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Abstract

We have developed a method to impose waste discharge charges, thus implementing the polluter-pays-principle, after measuring the pollution load discharged in surface waters (rivers). The developed method was applied at the fruit and vegetable canning industry in the region of Imathia in Nortern Greece.

The measurement of the pollution load leads to the assignment of "Pollution Units" (PUs) to the operation of each polluting source. The PUs are related to the time of operation of the polluting source, the quantity of water used, and the concentrations of BOD, COD, and SS. More parameters can also be incorporated in the model for a wider application.

The formula used is derived by the pollution caused by one person in the case of Greece, assessed against similar models around the world. To defince the "Pollution Unit per Person" (APU), specific characteristics of Greece are taken into consideration. We also relate the cost of "cleaning" this Pollution Unit to the charge that will be put to the industries, in order to estimate a “fair” level of charges for the polluting plants.

The estimated formula was applied at the fruit and vegetable canning industry of the Prefecture of Imathia in Norhtern Greece, where the charge per PU, corresponding to each pollution source was calculated. The imposed charge is calculated by the following formula:

$$\mathbf{X = F * PU}$$

where **X** is the total charge,

F is the charge that each polluter pays per each PU, and

PU is the number of the discharged Pollution Units.

F corresponds to the cost of "cleaning" each PU in the receptor, and is approximated having as a basis the APU, and the cost of cleaning per APU.

Introduction – Water Pollution

Economic development and pollution are two closely and many times negatively related to each other concepts. The level of environmental pollution is manifested by pollution indicators, which are traced in the environment. For each indicator we define a certain limiting value that should not be exceeded in order for the environment to be appropriate for a certain use. The indicators to designate suitability of use should be the appropriate according to the desired use. [Anagnostopoulos]
The water pollution indicators that are most appropriate to measure water pollution are Suspended Solids (SS), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). [Antonopoulos, Mitrakas, Stamou]

The Prefecture of Imathia-Greece

The prefecture of Imathia lies in the Northern part of Greece and is a part of the plains of Central Macedonia.
The area of the prefecture of Imathia has many aquatic resources, both surface and groundwater. 3.73% is covered by surface water while the average national figure is 2.62%. Rivers, such as Aliakmonas, Loudias, Tripotamos, Arapitsa and Waterway 66, that originate or cross the area, maintain their flow during the whole year.
The predominant rural activities are fruit and vineyards cultivation that are integrated within the development of production, processing and marketing sectors. Industrial development is important in terms of contribution to the region's total income and wealth (textile and canned food industries, ice-chambering and fruit-sorting activities, winery, etc.). [Ministry of Development]

Water Pollution

Due to the intensive economic development in the region a significant pressure has been put on the natural ecosystems. Moreover, there is an **unfair competition** which victimises environmental friendly but not profitable activities (i.e. industries adopting their own biological treatment units, tourism, production of the so-called natural products).
Other polluting sourses in the Prefecture of Imathia, such as slaughterhouses, use of pesticides, waste and fruit landfills, etc. led to further groundwater pollution in the region. Drinking water was no more available to the vilages of Arachos and Neochorio in the wider region [Ministry of Development]. Often, acute incidents of pollution bring to light new aspects of the problem (in August the last two years dead fishes were washed by the shores of Waterway 66 and Aliakmona's river), thus giving evidence of its dimensions, and raise considerable public awareness of the local population. Economic and social development in the region seen to be further questioned.
The authorities in the prefecture of Imathia being aware of the intensive environmental problem decided that only a detailed scientific approach to the problem, could bring about radical changes to an almost out of control, situation. There is a certain fear that if no steps are taken soon, the underground water reservoirs, will be inevitably contaminated. People of the area, being aware of the danger that threats both their public health and the region's ecosystem, protest against the situation and expect local governmental bodies to take a stand on the problem by directly applying very strict environmental rules in the region. Additionally, local

press and national TV channels present the current situation and constantly warn for the consequences, thus arousing public awareness.

