleven Towns/Municipalities which belong in two prefectures, that of Viotia and Attiki. These eleven Towns/Municipalities are the following: Plataion, Thivon, Tanagras, Dervenochorion, Oinofiton, Schimatariou, Avlona, Oropion, Erithron, Malakasas and Sikaminou. The last five Towns/Municipalities are a part of Attiki Prefecture while the rest form part of Viotia Prefecture. The included Towns/Municipalities are highlighted in pink in Figure 2.

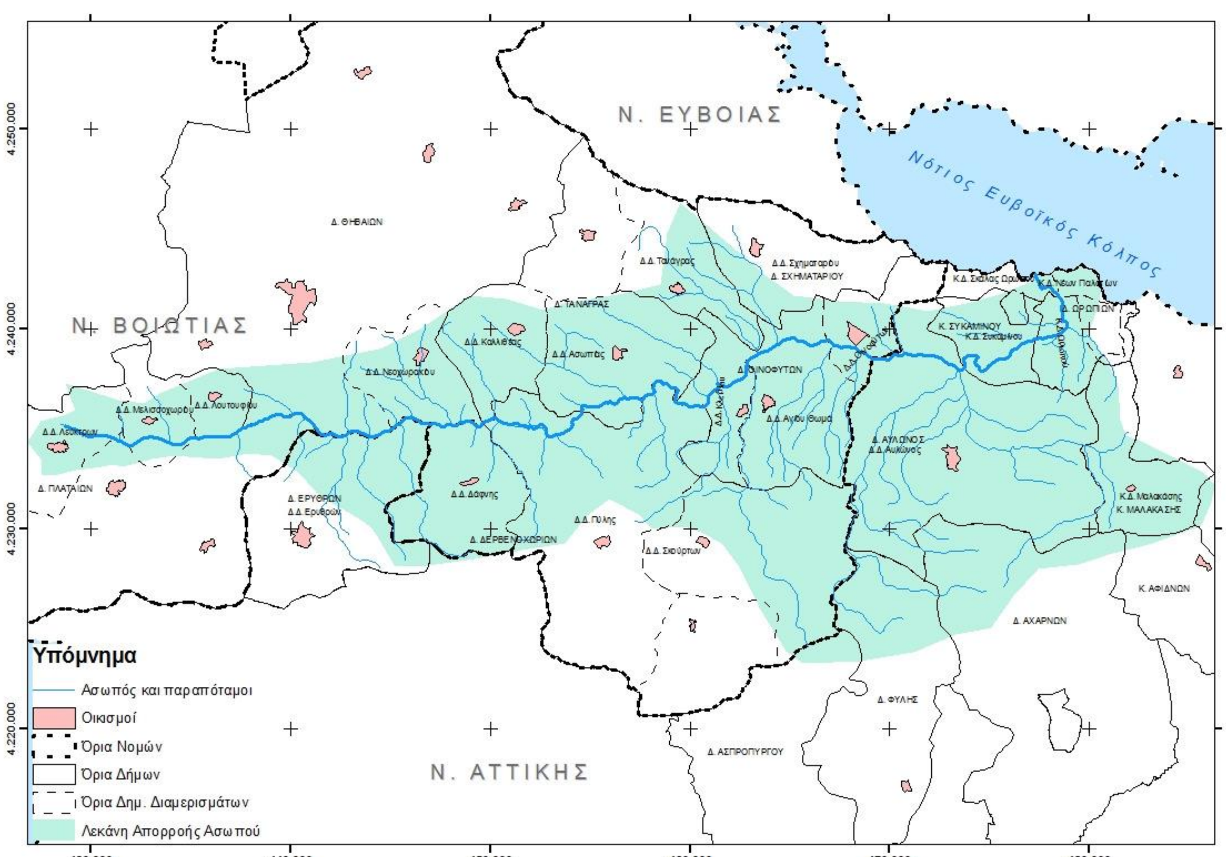

Figure 2: Asopos RB – Administrative borders (Source: Apostolopoulos, 2010)

Finally, regarding the geotectonic outline of the Assopos valley in Economou-Eliopoulos et al. (2011, p.40) it is reported that: "The Neogene Assopos basin is mainly composed of Tertiary and Quaternary sediments. The uppermost horizons, dominated in the studied area, are continental sediments consisting of conglomerates with small intercalations of marl, marly limestone, metaclastic schist, sandstone, clays and flysch. At the lowest parts there are alternations of lake yellow marls and marl limestones hosting small black lignite horizons."

2. Related legislation

Before, presenting the water quality related information and the identified pressures in the study area it is important to present the institutional framework that had its impact on the current situation. In 1969 with Presidential Decree it was allowed the establishment of industrial units in the broader area of Oinofita. However, this decision did not foresee their way of operation and did not specify limits related to the industrial activities. Hence, what characterized the location of those industries in the region was the lack of any planning and monitoring system for the control of the area's industries. Ten years later in 1979, the river was appointed by the Regional Authorities (Prefectures of Attica and Viotia) as receiver of industrial sewage however, without establishing any monitoring system for the enforcement of terms and conditions under which the industries would discharge their waste in the river. Although today these terms are obsolete and in opposition with more recent laws and regulations, the treaty is still in effect. In addition, more licenses were granted for the operation of industries in the area of the region where the construction was forbidden under the 1969 Presidential Decree. As a result, the river and groundwater have been subject to long-term industrial pollution.

