XX IASP WORLD CONFERENCE ON SCIENCE AND TECHNOLOGY PARKS
June 1-4, 2003 - Lisbon, Portugal

INNOVATION FOR A CLEAN ENVIRONMENT: THE CASE OF PORTUGUESE INDUSTRIES

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ABSTRACT

As a result of industrialization and the ensuing rapid increase in greenhouse gases in our atmosphere, most scientists agree that the earth's surface temperature will rise over the next decades. The UN's International Panel on Climate Change is eleven degrees Fahrenheit by the year 2100. The extent of the warming is uncertain, but during the ice age, the earth average surface temperature was only nine degrees Fahrenheit colder than it is today (Tietenberg, 2000).
It is really important to detect signals in the environment about potential for change. These innovations could take the form of new technological products, processes, equipments or legislation due to social pressure (Tidd, 1999).
This paper aims at analysing the behaviour and the implementation of innovation strategies for a clean environment by potential polluting industries in Portugal. Thus, a statistical model, with a confidence level of λ=95%, allows concluding that the mean value for the clean environmental strategies under analysis is medium x_m=3.1. However, environmental innovation programs aims at reducing air/water/soil pollution has high level x_m=3.7.
Additionally, in a high or very high level, 78% of the industries are introducing innovation in their production processes, as well as 45% of the industries are introducing eco-machinery in the plant.
The data analysis reveals that there are 5 groups of industries implementing differently the ten clean environmental strategies, under research.

INTRODUTION

Intelligent environmental strategic management in polluting industries can therefore play a vital contribution to raise our quality of life. (Henriques and Sadorsky, 1996; Porter and Linde, 1995). Also with the rising awareness of global ecological issues, consumers and ecological lobbies will increasingly require companies to accelerate implementation of cleaner production processes. They will force governments to respect anti-pollution laws, in particular the polluter-payer principle (Brockhoff et al., 1999; European Commission, 2000a, 2000b). Other authors suggest that environmental leadership can deliver competitive advantages, since companies will thereby improve their public image and market position, thus boosting sales and profits (Eaty and Porter, 1998, Klassen and McLaughlin, 1996; Prakash, 2001, Roy et al., 2001; Shrivastava, 1995). Most companies recognise the importance of innovation for a clean environment (Sarmento e Duarte, 2003).

At the present time, the environmental considerations transcend the perspective of the single company, they bring into focus the views of many other stockholders in the research, development and commercialization activities of companies, such as customers, suppliers, local and central government (Whalley and Whitehead, 1994).

Companies' impacts on the environment are determined by (1) the type and volume of goods and energy they use in there product processes and (2) the type of production system installed and used to supply those goods. In a context of a clean environment, companies can innovate at several levels to minimize the environmental impacts that they generate. Therefore the main types of innovation are specially addressed to:

- Product: changing it by another one, that is green. Furthermore the green product can be reused or recycled totally or some of its component parts.
- Production processes: making any change to reduce the natural resources or energy consumption or even the use of a renewable energy. These new processes often need a reconfiguration of the existing production chains, including the introduction of loops in the underlying production chains and the replacement of former technologies.
- Technology and equipment: substituting or transforming the existing in a clean one, reducing solid or liquid waste, polluting emissions and effluents.
- Waste: reducing, recycling and/or reusing it to avoid or reduce serious pollution of the air, of the groundwater and other environmental resources.
- Pollution: reducing the negative environmental impacts of company's activities on air, water and soil, that can be subject to some societal control.

The analysis and evaluation of innovation for a clean environment takes an integrative and holistic approach of the management. Nevertheless, the research presented in this paper is a window in the complexity of dimensions that influence innovation for a clean environment. This research is the continuation of the work that involves macro and micro environmental strategies for a clean environment that the authors are studying (Duarte, 2001; Sarmento and Duarte, 2001, 2003).

OBJECTIVES

The objective of this paper is to analyse the innovation for a clean environment in a Portuguese context through an inquiry answered by potential polluting companies.

The survey was sent to 480 large-, medium- and small-size enterprises, located throughout Portugal within the industrial sectors that are considered to be amongst the highest polluters (National Institute of Statistics, 2000). The paper presents the data analysis methodology, the survey implementation and the sample identification. The statistical software package, SPSS 11.0, was used to analyse the survey response database.