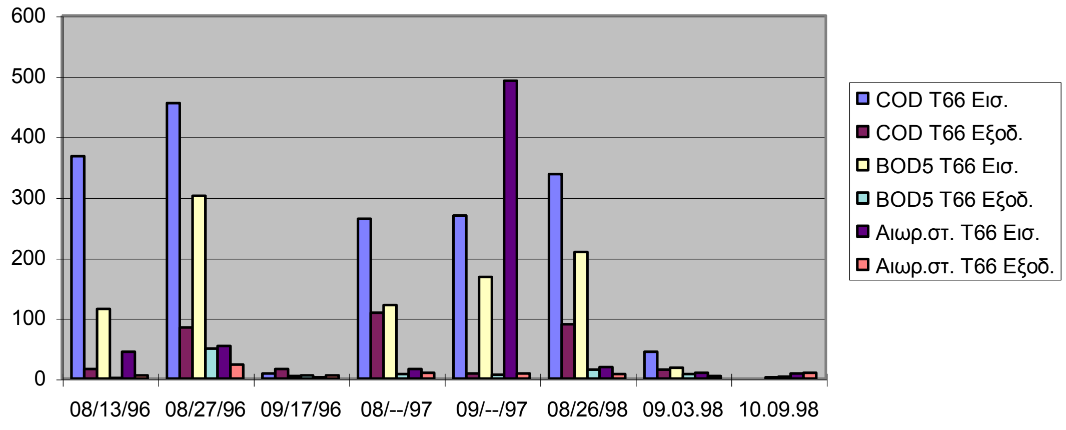
Waterway 66 has a total length of 35 km and its pollution has far exceeded any allowed or tolerable limit. It has found that the pollution problem of Waterway 66 is especially acute during the summer, August in particular, when the main polluters came from the seasonally operated fruit and vegetable canning industries. The observations of pollution indicators during the rest of the year show that their values are generally in normal levels. In the following table representative measurements of the pollution indicators for the years 1996, 1997 and 1998 are presented:

Table 1: Pollution load in W66

08/13/96	**W66 Entry**	**W66 Exit**	08/--/97	**W66 Entry**	**W66 Exit**	08/26/98	**W66 Entry**	**W66 Exit**
Ph	7.26	7.49	**Ph**	7.36	7.77	**ph**	7.34	7.75
COD	368	16	**COD**	264	109	**COD**	338	90
BOD$_5$	115	1	**BOD$_5$**	121	7	**BOD$_5$**	209	15
SS	44	5	**SS**	16	9	**SS**	19	7
08/27/96	**W66 Entry**	**W66 Exit**	09/--/97	**W66 Entry**	**W66 Exit**	09/03/98	**W66 Entry**	**W66 Exit**
Ph	7	7.25	**ph**	7.00	7.86	**ph**	7.65	7.81
COD	455	85	**COD**	269	8	**COD**	44	15
BOD$_5$	302	50	**BOD$_5$**	168	6	**BOD$_5$**	18	7
SS	54	23	**SS**	492	8	**SS**	9	4
09/17/96	**W66 Entry**	**W66 Exit**				10/09/98	**W66 Entry**	**W66 Exit**
Ph	7.52	7.57				**ph**	8.16	8.03
COD	8	16				**COD**	0	0
BOD$_5$	4	5				**BOD$_5$**	2	3
SS	2	5				**SS**	8	9

Part of the above measurements is presented in the following graph:

Diagram 1: Pollution load in W66



The polluter-pays-principle: Theoretical approach

To combat the pollution in the region, and to secure its optimal economic development, the Prefecture of Imathia initiated a project to implement the "polluter pays" principle, as far as water pollution is concerned. The polluter pays principle is a significant principle of international environmental law [OECD (1989, 1992)]. The principle's goal is that the polluter pays the full cost of the pollution it causes. In a broader sense, the principle's goal is that every human activity has to pay its full cost. This means that not only labor, capital, land, and raw materials should be accounted for, but also the cost to the society from the degradation to the environment, caused by the side-products (waste) of the human activity.

The polluter-pays-principle has been recognized as a general principle of international environmental law since 1990 [OECD (1989, 1992)]. However, it is an economic and not a justice principle. This means that the principle does not intent to punish the polluter, but to establish the necessary economic conditions so that all the environmental costs associated with the operation of a polluter are internalized, and the cost of production equals the real cost of produced goods, leading to sustainable development [Randall]. As it is evident, the principle aims at stopping the waste of natural resources and the cost-free use of the environment for waste disposal. The correct and full implementation of the principle leads to the more efficient and fair operation of the market, and eliminates conditions of unfair competition that might be present when the industry does not pay the full environmental cost of its operation. In economic terms, the principle aims at the internalization of all the externalities that are related to the operation of an enterprise (industry), and to the discharge of waste from this enterprise. [Kapp, OECD (1989), Pearce, Randall, Tietenberg]

The polluter-pays-principle:

i) General considerations

According to international experience, and also according to the specifics of the current case, a set of conditions should be met for the polluter-pays-principle to be successfully implemented. [Bromley (1989, 1991), EPA (1992, 1997), OECD (1980, 1994), Sen, Tietenberg] Specifically

1. The clear designation of the pollution sources and the accurate measurement of the pollution load is needed
2. A sense of fairness should be present and understood by all involved parties so that they agree to cooperate in good will
3. Public support is needed
4. A strong institutional framework is also needed to successfully implement any suggestions

ii) Description of the model

The following steps were taken for the proper implementation of the principle in the region of Imathia:

1. The pollution activity was identified and measured.
2. The cost of control of this activity was identified and measured.