Regarding the implications of the related legislation the following are emphasized:

1. According to the Public Health Act/Regulation E1b/221/65 the disposal of the treated waste water and industrial wastes is allowed either in surface water bodies after asking for Permission by the Prefect or underground (after asking Permission from the Planning Service of Northern Attiki). This Regulation is rather general and as long as the underground disposal of the treated industrial wastes are concerned, it is not referred particularly, to dangerous and toxic substances and it does not set limits for the disposal of dangerous substances.
2. The legislation for the management/disposal of the toxic-dangerous industrial wastes according to the law L. 1650/86 includes a plethora of provisions which most of them concern harmonization of the national Law with successive EU Directives. However, these provisions do not face with a single and concise way the whole issue since there are gaps, discontinuities and overlapping. Hence, although there is adequate environmental legislation relevant to the management/disposal of dangerous industrial wastes, these issues are still regulated by the Public Health Act/Regulation E1b/221/65.

In Greece, the WFD has been transposed into the national legislation with the Law 3199/2003 (MoEPPW, 2003) however, till recently there was neither a Management Plan for the protection of the Asopos RB nor a Monitoring Program for its waters which should have become operational the latest until 23-12-2006 according the P.D. 51/2007 in compliance with the Directive 2000/60/EC.

The substantial response of the State regarding Asopos was initiated in the beginning of 2010 where it was presented by the Minister of Environment, Energy and Climate Change a Program for the management of the environmental crisis in Asopos which aimed at the following objectives[1]:

-Ensure safe water

-Institutional safeguard of the broader area

-Effective monitoring of the pollution sources (industrial, agricultural, urban) aiming the limitation of the discharged loads

-Intensification of the controls

-Exploration of restoration measures of the environmental degradation

-The spatial planning/organization of the area

As far as the institutional and legislative framework is concerned[2]:

-The Joint Ministerial Decision was issued for the "Establishment of Environmental Quality Standards in Asopos River and Emission Limit Values for Liquid Industrial Wastes in Asopos RB", according to which (i) outdated provisions according to which the industrial units in the area could dispose their wastes in Asopos were abolished (ii) the Joint Departmental Decision according to which Asopos was defined as a disposal pipeline of industrial wastes in Evoikos has been abolished, (iii) the cost of sampling and of the laboratory analysis for the verification of complying with the relevant legislation was attributed to the controlled activity.

[1] http://www.ypeka.gr/Default.aspx?tabid=389&sni%5B524%5D=1561&language=el-GR (in Greek)
[2] Op.cit 10.

- The Joint Ministerial Decision was issued according to which the Asopos RB is characterized as area vulnerable to nitrate pollution and an appropriate agri-environmental program is formed in compliance with the European Directive regarding nitrates from agricultural sources.

-The concept and implementation of criminal liability is reinforced and parallel to the Directive for environmental liability this framework promotes the concept of the "polluter pays" but also the principles of prevention and precaution for a more effective protection of the environment and public health. This action is also translated to the direct adoption of measures to prevent and remedy environmental damage, the cost of which is transferred to the polluters.

3. Quality of surface and groundwater in Asopos River Basin

3.1 Surface water

Regarding the quality of surface waters according to the monitoring data (MoEPPW, 2006, p.81): " nitrates and phosphorus concentrations in Asopos River were high whilst BOD and D.O. measurements indicated pollution caused by high organic loads due to industrial and urban wastes as well as agricultural run offs in its catchment area". According to the same report it is also noted that concentrations of microorganics, priority substances (Decision No. 2455/2001/EC) and dangerous substances (Directive 76/464/EEC) at Asopos River were lower than the threshold values set for the water quality objectives by the National Legislation (Decision 2/1-2-2001).

In the context of a research program of the Hellenic Centre for Marine Research (HCMR) (Chatzinikolaou, 2009) aiming to assess the ecological condition of the Greek rivers using biological parameters, water samples from Asopos were analyzed. The day of sampling was chosen so as to reflect the worst situation in terms of surface flow in the river while sampling took place in three points/sites.

Table 1: Results of sampling 2/8/2008[3]

			D.O. (%)	D.O. (mg/l)	T (^oC)	Conductivity (mS/cm)	TDS (mg/l)	Salinity (ppt)	pH	N-NH4 (mg/l)	N-NO2 (mg/l)	N-NO3 (mg/l)	P-PO4 (mg/l)
Όρια Οδηγίας 98/93			>75%*	5		2,5			≥ 6,5 and ≤ 9,5	0,5	0,5	50	
SiteName	Date	Time											
ASOPOS_UP	2/8/08	12:30	91,0	7,31	26,3	0,382	181	0,1	8,39	0,012	0	0	0,43
THERMIDONAS	2/8/08	13:15	1,5	0,10	26,3	2,900	1456	1,5	7,73	0,433	0,016	0,3	21,6
ASOPOS_DW	2/8/08	14:00	1,2	0,10	26,5	3,690	1853	1,9	8,62	0,295	0	0,13	2,78

*Όρια προηγούμενης Οδηγίας

Source: Chatzinikolaou (2009)

From the above table (Table 1) it is concluded that the ecological quality of waters in the study area according to the measurements of the HCMR[4] is characterized according to the EU Directive 2000/60 as “bad” in the two stations ASOPOS_DW and THERMIDON and “poor” in the station ASOPOS_UP. In addition, according to the first results it was found out that in Asopos water lived only one larva (Largo) of a kind of fly, which can only live under conditions of zero oxygen.

Furthermore, following the research of the National Technical University of Athens led by Professor Loizidou for the estimation of the environmental degradation because of the discharge of industrial outflows in the environment, sampling took place during June 2004, at different

[3] Second raw of the table presents the limits/standards set by the Directive 98/93, while the asterisk is referred to limits/standards of the previous Directive

[4] http://www.hcmr.gr/en/

points of the area (along the river and at the coastal area of the estuary). The results showed that waters along the river and at the coastal area are polluted with inorganic and organic load.