The research intends to identify and characterise groups of companies that share comparable clean environmental strategies. Thus, the Cluster analysis applied to the data allowed the identification of these groups of companies sharing relatively homogeneous clean

environmental strategies (Sarmento, 1997). On this basis, companies within any one group are implementing similar clean environmental strategies, distinct from those used by companies belonging to other groups.
The research also wishes to gauge industries' environmental concerns and the links between innovation and corporate characteristics. According to the statistical study, these results are correct for the population with a confidence level of λ=95%.

THEORETICAL FRAMEWORK FOR THE FORMULATION OF THE SURVEY

The present research on "Innovation for a Clean Environment: The Case of Portuguese Industries" is based on a survey, carried out between October 2002 and February 2003, composed of fifteen questions. The Likert scale with five levels, from 1=never to 5 =always, was used in order to assess each manager's assessment of the strategies pursued by his company.
The questions presented in the survey are based on the field experience that the authors have as consultants and researchers in this area (Sarmento, 1999a) and in a brainstorming session done with a panel composed by five top managers from industrial companies and one expert from the Ministry of Environment. Special attention was given to the total number of questions of the inquiry, in order to maximize the number of answers without affecting the global information to gather (Sarmento, 1999b). Long inquiries do not motivate the answers, and more than thirty questions and/or more than a sheet paper reduces the number of answers. The decision making about the four industry identification variables and the eleven questions about environmental innovation were selected during a brainstorming session (Sarmento, 1999c). The survey questionnaire was validated by the referred panel before starting the research, which was done by mail and e-mail.

DATA ANALYSIS METHODOLOGY

The statistical software package, SPSS 11.0, was used to analyse the database constituted with the answers. The statistical methods applied were as follows

- Descriptive analysis: to determine the frequency and percentage of company identification variables and the mean value, standard deviation, and maximum and minimum values of the ten factors under consideration;
- Bivariate analysis, namely the Chi-square test: to verify whether the survey responses depend on the industrial activity, size, location and head-office nationality of the potential polluting companies;
- Multivariate analysis, namely the:
  - Cluster analysis: to determine homogenous groups, whereby each element of a group is more similar to the other elements of that group than to the elements of any other group;
  - One-way analysis of variance: to check whether there are significant differences within the groups identified via cluster analysis and to characterise each group.

The research was based on a 500 survey questionnaires that were sent by post and e-mail to potential polluting companies in Portugal (National Institute of Statistics, 2000). In order to calculate the size (n) of the adequate sample of a finite population, which guarantees a confidence level (λ) and a precision level (D) for the population proportion (p), the following formula (1) was used:

$$n=\frac{p\times(1\text{-}p)}{\left[D/(z_{\alpha/2})\right]^2+\left[p\times(1\text{-}p)\right]/N} \qquad (1)$$

For a precision level of D=±5% and a confidence level of λ=95%, the normal distribution has the value $z_{\alpha/2}$=1.96. In the worst-case scenario, where dispersion is at a maximum, the proportion is p=0.5 (Sarmento, 2000c).
As a result, the sample should have the size of n=100 surveys. The database has 98 survey responses, however, 21 were rejected because they had several missing values. The response rate to the survey was 23.8%.

RESULTS OF THE SURVEY ADDRESSED TO POLLUTING INDUSTRIES FACING INNOVATION FOR A CLEAN ENVIRONMENT

The identification (industrial activity, size, location, and head office nationality) of industries belonging to the sample is shown in Figure 1. According to the statistical study, these results are accurate for the population assuming a confidence level of λ=95%.