3. Each source of pollution was allocated the charge that corresponds to the cost of control of its pollution activity.

The accurate measurement of the pollution load leads to the calculation of "Pollution Units" associated with the operation of each industry. In other words, each industry, according to its time of operation, the quantity of raw materials it processes, the quantity of water it consumes, the type of biological treatment facility that it operates, etc., discharges some amount of waste. This waste is calculated in Pollution Units. Then each industry is assigned a charge according to the Pollution Units it discharges. One PU correlates the discharges of BOD, COD, and SS, and also of other pollution indicators if later so decided. One PU is defined as follows:

$$PU = (Qd/150) * (0{,}40SS/600 + \{0.60[2BOD + COD]\}/1200)$$

where Qd is the water consumption in 24 hours in lt, BOD, COD and SS are the corresponding concentrations of BOD, COD and SS in mg/lt.
The above formula is derived by the pollution that is caused by one person in Greece. One such person is estimated to consume 150lt of water per day, and to pollute with 600mg/lt SS, 300mg/lt BOD and 600mg/lt COD. If we replace these numbers in the above formula, we derive the Pollution Unit per Person (APU). If we relate the cost of "cleaning" this Pollution Unit to the charge that will be put to the industries, we come with an objective and fair method to calculate the magnitude of the charge. For example, one industry that pollutes like 1000 persons will pay 1000 times the charge for one person. The quantity of water used is also a significant factor because the water is seen as a natural resource "wasted" in the waste treatment, and so the environmental cost should also be calculated.
One PU is defined by 60% by the organic matter, and by 40% by the suspended solids. The inclusion of more parameters in the model will transform these weights according to the importance of the pollution parameter that will be included.
We would like to note that for the implementation of the model in a larger scale, there is a need to calculate more pollution indicators (phosphates, nitrates, heavy metals, pesticides, insecticides, etc), which do not play a significant role in the operation of the canning industry. Similar models are used in various parts of the world, such as in Belgium, the Netherlands, Germany, the UK, the USA, Brazil, the Czech Republic, Poland, etc. The formula we propose was formed after comparisons among these models, and taking into consideration the particularities of Greece, especially in the definition of the APU. [EPA (1992, 1995, 1997), European Commission, OECD (1980, 1994), Pearce]
The imposed charge is calculated based on the following formula:

$$t_i = a_i \times F$$

where t_i is the charge per PU that the i-th source is paying, α_i is the "transport coefficient" of the i-th source, and F is the marginal cost of reducing the concentration of the pollution load by one PU in the receptor, and should directly mirror the real environmental cost of the pollution, which is estimated according to the APU and to the cost of cleaning up the pollution that is caused by one APU. We initially estimated this cost to reach 5.475drch/year or 15drch/day, which is the average cost of a biological treatment plant to "clean" one such unit. [EPA (1997), European

Commission, O.A.Th., Stamou] Since we did not have the necessary information to calculate the "transport coefficient", for each source, its value was set to one (1) for all the sources.

Hence, each source pays

$X = t_i$ x PU, or, since all transport coefficients are equal to one,

X = F x PU

where X is the final charge, t_i is the charge per PU that the i-th source is paying, and PU is the number of Pollution Units that the source discharges during its operation.

The cost of cleaning the pollution has been approximated with the use of the cost to treat and cleanup municipal waste, for which there is information originating from the treatment authorities in Greece. The cost of treatment of municipal waste is approx. 10-20 drachmas per PU. [O.A.Th., Stamou, personal communications with industry representatives].

Also the above charge has been compared with corresponding charges of other members of the European Union, for the pollution that is created by industries and also by households. The following charges exist for the corresponding "Pollution Units" (which are calculated with a very similar qualitative and quantitative way to the one that we use in this case) of these countries: [European Commission].

Germany	2.70 DM/m^3	or	81 drch/PU
Netherlands	30-90 Euros/year	or	27-81 drch/PU
Belgium	9-22.1 Euros/year	or	8-20 drch/PU
UK	1.88 Euros/m^3	or	93 drch/PU
France	0.9 Euros/m^3	or	45 drch/PU

All the above should be accompanied by a pilot implementation and testing on the industries' operation, and be modified accordingly to the possible change in the pollution activity of the industries in the coming years. An important factor will also be the general state and development of the area, as well as a much needed hydrogeological survey of the area. Then a model, which accurately reflects the environmental degradation of the area and its relation to the pollution activity, can be developed.

iii) Application

Data for the concentrations of BOD, COD, and SS were collected for1998 and 1999. According to the model presented, total charges per pollution unit to various rates of pollution are presented in the following indicative tables. From the total charges we subtract the charges that correspond to the pollution units that are discharged within the limits set by the Greek and the European legislation, and which are 60mg/lt BOD, 150mg/lt COD and 60mg/lt SS. In the tables we present information for what corresponds to the two biggest polluting industries, and to the less polluting one, both in peach and tomato canning.