3.2 Groundwater quality

Based on the study of the Institute of Geology and Mineral Exploration (Gianoulopoulos, 2008b: cited in Technical Chambers, 2009, p.22) the qualitative characteristics of the groundwater were examined and classified into two different categories: the ions and the trace elements. Regarding the distribution of the main ions the following were concluded that: "(i) In the area between Avlona, Ag. Thoma and Asopos River there are fresh waters enriched in HCO_3^- with a low total of dissolved salts (TDS). Eastern and at both sides of Asopos river bed the concentrations of TDS gradually increase and their hydro chemical type advances to Mg-HCO3 and to mixed type of waters. (ii) The majority of the groundwater is overloaded with nitrates demonstrating concentrations almost double compared to the 50 mg/L legal limits for drinking water. In addition, their concentration in Cl^- ions is increased while along Asopos it was also observed increase in PO_4 ions. Furthermore, in specific areas there were recorded increased values of Nitrite and Ammoniacal ions.

Following the same study of the Institute of Geology and Mineral Exploration (Gianoulopoulos, 2008b: cited in Technical Chambers, 2009, p.22): "(i) The source of the nitrates is mainly agrochemical (nitrogen fertilizers) while the presence of nitrite and Ammoniacal ions is due to the urban and industrial pollution sources, while (ii) the increased values of Cl^- and PO_4 ions are also due to the industrial pollution sources. The increase of the Cl^- ions in the alluvial coastal aquifers of Oropos and Avlida is due to the mechanism of salinization."

Finally, an alarming groundwater related quality parameter which made its presence in the area is that of hexavalent chromium Cr(VI). Economou-Eliopoulos et al. (2011, p.40) note that: “although the control of the chromium content in the industrial wastes is a requirement the Assopos basin (Thiva, Oinofita, Oropos, Avlona) was known from the impact of groundwater by Cr(VI), due to intensive industrial activity at this area, such as plating metals, leather processing, stainless steel, Cr-bearing alloys resistant to corrosion and oxidation, which may be discharged into the environment.” As it is demonstrated in the following figure and commented by the authors (p.39): “Groundwater samples from the Asopos aquifer showed a wide spatial variability, ranging from <2 to 180 ppb Cr_{total} content [almost same to the Cr(VI)-values] despite their spatial association. The presence of Cr(VI)-contaminated groundwater at depths >200m is attributed to a direct injection of Cr(VI)-rich industrial wastes at depth rather than that Cr(VI) is derived from the Asopos river or by the interaction between water and Cr-bearing rocks.”

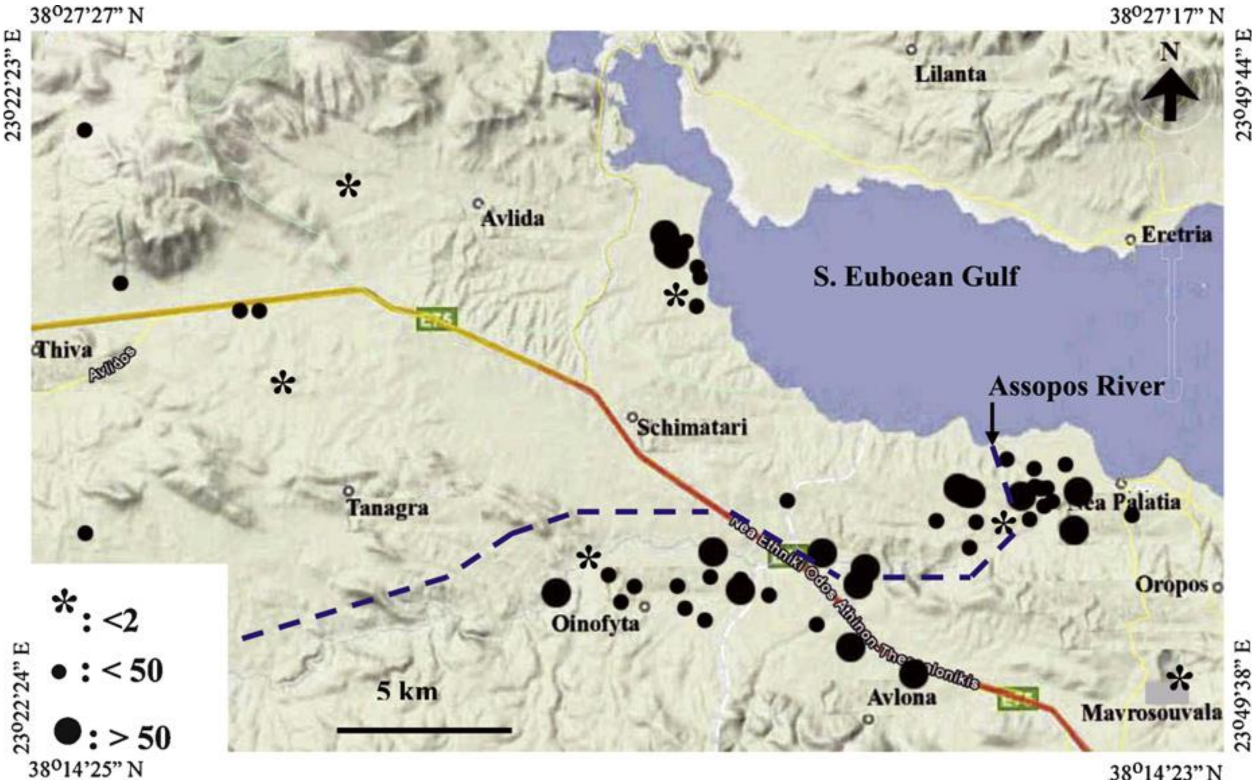

Figure 3: Location of the groundwater boreholes and distribution of the Cr_{total} concentration (in ppb) throughout the Asopos basin. The groundwater samples were classified into tree groups: (a) lower than 2 ppb Cr_{total} , (b) lower than 50 ppb Cr_{total} , and (c) higher than 50 ppb Cr_{total} .
Source: Economou-Eliopoulos et al. (2011, p.45)

In Vasilatos et al. (2008) study it is documented that (pp 61-62): "Concentrations over the maximum acceptable level for Cr_{total} in drinking water (50 Ig/L), according to the EU Directive (EC, 1998), were found in several groundwater samples from Thiva – Tanagra – Malakasa basin. The contamination of groundwater by Cr(VI) that was found in the majority of groundwater samples in the Thiva – Tanagra – Malakasa basin has been related to the widespread industrial activity for the last 40 years and the usage of hexavalent chromium in various processes. … In the Asopos River, that crosses the Thiva – Tanagra– Malakasa basin, although total chromium is up to 13Ig/L, hexavalent chromium less than 5 mg/L and the other toxic element concentrations were relatively low during our research, their values suggest their relation with the industrial activity in the area."