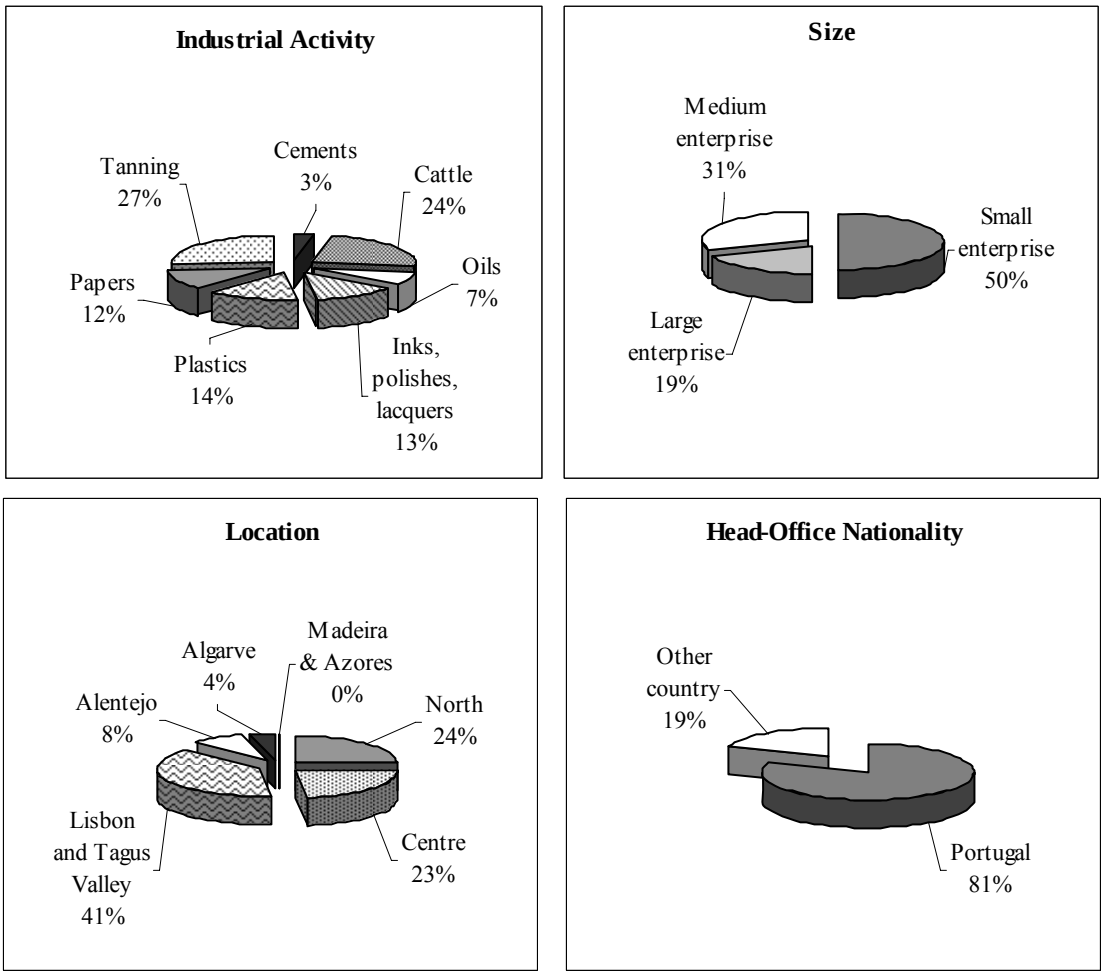

Figure 1. Industrial activity, size, location and head-office nationality of potential polluting companies.

Table 1 presents the mean values (x_m) and standard deviations (s) for the ten factors under research. These factors were chosen based on an empirical research done by the authors and also considering the clean environmental concerns of the selected panel composed by 5 top managers of potential polluting industries.

Table 1 Mean values and standard deviations of clean environmental strategies

Clean Environmental Strategies	Mean Value (x_m)	Standard Deviation (s)
1 Company introduces innovation in production the processes	3.4	1.1
2 Company introduces innovation using eco-machinery in the plant	3.0	0.8
3 Environmental innovation programs aims at reducing air/water/soil pollution	3.7	0.7
4 Raw resources and the incorporation products are considered green	3.0	0.9
5 Company uses external equipment to minimize the environmental impacts	3.4	1.0
6 Company evaluates the eco-indicators of the environmental efficiency	2.6	0.7
7 Company recycles the generated wastes during the production process	3.6	1.1
8 Company substitutes some commercial products with harmful environmental effects by green products	3.6	0.9
9 Company uses renewable energies	2.5	0.8
10 Employees have environmental training	2.3	0.6

The inquiry applies the Likert scale with five levels [1: never, 2: seldom, 3: sometimes, 4: often and
5: always]. "Environmental innovation programs aims at reducing air/water/soil pollution" has the mean values, x_m=3.7 showing that companies are highly concerned by environmental issues. "Employees have environmental training" has the lowest mean value x_m=2.3, meaning a weak level.