Peach canning - Pollution activity

Exit of biological treatment facility – water load of 150m^3/hour

	24hours operation			16hours operation			8hours operation				
	max1	max2	min	max1	max2	Min	max1	max2	min		
BOD	1548	1113	9	1548	1113	9	1548	1113	9		
COD	3764	2445	77	3764	2445	77	3764	2445	77		
SS	140	880	40	140	880	40	140	880	40		
PU	84560	70132	1780	56373	46755	1187	28187	23377	593		
PU of limits	4200	4200	4200	2800	2800	2800	1400	1400	1400		
PU final	80360	65932	-2420	53573	43955	-1613	26787	21977	-807		
	1.607.200	1.318.640	-48.400	1.071.467	879.093	-32.267	535.733	439.547	-16.133	20	drch/PU
Charge/	1.205.400	988.980	-36.300	803.600	659.320	-24.200	401.800	329.660	-12.100	15	drch/PU
day of	964.320	791.184	-29.040	642.880	527.456	-19.360	321.440	263.728	-9.680	12	drch/PU
operation	803.600	659.320	-24.200	535.733	439.547	-16.133	267.867	219.773	-8.067	10	drch/PU
	642.880	527.456	-19.360	428.587	351.637	-12.907	214.293	175.819	-6.453	8	drch/PU
	401.800	329.660	-12.100	267.867	219.773	-8.067	133.933	109.887	-4.033	5	drch/PU

Tomato canning - Pollution activity

Exit of biological treatment facility – water load of 150m^3/hour

	24hours operation			16hours operation			8hours operation				
	max1	max2	min	max1	max2	Min	max1	max2	min		
BOD	1108	254	2	1108	254	2	1108	254	2		
COD	2264	461	15	2264	461	15	2264	461	15		
SS	2100	38	8	2100	38	8	2100	38	8		
MP	87360	12236	356	58240	8157	237	29120	4079	119		
PU of limits	4200	4200	4200	2800	2800	2800	1400	1400	1400		
PU final	83160	8036	-3844	55440	5357	-2563	27720	2679	-1281		
	1.663.200	160.720	-76.880	1.071.467	879.093	-32.267	535.733	439.547	-16.133	20	drch/PU
Charge/	1.247.400	120.540	-57.660	803.600	659.320	-24.200	401.800	329.660	-12.100	15	drch/PU
day of	997.920	96.432	-46.128	642.880	527.456	-19.360	321.440	263.728	-9.680	12	drch/PU
operation	831.600	80.360	-38.440	535.733	439.547	-16.133	267.867	219.773	-8.067	10	drch/PU
	665.280	64.288	-30.752	428.587	351.637	-12.907	214.293	175.819	-6.453	8	drch/PU
	415.800	40.180	-19.220	267.867	219.773	-8.067	133.933	109.887	-4.033	5	drch/PU

iv) Environmental impact

The most important economic advantage of a pollution charge system is its cost-effectiveness. Since the target is to eliminate the untreated waste discharged, and the maintenance of acceptable environmental conditions in the area, a system like the one proposed achieves this target with the minimum cost. With such a system when a company incurs larger costs when it pollutes than when it operates anti-pollution equipment, then it chooses to operate the anti-pollution equipment. While a company that has a larger cost of anti-pollution equipment operation than of the pollution charges, then it chooses to pollute [Bromley (1989), Randall, Tietenberg].

The implementation of the polluter-pays-principle can of course also lead to better environmental conditions in the area. This happens when the principle's implementation creates incentives for the industries to decrease pollution discharges. This in turn happens when the charge relates to the pollution discharges, a situation that holds true in the Imathia case. Also the charge should be sufficiently large so that the industries will have a bigger financial burden when they pollute than when they operate waste treatment facilities.

Beside the temporary reduction in discharged pollution, the implementation of the system leads to constant investment and research and development in anti-pollution technology, aiming at the largest possible reduction of the discharges. This creates a positive externality for companies of environmental research and technology, which grow and create new wealth for the economy (and new jobs).

In conclusion, the implementation of the **polluter-pays-principle** will result in

- controlling the pollution in the region as far as possible,
- putting a cost barrier at the use of environment as a receiver of everyone's wastes,
- creating a new kind of approach and rendering governmental bodies in charge, more sensitive to the crucial, though constantly neglected, environmental matters of the region
- putting an end at the dissipation of natural resources,
- providing an environment of fair competition for all the activities in the region
- inducing the development of the area providing for the optimum socio-economic criteria

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