"The higher values of Cr_{total} are observed in the area of Avlida (180 ppb) and in the areas of both sides of Asopos river bed (40-107 ppb) till the broader area of Oropos (17-85 ppb), as well as in the area Southeast of Asopos till the area of Avlona (20-118 ppb). Increased concentrations were also observed in a borehole in proximity to Asopos river bed at North of Ag Thomas (163 ppb)" (Technical Champers, p.23). As commented in the Technical Champers (2009) report in most of the cases these increased values of Cr_{total} are the result of industrial pollution, while the concentrations of Cr(VI)/(Cr_{6+}) demonstrate a similar distribution to that of Cr_{total}.

4. Pressures and impacts of pollution in Asopos River Basin

As it must be obvious to this point the broad Asopos area is the largest industrial region of Greece, supporting 1300 industrial facilities such as metal processing agrochemical, and food/drinks industries among others. Hence, the industrial activity in the area of Asopos, which started at the end of 1970, and in particular in Oinofita-Schimatari is considerable and increasing. According to the results of Loizidou (2009) study presented in Table 2, there were reported 378 industrial units in the area of which 23 were closed and the rest 5 were new and under construction. From the total of the existing units the 130 produce waste waters during their production function. The total daily produced quantity of waste waters reaches the 9.044 m^3/day of which 84% corresponds to the industrial waste waters. More particularly, the total daily produced quantity of industrial waste waters from the total of the industrial and artisanal units located in the area reaches the 7.605 m^3/day and the total daily quantity of waste waters of the employed in these units reaches the 1.439 m^3/day. The main flow of the produced industrial waste waters is coming primarily from the sectors of "Textile and leather industries", "Metallurgy related industries" and "Industries of Foods and Drinks" at 25%, 21% and 30% respectively.

Table 2: Industrial units distribution and average daily flow of waste water for each industrial activity (m^3/day)

Industrial Sector	**# of industrial units**	**average daily flow of waste water (m^3/day)**
Livestock farms	11	539
Food and drink industries	41	2198
Textile and leather industries	20	1925
Woodworking industries	15	2
Pulp and paper industries and printing industries	17	8
Chemical industries	77	154
Non metallic mineral industries	20	908
Metallurgy related industries	96	1615
Commercial industries	9	-
Warehouses	26	-
Other industries	46	256
Total	**378**	
Closed	**28**	
Total	**350**	**7605**

Source: Loizidou (2009)

Loizidou (2009) also offers a disaggregated view of the above industrial activities for each active industrial unit in Asopos RB as far as wastewater in m^3/day is concerned. Table 3 presents the industrial pollutants (Kg/d) in the current situation (during the research).

Table 3: Industrial pollutants (Kg/d)

BOD	203.8
COD	6279
SS	2275

Fats (Λίπη;)	765.5
MBAS	12
NH_4^+	
NO_3^-	46.95
PO_4^{-3}	13.86
SO_4^{-2}	2.774
CN^-	0.25
Phenols	16.66
AI	3.52
Fe	5.38
Sn	
Cr^{+3}	4.3
Cr^{+6}	0.00
Cu	2.94
Cd	0.35
Pb	1.71
Ni	42.27
Zn	2.11

Source: Loizidou (2009)

Loizidou’s (2009) study explores also the potential for the creation of a Central Wastewater Treatment Plant (CWTP) and of a Central Sewerage Network of the Industries (CSNI). For this purpose it is important to predict the quantity and quality of the produced waste waters in the future. Results are presented in the following table giving us an indication of the trend of the industrial development in the area. Hence, apart from the Textile and Leather industries all the other sectors demonstrate an increasing activity. Furthermore, in order to assure applicability of the project even when faced with a higher volume of waste waters than those predicted a 15% (last column of Table 4) safety factor is added to the calculation of the future loads.

Table 4: Average daily flow of waste water for each industrial activity (m^3/day)

Industrial Activity	**Current**	**10 years**	**20 years**	**20 years +15%**
Livestock farms	539	807,9	1091	1254
Food and drink industries	2198	3298	4451	5119
Textile and leather	1925	1925	1925	2214

industries				
Woodworking industries	2	2,9	3,8	4,4
Pulp and paper industries and printing industries	8	12,2	16,4	19
Chemical industries	154	231,2	312,1	359
Non metallic mineral industries	908	1362	1839	2114,9
Metallurgy related industries	1615	2422,8	3269,8	3760,3
Other industries	256	384	518,4	596,2
Total	7605	10445	13427	15441

Source: Loizidou (2009)

Regarding water consumption Table 5 shows that the most water demanding sectors are those of "Metallurgy related industries", "Food and drinks industries", "Textile and Leather industries" and "Chemical industries".