Figure 2 shows that 31% of surveyed companies had never suffered a polluting accident, therefore polluting accidents occurred mainly in the soil - 21% ("soil" - 12% and "soil and water" - 9%).

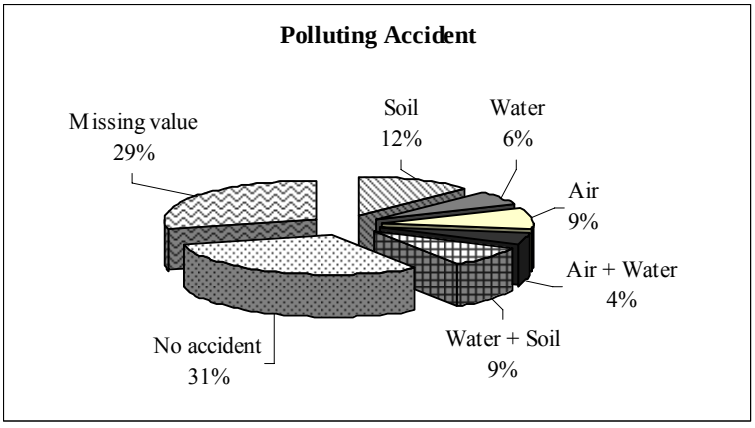

Figure 2. Percentage of polluting accidents.

RELATIONSHIP BETWEEN THE INDUSTRY IDENTIFICATION AND CLEAN ENVIRONMENTAL STRATEGIES IMPLEMENTED BY COMPANIES

To determine whether a strategy is dependent or independent of the activity, size, location and head-office nationality, the Chi-square test was used. Without detailing the theoretical aspects of this statistical method, it is relevant to emphasize that it compares the observed and expected frequencies of two variables of the sample and checks whether it is possible to accept the hypothesis of independence between these variables within the population. According to Newbold (1995) if Pearson significance is less than alpha significance α=5% there are no reasons to accept the independence between these variables. Table 2 presents the results and conclusions of the Chi-square test applied to clean strategies and to industry identification.

Table 2. Relationship between factors and industry identification.

Clean Strategies	Activity		Size		Location		Head-Office Nationality	
	Pearson Asymp. Signif.	Conclusion	Pearson Asymp. Signif.	Conclusion	Pearson Asymp. Signif.	Conclusion	Pearson Asymp. Signif.	Conclusion
1	0.001	Dependent	0.011	Dependent	0.767	Independent	0.212	Independent
2	0.004	Dependent	0.010	Dependent	0.434	Independent	0.312	Independent
3	0.057	Independent	0.675	Independent	0.857	Independent	0.912	Independent
4	0.032	Dependent	0.009	Dependent	0.007	Dependent	0.024	Dependent
5	0.876	Independent	0.008	Dependent	0.006	Dependent	0.121	Independent
6	0.041	Dependent	0.017	Dependent	0.342	Independent	0.326	Independent
7	0.749	Independent	0.786	Independent	0.231	Independent	0.422	Independent
8	0.323	Independent	0.536	Independent	0.630	Independent	0.002	Dependent
9	0.036	Dependent	0.032	Dependent	0.035	Dependent	0.018	Dependent
10	0.028	Dependent	0.078	Independent	0.122	Independent	0.010	Dependent

The opinions expressed in "environmental innovation programs aims at reducing air/water/soil pollution" and in "company recycles the generated wastes during the production process" are always independent of industrial activity, size, location and head-office nationality.
"Raw resources and the incorporation products are considered green" and "company uses renewable energies" are dependent on industrial activity, size and head-office nationality.
Table 3 reveals that the strategies implemented by Portuguese potential polluting companies are independent of activity 30%, location 70%, size and head-office nationality 40%.

Industry Identification	Dependent on Environmental Strategies	Independent on Environmental Strategies
Activity	70%	30%
Size	60%	40%
Location	30%	70%
Head-Office Nationality	60%	40%

Table 3. Percentage of dependent / independent environmental strategies in function of industry identification.

DETERMINATION OF GROUPS

Cluster analysis was used in order to identify groups of companies sharing relatively homogeneous clean environmental strategies (Sarmento, 1997). On this basis, companies within any one group are implementing similar strategies, distinct from those used by companies belonging to other groups.
Without detailing the theoretical aspects of this statistical method, it attempts to identify groups of companies based on ten clean environmental strategies, using a specific algorithm which definition is the following: Squared Euclidean distance for the similarity measure and the Ward method for clustering.
This analysis allows the conclusion that there are five strategic groups that aggregate the following number of companies:

- Group 1: 22 companies
- Group 2: 4 companies
- Group 3: 18 companies
- Group 4: 20 companies
- Group 5: 34 companies

The discriminant analysis demonstrates that 100% of assembled companies are correctly classified in the five groups.

VALIDATION OF THE FIVE STRATEGIC GROUPS

To validate and characterize the five groups identified in the cluster analysis, one-way analysis of variance was used.
The present objective is to apply statistic methods to strategic decision making and the theoretical details are presented by Sarmento (1999b). All the steps required for applying this method were accomplished, considering the significance level α=5%, whereby it can conclude that there are five different groups.
The mean values of the factors for each group are displayed in Table 4.

Clean Environmental Strategies	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Mean Value per Strategy**
	22.4%	5.1%	18.4%	20.4%	33.7%	100%
	22 cases	4 cases	18 cases	20 cases	34 cases	98 cases
1 Company introduces innovation in production the processes	3.9	4.1	3.6	3.4	2.9	3.4
2 Company introduces innovation using eco-machinery in the plant	3.6	3.9	3.2	3	2.4	3.0
3 Environmental innovation programs aims at reducing air/water/soil pollution	4.8	4.6	3.5	3.9	2.9	3.7
4 Raw resources and the incorporation products are considered green	3.2	2.9	3.2	3.4	2.4	3.0
5 Company uses external equipment to minimize the environmental impacts	4.0	4.5	3.7	3.2	2.7	3.4
6 Company evaluates the eco-indicators of the environmental efficiency	3.3	4.6	2.2	2.4	2.1	2.6
7 Company recycles the generated wastes during the production process	4.1	3	2.9	3.6	3.7	3.6
8 Company substitutes some commercial products with harmful environmental effects by green products	3.9	3.8	3.3	4.4	3.1	3.6
9 Company uses renewable energies	2.8	2.1	2.4	2.7	2.4	2.5
10 Employees have environmental training	2.9	1.9	1.7	3.3	1.6	2.3
Mean Value per Group	3.7	3.5	2.9	3.2	2.5	3.1

Table 4. Mean values of factors for each group.

Group 1 presents the maximum mean value (x_m=4.8) in the clean strategy "environmental innovation programs aims at reducing air/water/soil pollution". Nevertheless, "employees have environmental training" has the minimum mean value (x_m=1.6) in group 5.
Figure 3 illustrates the profile of each group in relation to the clean environmental strategies.