Table 5: Water consumption per industrial activity

Industrial activity	**Quantity (m^3/year)**
Food and drink industries	1.235.336
Livestock farms	35.650
Textile and leather industries	562.228
Woodworking industries	3.480
Pulp and paper industries and printing industries	4.015
Chemical industries	111.260
Non metallic mineral industries	40.805
Metallurgy related industries	1.240.540
Other	2.425
Total	3.235.739

Source: Loizidou (2009)

As it is also noted in Loizidou (2009) from the total of the industrial and artisanal units that produce waste waters, that is from the 130 units (37% of the total of the units in operation) the 65 units (that is 50% of these that produce waste water) have a treatment facility for their produced waste waters. In general, from the total quantity of produced waste waters (industrial and urban waste waters) the 97% is subject to a treatment. As Table 6 shows the existing ways of waste water disposal in the area are the surface disposal, the underground disposal, the recycling of the treated out flow (within production activity), the disposal in a municipal wastewater treatment plant or in an authorized management body and the disposal in the Asopos River or its tributaries. Finally, some of the industrial units not having an alternative option collect temporally their wastes which are then managed by an authorized body.

Table 6: Current ways of disposal of waste waters in the study area

Ways of disposal	**# of industrial units**	**Quantity of waste water (m^3/day)**	**Percentage (%)**
Surface disposal	15	454	6
Underground disposal	25	104	1,4
Recycling	22	946	12,4
Temporal collection	2	1	0,01
Municipal wastewater plant	19	95	1,3
Authorized management body	23	19	0,3
Asopos and its tributaries	24	5985	78,7
Total	130	7605	100

Source: Loizidou (2009)

Overall, Loizidou's (2009) study reports that considering the 350 industrial units that operate in the area the produced: a daily quantity of industrial waste waters of 7.605,0 m^3/day, 1.438,8 m^3/day of sewage, 3.458.034 m^3/year total annual water consumption and an annual quantity of sludge of 15.096 tn/year.

In addition, considering the study of the Agricultural University of Athens which recorded the industrial and artisanal units in the area it was concluded (Masoura, 2008: cited in Technical Champers, 2009, p.29) that: (i) North East of the Asopos' river bed in a stretch of 7 km there is a big number of industrial and artisanal units (407) which produce a daily volume of waste waters ranging from 0,3 m^3/d to 3000 m^3/d depending on the production procedure that is followed and the size of each industry, and (ii) these waste waters are mainly produced by the textiles-varnishes-finishing, the food industries, the metallurgic units, the chemical units as well as from the livestock units.

An additional pressure in the area is also put by the agricultural activity which includes arable and tree crops. As stated in the Report of the Technical Champers (2009, p.28): "there are 351.400 str. which are cultivated from which the 45% are irrigated and the 55% non-irrigated. In general, in the area an intense agricultural activity is observed in the upstream of Asopos." As it has been demonstrated in the previous section the production of the area is mainly characterized by hard wheat, pulses, cotton and some categories of fodder and vegetables. Therefore, the pollution of Asopos surface water from agricultural run offs is expected to aggravate the problem. Furthermore, in the same report it is noted that there are also natural sources of pollution apart from the industrial, urban and agricultural activities.

Apart from the obvious environmental impacts in the area there are also worrying human health impacts due to the presence of the highly toxic heavy metal hexavalent chromium (CrVI) (or chromium 6) which was traced at high concentrations (ranging from 10 ppbs to 330 ppbs) in both surface and groundwater samples from the area. As commented also previously the evidence show that the presence of hexavelent chromium in surface and groundwater is clearly and indisputably linked to industrial contamination of soils and waters from illegal discharge of industrial, hazardous waste and sludge. It is regarded that water consumption of high concentrations of hexavalent chromium harms human organism not only by drinking water but also by skin contact or the consumption of fruits and vegetables. Current scientific evidence has shown that hexavelent chromium is absorbed through the gastrointestinal tract and can reach many organs causing serious damages and cancer. Even the inhalation of hexavalent chromium can cause mainly lung cancer.

Furthermore, it has been noted that apart from the intense, human induced pollution of waters of Asopos River, which comes from the industrial activities in its catchment, in the coastal wetland complex the human influence is intense as well mainly due to expansion of settlements, impacts from traffic during the summer months, and garbage. A number of roads form blocks and the residential pressure goes up to the coastline. Indeed, the remnants of natural vegetation in some of the residential blocks indicate that parts of salt meadows have been filled to cross roads. Within the wetland toward the Oropos area the pressure from the filling and movement of vehicles is obvious. Part of the area at the mouth of Asopos River has been covered by the aviation with a variety of antennas and some of the area on both sides of the riverbed has been fenced.

5. Functions and values of Asopos River and Oropos Lagoon[5]

This section offers a short overview of the functions and values of the area, based on literature review and field visits, associated with the wetland complex composed from Asopos River (including its estuary) and the coastal lagoon of Oropos. It is noted that Chapter 9 summarizes results of a qualitative evaluation of these wetland functions and related values by hydrogeomorphological unit.

[5] EKBY (2010) (Available at: http://www.aueb.gr/users/koundouri/resees/uploads/envstudyen.pdf

The study area (Figure 4) comprises the river and estuary of Asopos and the lagoon of Oropos northeast of Attica. Along the Asopos river human activities, mainly agriculture and industrial take place. For at least three decades industrial effluents pollute the river, the aquifers and the soils of the area, making it a negative example of the impacts to humans and environment that arise from non sustainable use of natural resources. The mouth of Asopos River and the lagoon of Oropos (on right hand side of Figure 4) are located at around 2 km distance and are remnants of a single wetland system in the past associated with coastal marshes. Today, settlements have expanded in the in-between area. The road is located just few meters from the coast and halophytic vegetation is only sporadically present, resulting in the interruption of the structural continuity of the two wetlands.

Figure 4: Satellite picture of Asopos river and mouth, of Oropos lagoon and the wider area (Date: August 2004, Source: GOOGLE EARTH).

Values for humans result from the structural features and functions of wetlands. These are the goods and services provided or potentially provided to humans as a result of functions that take place there. A wetland function can benefit humans in many ways, that is, to provide more than one values. Wetlands differ in the number of functions performed and in the degree to which they perform them; as a result, the values obtained by humans differ as well. Furthermore, many wetland values are derived from a combination of functions and a value may depend on one or more other values.