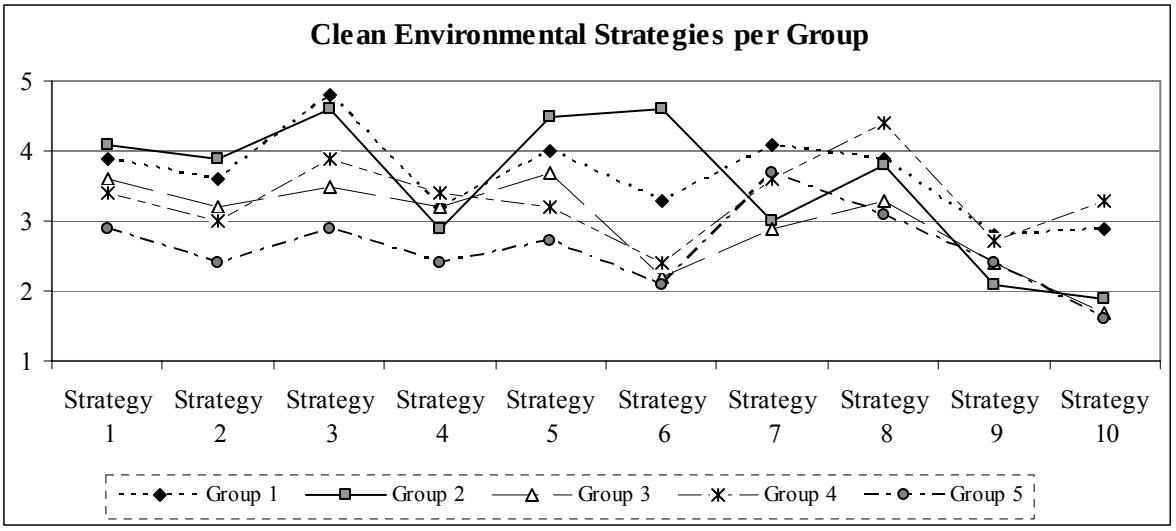

Figure 3. Clean environmental strategies per group.

The best strategy is "environmental innovation programs aims at reducing air/water/soil pollution" in group 1 and the worth is "employees have environmental training" in group 3.
To confirm this conclusion we apply the Scheffé test, whereby for each one of the ten factors, each of the five groups is significantly different from the others (Sarmento, 1999b).
In fact, the F and Scheffé tests, as well as the mean values of factors per group are crucial for defining the environmental strategies implemented in each group of industries.

Table 5 shows the activity, size, location and head-office nationality for each group in percentage.

Identification Characteristics of Industries		**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Total**
		22 ind.	4 ind.	18 ind.	20 ind.	34 ind.	98 industries
		22.4%	5.1%	18.4%	20.4%	33.7%	100%
		x_m=3.7	x_m=3.5	x_m=2.9	x_m=3.2	x_m=2.5	x_m=3.1
Activity	Oil	4.5%	25.0%				2.0%
	Paint, ink, polish & lacquer	9.1%		11.1%	60.0%		16.3%
	Plastic	54.5%			10.0%		14.3%
	Paper	31.8%			30.0%		13.3%
	Tanning			88.9%		20.6%	23.5%
	Cement		75.0%				3.1%
	Cattle					79.4%	27.6%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Size	Large entreprise	45.5%	100.0%				21.4%
	Medium enterprise	54.5%		38.9%	65.0%	8.8%	33.7%
	Small enterprise			61.1%	35.0%	91.2%	44.9%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Location	North	36.4%				20.6%	15.3%
	Centre	31.8%		50.0%		17.6%	19.4%
	Lisbon and Tagus Valley	27.3%	50.0%	33.3%	80.0%	47.1%	50.0%
	Alentejo	4.5%	25.0%	16.7%	20.0%	14.7%	14.3%

	Algarve		25.0%				1.0%
	Madeira & Azores						
	Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Head Office	Portuguese	63.6%	75.0%	100.0%	90.0%	82.4%	82.7%
	Other country	36.4%	25.0%		10.0%	17.6%	17.3%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

*Table 5. I*dentification variables for each group.

CHARACTERIZATION OF THE ENVIRONMENTAL STRATEGIC GROUPS

As showed in previous section and as far as the implementations of the innovation strategies for a clean environment are concerned, the industries of the sample can be aggregated into five clean environmental strategic groups.

Each group has a distinct approach relatively to the clean innovation strategies and four identification variables.

- **Group 1**:

  Identification characteristics: This group of industries represents 22.4% of the sample. It includes companies pertaining to four industrial activities, whereby plastic companies represent 54.5% of the group and paper companies 31.8%. Large- and medium-size industries represent 100% of the group. 36.4% of industries are located in the north and 31.8% in the centre of Portugal. The industries of this group are 63.6% Portuguese and 36.4% are foreign companies.

  Environmental strategies: This group has a mean value of x_m=3.7, denoting that companies have high concerns regarding the ten clean environmental strategies.

  The companies pertaining to this group have strong environmental innovation programs aims at reducing air/water/soil pollution (x_m=4.8), and they also recycle the generated wastes during the production process in a high level (x_m=4.1).

  Alternatively these companies assume that have moderate environmental training (x_m=2.9), as well as the use of renewable energies (x_m=2.8).

- **Group 2**:

  Identification characteristics: This group of industries is the smallest of the sample representing 5.1%. Among the five groups, this has the highest percentage of cement companies - 75%, of large enterprises - 100% and of industries located in Lisbon and Tagus Valley- 50%. Foreign companies represent 25% of the group.

  Environmental strategies: The companies belonging to this group have strong environmental innovation programs aims at reducing air/water/soil pollution (x_m=4.6) and the companies evaluate the eco-indicators of the environmental efficiency in a very high level (x_m=4.6). But, in a weak level they use renewable energies (x_m=2.1) and also the employees' environmental training (x_m=1.9).

- **Group 3**:

  Identification characteristics: This group of industries represents 18.4%, located in Centre - 50%. All are Portuguese - 100% and 61.1% are small companies.

  Environmental strategies: Group 3 has a mean value of x_m=2.9 which means that companies demonstrate some interest on the ten clean environment strategies under investigation.

  The companies pertaining to this group use strongly external equipment to minimize the environmental impacts (x_m=3.7) and they also strongly introduce innovation in production process (x_m=3.6). Nevertheless, evaluation of eco-indicators is also weak (x_m=2.2) and the employees' environmental training is low (x_m=1.7).

- **Group 4**:

Identification characteristics: This group of industries represents 20.4% of the sample. 60% are paint, ink, polish and lacquer companies. 65% are medium-size enterprises, 80% are located in Lisbon and Valley region and 90% are Portuguese.

Environmental strategies: This group has a mean value of x_m=3.2, expressing a moderate concern in the ten clean environmental strategies.

The companies belonging to this group are very concerned with the substitution of some commercial products with harmful environmental effects by green products (x_m=4.4), as well as with the environmental innovation programs, in order to reduce air/water/soil pollution (x_m=3.9). However, in a low level, companies use renewable energies (x_m=2.7) and evaluate the eco-indicators of the environmental efficiency (x_m=2.4).

- **Group 5**:

  Identification characteristics: This group of companies is the largest, representing 33.7% of the sample. Of all groups, this has the highest percentage of cattle companies – 79.4%, of small-size enterprises – 91.2% and 82.4% of companies are Portuguese, located throughout Portugal.

  Environmental strategies: This group has a mean value of x_m=2.5, expressing a low level of concern in the ten clean environmental strategies. This group of companies recycles the generated wastes during the production process, in a high level (x_m=3.7) and they also have a moderate level for substituting some commercial products with harmful environmental effects by green products (x_m=3.1). On the other hand, in a low level, they evaluate eco-indicators (x_m=2.1), as well as the employees' environmental training is weak (x_m=1.6).

Globally, the companies involved in this research are moderately implementing the ten clean environmental strategies (x_m=3.1).

CONCLUSIONS

The main purpose of the research presented in this paper is to analyse the clean environmental innovation strategies of potential polluting companies. Strategic profiles of industries were studied on the basis of ten clean environmental strategies and four company's identification variables.

This research was based on a survey that had 98 valid answers which were processed using the statistical software package SPSS 11.0 and the conclusions are valid for the population with a confidence level of λ=95%.

During the presentation of the statistical results some conclusions were already mentioned. This research identifies that there are five organised groups of potential polluting companies in respect to the clean environmental strategies.

The data analysis reveals that most companies are innovating for reducing or eliminating pollution (Group 2), or some companies recycle the generated wastes during the production process (Group 5) or even other companies are using external equipment to minimize the environmental impacts (Group 3). Indeed, a large number of companies (Group 2, 3 and 5) still consider that their employees have no need of environmental training.

Nevertheless, companies are in general concerned with innovation and almost all groups are implementing innovation strategies for a clean environment.

The results also suggest that large environmental efforts of innovation are positively related with company size (Group 1 and 2). Small enterprises have less environmental innovation and lower employees' environmental training.

On the basis of our knowledge about the sector and the interviews with top managers, it is possible to conclude that environmental innovation matters in Portugal are better than they were a decade ago.

In fact, companies are very concerned with the environment, given that for the environmental innovation programs aims at reducing air/water/soil pollution in a high level, since for group 1 the mean value is x_m=4.8, and for group 2 is x_m=4.6.

The implementations of clean environmental strategies are dependent on the industrial activity in 70%, head office nationality and size in 60% and location in 30%.

Globally, the implementation of clean environmental strategies is moderate (x_m=3.1) for the 98 potential polluting companies analysed.
Finally, it is certain that the success of the implementation of the environmental innovation in industrial companies will give rise to a higher quality of life for citizens.

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