The functions that were considered necessary to evaluate in the area were: a) water storage, b) food web support, c) nutrients removal and transformation, d) sediment and toxic trapping, e) floodwater attenuation, f) groundwater recharge, g) shoreline stabilization. The next sub-section presents in more detail the above mentioned functions.

5.1.1 Food web support

Wetlands, and especially those with a variety of vegetation units, depth and current velocity, and considerable vegetation cover, host a variety of habitat types. In the wetland complex of the estuary of Asopos River and the Oropos lagoon, characteristic vegetation types of the coastal zone appear, that create a variety of habitats for species and mosaic in physiognomy of the area. The change in the water depth due to the microtopography from the coast to inland area, also due to the periodical and seasonal inundation favors the development of vegetation types and the presence of species. With regard to the vegetation types, in sub sites (mouth of Asopos River and Oropos lagoon), Mediterranean halophilous scrubs and Mediterranean salt meadows develop with more than one plant communities.

In particular, the Mediterranean halophilus scrubs (*Arthrocnemetalia fructicosae*) consist of four plant communities: a) with dominant *Sarcocornia fruticosae* which occupies the largest surface area of the scrubs, b) with *Halcocnemum strobilaceum* as dominant species, c) with *Arthrocnemum macrostachyum* as characteristic species and d) with characteristic species the *Aeluropus littoralis*. The Mediterranean salt meadows (*Juncetalia maritimi*) appear with two plant communities. The one is formed by the species *Elytrigia elongata* (=*Elymus elongates*) or *E. Flaccidifolius and Juncus acutus* as dominant in salt and wet soils, behind the zone established by halophilus scrubs, whereas in the other, *Juncus maritimus* and *Arthrocnemum macrostachyum* dominate. Moreover, in the area, depressions between dunes with reeds and sedge appear, and annual vegetation along the coastline. It is noted that the shallow lagoon of Oropos is partially connected with Evoikos gulf through a narrow channel and is a priority habitat type of Community importance (code 1150) according to Directive 92/43/EEC.

With regard to the diversity of animal species, we consider birds as a group of species indicative of the quality of the function, as it was previously described. In the study area, in total 101 bird species have been observed (Tzali et al., 2009), being the largest number compared to other wetlands of Attica region; they comprise raptors, herons, waterfowl present during the winter (November to February), waders all year round, with their peak during migration in winter. Important is considered the presence of *Larus melanocephalus* that is endangered according to the Red Data Book, among others. It is noted that 19 bird species belong to Annex I to the Birds Directive, out of which in the area the following reproduce: *Charadrius alexandrinus*, *Himantopus himantopus*, *Sterna albifrons* and *Calandrella brachydactyla*. The large number of bird species during migration shows the importance of the area as a stopover (Tzali et al., 2009, WWF Hellas and Hellenic Ornithological Society 2008 and on site visits 2010). However, with regard to fish, it is noted that endangered freshwater species such as *Pelasgus marathonicus* (Vinciguerra, 1921) and Telestes beoticus (Stephanidis, 1939) have probably been extinct from Asopos River (Economides and Chrysopolitou 2009a, b). As regards reptiles, only the species *Ablepharus kitaibelii* has been observed in an oliveyard near the river, *Chalcides ocellatus* is also referred to. Moreover, around a kilometer north east of Oropos lagoon, the snake *Malpolon monspessulanus* has been observed (Ioannidis unpublished data 2002) and so its presence in the study area is probable. As to the mammals, there are no published data; however, it is probable that certain human acclimatized species such *Rattus rattus*, whose presence has been recorded in the study area, are present. It is also probable that some bat species also use the wetlands for food. In any case, the habitats for most reptiles and mammals are degraded. It is also noted, that the wetland complex, although small in size (around 100 ha), is the only remnant wetland between two larger coastal wetlands of the wider area, those of Sperheios and Shinias that belong to the NATURA 2000 network. As such, it contributes significantly to the conservation of habitats to the coherence of the network. This role is also acknowledged in article 10 of Directive 92/43/EOK, which encourages member states to conserve and manage those sites as special landscape features.

Given the above it becomes clear that the wetland complex performs the function Food web support. But the continuing deterioration of the function is obvious and results mainly from the expansion of settlements at the expense of wetland area and water pollution of the river Asopos. The upgrading of this function is directly related to the removal of these two threats. The expansion of settlements should not be pursued at the expense of wetland area and water quality of the Asopos must be restored so that the function is upgraded and maintained at a high degree.

Furthermore, the development of targeted activities such as environmental information, education and recreation would probably prevent the degradation of salt meadows adjacent to the coast from vehicles especially during the summer months (the area is not flooded) and would encourage the sustainable use of the wetland complex.

5.1.2 Water storage

The storage of surface water is a function that almost all the wetlands can perform. The storage of water from precipitation and the time required for the gradual discharge of the water varies between wetlands. The depth of water in a wetland provides a clear picture of the volume of water that can be stored. The wetlands that have shallow water warm faster than the deeper ones and have greater water losses due to evaporation. In contrast, wetlands with steep slopes maintain deep water throughout the area and have less water loss by evaporation. In the case of the Asopos River, despite the relatively large size of the basin, water is kept only for a minimum time in the river bed, due to rapid percolation to karstic aquifers in the basin. It therefore appears that the ability to perform this function is limited along the Asopos River but also in its estuary. Similarly limited is the extent to which this function is performed in the lagoon of Oropos. Limiting factors is the shallowness, the existing channel of water and the little inclined regions upstream of the lagoon, which contribute only little with water runoff.

5.1.3. Nutrients removal and transformation

The water entering a wetland inevitably carries nutrients dissolved in water and adsorbed to soil particles. The nutrients can come from the fields, villages and industries. Wetlands have the ability to improve water quality, through the retention of nutrients and their conversion into other forms. The removal is achieved by physico-chemical and biological processes that are performed in wetlands. The presence of plants favors the function of removal and transformation of nutrients, because they contribute to both slowing the water flow and absorbing the entering nitrogen and phosphorus. In addition, plants are the substrate for the growth of microorganisms, by which many substances are transformed into other forms. The wetland vegetation is particularly effective in the retention of nutrients. Therefore, the higher the coverage with vegetation, the more that function is favored. Moreover, this function is favored not only when there is vegetation in the wetland, but rather when there is a diversity of species. However, as mentioned above, Asopos River maintains permanent flow only for a limited time. Thus, this function is severely constrained by lack of water in the riverbed. In the lower reaches, where large quantities of liquid waste are disposed of, the presence of water is almost permanent, and despite the existence of wetland vegetation (especially reeds), nutrient concentrations are very high. Therefore this function seems to be limited along the riverbed and is further degraded in the section towards the exit to the sea. In terms of the lagoon of Oropos, theoretically there is the ability to perform this function. However, this is limited by the salinity of the water, which does not favor this function in general and the more specifically the presence of those plant species that support some of the processes of removal and transformation of nitrogen and phosphorus. The presence of plants as they grow around the lagoon, would enhance the degree of this function.

5.1.4. Sediment and toxic substances trapping

The water runoff, atmospheric precipitation and wind drift within the wetland solid materials. These materials are trapped temporarily or permanently in the wetland so that the wetland

improves the quality of water flowing through it. The sediments may contain nutrients, heavy metals and pesticides according to the land use of the catchment (agricultural, urban, industrial, etc.). The processes that trap pollutants entering into the wetlands, are due to slow speed of water and subsequent retention of nutrients by wetland vegetation, to the decomposition of organic matter by microorganisms, to the metabolism of plants and animals, and to photosynthesis. In the wetland of Asopos, the velocity of water is small and therefore there is a great likelihood of precipitation of particulate material, with subsequent retention and deposition of sediments and toxic substances within the wetland. The areas with wetland vegetation (especially reeds) reduce the speed of water in the wetland due to friction, contributing to the rapping of sediments and preventing re-suspension of sediments. Furthermore, the vegetation contributes to coating of pollutants and sediments with dead plant material, which is good feature. Also, the shallow water, contributes to the entrapment of pollutants and toxic substances, because the speed of the water is low due to friction and facilitates the trapping. The type of substrate determines the degree of adsorption of contaminants from the wetland soil. The presence of organic substrates favors the absorption and retention of certain toxic heavy metals and synthetic organic compounds. Therefore, wetlands with a high proportion of organic soils perform this function.
On this basis it is assumed that there is expression of that function, at the mouth of Asopos.

The lagoon can act as trap of sediment and toxic substances through sedimentation processes and coating with other materials or through biochemical processes in the water flowing in the lagoon from runoff from the nearby upstream region. The sediments sometimes carry, by chemical and physical bonds, toxic substances like heavy metals and pesticides. The site has features that enable it to perform this function to an appreciable extent; however, in practice, this function is limited because only limited amounts of water runoff flow through the Oropos lagoon.

5.1.5 Floodwater attenuation

The function of amending the flood is very important for humans, due to the slowing of water velocity and the reduction of the area affected by flood. Wetlands can temporarily store large amounts of water during floods and mitigate the damage to agriculture and settlements. The ability of the wetland is to store flood water and gradually recharge, after the flood, thereby reducing the flood peak. This function is performed at an optimal level in ecosystems found in higher parts of the catchment, where the floods occur, and in wetland areas that are a recipient of torrential flow. The factors on which the efficiency of the function depends are: a) the type of wetland and the morphology of the catchment, b) the location and size of the catchment, c) a channel of water, d) water movement and e) the vegetation cover.

In the case of Asopos River this function is not considered as particularly important given the high degree of infiltration of rainwater in the catchment through the carbonate rocks that prevail in the basin in approximately 50%. It is most likely that underground water from side enters Asopos River which is moving slowly and not flood peaks from surface water. In the case of the lagoon of Oropos, this function seems to be performed quite well, protecting the residential area upstream from the sea water during extreme weather and tide, however limited it is. This is achieved through its ability to store and halt the rising waters and recharging them again to the sea through the channel.

5.1.6 Groundwater recharge

Wetlands retain large amounts of surface water from the catchment area and they play a valuable role in the enrichment of underground aquifers, as water retained then flows through the soil layers to the aquifer, enriching it with water that would be lost otherwise. The enrichment is done both in the vertical and the horizontal movements of water, especially in cases of shallow aquifers. Whether a wetland has the potential to enrich the groundwater aquifers is mainly dependent on the substrate of the wetland that is the main factor in the performance of that function. If the substrate is practically impermeable, this function is not existent, even if all other factors are favorable. In the area of the Asopos River, there are two main aquifers; the upper aquifer of granular deposits and underlying karstic aquifer formations. The movement of groundwater varies vertically and horizontally between different aquifers and although the bed of the river in only small parts comes in contact with the karst aquifer, the river Asopos has no permanent water supply. Thus, it appears that a large volume of runoff water percolates to the groundwater and therefore the function of the enrichment of groundwater aquifers is performed widely.

For the Oropos lagoon no analytical data on the permeability of the substrate exist. From hydro-lithological data of the wider region it comes that formations of medium to low permeability dominate. Taking into account also the proximity to the sea and the possible entry of underground salt water, it is estimated that the lagoon does not perform this function.

5.1.7 Shoreline stabilization

The stabilization of coasts by wetlands is associated with the retention of soil on the coast (e.g., from roots of wetland plants) to prevent the erosive action of waves and currents. The existence of specialized wetland flora, tolerant of increased salinity in coastal areas, plays a special role in this direction with their roots. However, resistant to erosion are not only wetlands with vegetation but also other coastal wetlands that are flat or nearly flat with no vegetation. The lagoons are a typical case of wetland ecosystems that absorb the energy of waves and currents, preventing them to enter the land and erode it. The lagoon of Oropos is assumed to perform this function until today, although the surface has been limited by residential development. Stabilization of coast is also achieved through the deposition of river delta wetlands. The delta, first absorb the erosive action of waves and currents and also provide the fine material which spreads and / or is deposited subsequently by waves, usually in the neighboring coasts, providing in this way double protection on the latter. Thus the estuary of Asopos River is assumed to perform this function that needs to be maintained.

With regard to the values it is noted that a value originates from one or more functions, whereas a function could shape more than one values. Wetland values could be separate, complementary or even contradictory. Wetlands differ in the number and magnitude of values. In the case of study area, the following wetland values were evaluated: a) biological, b) scientific, c) education d) recreational, e) hunting, f) improving of water quality, g) protection against floods, and h) protection against erosion.

Detailed performance of the hydrogeomorphological units with regard to values is reported in Chapter 9. However, it is noted that one of the principal values of wetlands is biological value. It is related to the number of plants and animals, which can be considered rare or protected and their presence is associated with wetlands. The maintenance of high biodiversity contributes to the enhancement of values, such as scientific and educational. This value is directly affected by the function of food web support and indirectly from other functions. The study area has a biological value, since habitat types of Annex I of Directive 92/43/EEC, of which the lagoon is a priority for protection, are encountered. At the same time, the area has value in terms of birds, while for the rest of the fauna it appears to be limited because of its conservation status and of the threats it faces. Furthermore, wetland biodiversity makes them attractive locations for research from many disciplines. They are living laboratories for the observation and therefore frequently used for research. The area has vegetation units and plant and animal species that require scientific research and study (e.g. birds, habitat types of Annex I of Directive 92/43/EEC). The biological value of the region, particularly in the lagoon of Oropos, combined with the characteristics of the surrounding area make it attractive from a scientific and educational aspect, but this value is expected to rise following the implementation of management measures.

Wetlands are also highly valuable in terms of recreation. They offer possibilities for viewing and enjoying the landscape, observing flora and fauna, sports, excursions, walks and general mental and physical exaltation and contact with nature. In the case of river Asopos this value is very limited, whereas in the lagoon of Oropos it is assumed that the area has recreational value, which, after application of management measures would increase. Finally, wetlands, through the function of trapping sediment and toxic substances and the transformation and removal of nutrients, have the capacity to improve the quality of water flowing through them. This value is very poor especially for Asopos River. The impact of this (social, economic, environmental), is already visible in the catchment of wetlands under study whereas intense are considered the pressures on the coastal ecosystem of the South Evian Gulf, because of the direct relationship and proximity to this.

6. Conclusions

Although the impact of the industrial activity on the water use is not that important compared to other uses (irrigation, water supply), it is observed that some of the industrial units have a considerable production of waste water of diverse pollutants which depend on the type of production. Regarding the estimation of the pressures on the water quality due to the industrial activity, it is necessary to analyze in detail the total amount of polluting material in the area as well as the part of the polluting material that is related to the industrial activity. In general, it is observed that the sectors of Basic metals and Foods and Drinks which are of great importance in the area produce a considerable number of wastes compared to the other sectors of the industrial activity.

It should be noted that apart from the industrial waste waters which are the byproduct of production, there are also urban waste waters that come from the employees of the relative units. The fact that the basin is in close proximity to Athens has played an important role due to the special conditions of the capital the last years as a result of the population growth, the increase in land prices, the urbanization of suburban areas. These are some of the factors that made difficult the establishment of industrial units in close proximity to Athens and indicated the case study area to be a more attractive option.

As it will be also emphasized in Chapters 3 and 9 the agricultural activity in the area is important for the local economy while at the same time puts a considerable pressure on water use. Regarding its effect on water quality it is estimated that it plays an important role and is mainly due to the nitrates run off due to the excessive use of fertilizers. However, the impact of the sector is even more important regarding water quantity. In order to estimate correctly this impact it is necessary to record the way of water supply for irrigation purposes as well as the existing boreholes.

As commented in Loizidou (2009) the considerable industrial activity combined with the lack of necessary infrastructure results in serious pollution problems in the wider area. In particular, the lack of a holistic plan for the treatment of the produced liquid, solid and air wastes creates important environmental problems. A main problem is the uncontrolled disposal treated or not industrial waste waters in different natural receptor and mainly in Asopos River or its tributaries leading in the surcharge of the stream. It should be also noted that despite the fact that the majority of the existing in the area industrial units has a system of waste water collection and treatment, the problem of the degradation of the water quality of the receptors and in general of the aquifer of the area remains severe. This fact is due to either the non satisfactory operation of the wastewater systems because of technical or operational problems or to the small degree of effectiveness of the existing wastewater treatment systems. All these factors have contributed to characterize Asopos as one of the most polluted rivers having an impact not only to the areas that it crosses but also to the coastal area of Chalkoutsi in which it flows into.

Biological, scientific, educational, recreational and other different wetland values were evaluated in the study area. The maintenance of high biodiversity contributes to the enhancement of such values. This value is directly affected by the function of food web support and indirectly from other functions. It should be stressed that wetland values could be separate, complementary or even contradictory.

Finally, as a solution to the problem Loizidou's (2009) study explores the possibility of the creation of a management system for wastewater treatment which will involve the collection, transfer and treatment of the produced wastewaters. It has to be noted that the optimal management of the waste waters will contribute significantly to the restoration not only of the Asopos River but also to the environmental enhancement of the area and will decrease the negative environmental consequences leading to a sustainable development. In addition, measures are deemed important as a result of the serious impacts of pollution on human health as well as of the high significance of biological, scientific-educational and recreational values of the study area.

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