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Evaluation of Industrial Policies on the Boom of Domestic Production of Advanced Ceramics Based on an Approach to Environmental Protection

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ABSTRACT

Each year, production of ceramic materials causes many environmental repercussions including air and soil pollution. In addition, due to their nature, industrial environments are susceptible to serious damages and risks that can be potentially exacerbated with the increasing growth of technology. In this regard, the current study aims to evaluate the policies on the prosperity of the domestic production of advanced ceramics with the approach to environmental protection. The current research is among the mixed and exploratory researches that was carried out in two qualitative and quantitative stages. The statistical population includes the senior and executive managers of the "advanced ceramics production industries" in the Ministry of Industry, Mining, and Trade, Iran. This study used the document review tools and semi-structured interviews with 14 academic and executive experts in this industrial field. Based on the "theme analysis" method in this research, the results and consequences of industrial policy assessment were extracted according to the environmental protection approach and finally, these policies were evaluated. The results of this evaluation showed that although some of the production processes of ceramic materials have been modified based on the environmental policies, some other processes are still inconsistent with environmental policies and requirements; therefore, the extent of pollutants in the industrial processes is not accurately monitored and measured, and the level of pollutants in most industrial places is more than the standard level.

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1. INTRODUCTION

The world has been witnessing the emergence and advancement of various forms of changing technologies including information technology, biotechnology, energy, and advanced materials, to name a few. The technologies are expected to have a tremendous economic impact by 2025. Such technologies have four general characteristics in common namely their rapid rate of change, wide area of impact, significant impact on the economic value at a high level, and considerable potential to economic impacts as a projector [1]. One of these technologies is advanced ceramic materials. Advanced ceramics have been included in the list of

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highly important and strategic components in many industries owing to their properties such as stability at high temperatures, high strength and resistance to corrosion, and unique magnetic and electrical properties such as piezoelectricity, superconductivity, insulation or semi-conductivity, etc. In the last 60 years, extensive research has been conducted on 25 different groups of advanced ceramics, which facilitated their vast productions. In recent years, the flourish and expansion of the electronics industry as well as the broad application of advanced ceramics in medical technologies and automobile manufacturing industries has led to the significant growth of the advanced ceramics market and now, these ceramics account for about 50 billion dollars share in the market. In short, since the beginning of the 21^{st} century, some areas such as photonics, biological sciences, and material technology have been assumed to be the most important areas of scientific and industrial progress, and ceramics has been playing a strategic role in all these areas since then. In Iran, like many other parts of the world, a great deal of attention has been paid to these new fields and applications of ceramics and new materials in recent years.

In non-metallic industries, production and progress of tiles and ceramics have caused many environmental problems including air and soil pollution as well as waste production. It goes without saying that the industrial environments are exposed to serious damages that can be potentially intensified and expanded with the increasing growth of technological advancements [2].

For this reason, many international meetings were held in the last years to prevent further environmental destructions in the global scale, and the Islamic Republic of Iran has participated in many of these meetings. It is also committed to taking effective measures in line with the objectives stated in this convention to comply with the environmental requirements [3]. In this regard, more attention has been significantly paid to the evaluation of green industrial policies in recent decades. Governments around the world have intensified their efforts to institutionalize the evaluation of these policies for more efficient, effective, and democratic decision-making [4]. Given the implementation of industrial policies on the boom of production in recent years, it is necessary to make a detailed evaluation of these policies to determine to what extent these policies have been in line with the environmental policies and also to what extent the results of the implementation of these policies could meet the expectations in the field of environment.

2. INDUSTRIAL POLICIES WITH AN ENVIRONMENTAL APPROACH

Industrial policy is about anticipating long-term trends in technology and market development and providing incentives to adapt the structure of the national economy in a way that can take advantage of changes. As climate change and other environmental challenges increasingly affect the future direction of economic development, environmental considerations should become a major part of industrial policy [5]. The main objective of environmental policies is the protection and sustainable use of our natural environment. Intentionally or unintentionally, some of these policies cause structural changes. In these cases, green industrial policy is proposed to include any government action aimed at accelerating the structural transformation towards a low-carbon and resource-efficient economy to flourish productivity in economy [6]. In order to create sustainable economic development, the rate of resource productivity should increase at least with the same amount of economic production. For this purpose, many commercial leaps are technologically possible such as switching to renewable energy, using smart and communication systems, implementing energy-saving technologies, and considering the changes in consumers' behavior. However, to accelerate the required technological and business model innovations, the economic incentives must be very different. Above all, environmental costs should be much better reflected in prices, regulations should be tightened, and subsidies for fossil fuels and other unsustainable products and practices should be reduced. Of note, the global economy is on an unstable path. To be specific, since the Industrial Revolution, the global economy has grown at the expense of destroying the environment. Natural resources have been exploited without permission, pollutants have been accumulated in the biosphere, ecosystems have been severely degraded, and biodiversity has been lost at an alarming rate. Already in the early 2000s, the Millennium Ecosystem Assessment, an UN-led global assessment of the Earth's ecosystems, concluded that about 60 % of ecosystem services have been exploited or used in unsustainable manners.

3. ADVANCED CERAMICS

The term "advanced ceramics" was first coined in the 1970s to designate a new category of engineering materials to introduce new technologies into the 21^{st} century. Since then, there has been phenomenal growth in the technological advancement of these materials. A report from Research and Markets projected the advanced ceramics market to reach US$ 10.4 billion by 2021, growing at a Compounded Annual Growth Rate (CAGR) of 6.5 % [7]. Advanced ceramics are considered integral parts of modern technology. Most of these products perform crucial functions behind the scenes in a number of applications in everyday life. They usually exhibit admirable performance that cannot be easily replicated by other materials [8]. Advanced ceramics today play a key role in technologies such as energy and environment, transport, life sciences, and communication and information technology [9].

Advanced ceramics exhibit phenomenal performance under severe conditions in a number of areas, including transport, energy and environment, health, high-temperature, electronic, and wear-related applications. However, they have yet to attain the long-expected broad market penetration, especially on the African continent. To be specific, the growth of advanced ceramics usage has been hindered mainly due to the low reliability, brittleness, unfamiliarity to potential users, redesign requirements, and high cost of components. Research and development have led to significant improvements in the properties of advanced ceramics. The past few decades have witnessed the emergence of newer technologies which demand more advanced and higher performance engineering materials in a wide range of applications. Advanced ceramic materials have surpassed a majority of their traditional engineering counterparts and remained uncontested in a wide range of applications. The phenomenal growth experienced is testimony to this. This has been driven mainly by the Asian markets, especially China and Japan [10].

In the last few decades, rapid development in modern communication devices such as cellular telephones, antennae, and global positioning systems has encouraged more thorough research in microwave dielectric materials. Dielectric ceramics are widely used in advanced electronic devices such as capacitors and microwave resonators. They are classified into two broad groups based on their dielectric properties. High quality factor materials are characterized by linear changes in polarization with applied electric field [11].

Thermoelectric (TE) ceramic materials can directly convert heat energy into electrical energy due to the TE effects. A majority of TE devices operating at approximately room temperature are based on bismuth telluride (Bi_2Te_3) and its alloys [12].

The ceramic industry, like all other resources that deal with the transfer and processing of raw materials, has a great impact on the surrounding environment. In fact, a ceramic factory is an open system that receives raw materials, water, fuel, and electricity from the environment, processes and exhaust gases, and produces solid and liquid sewage waste, thermal energy, and smoke.

It should be noted that a ceramic factory has less pollution than many other sources because a significant part of the pollutants created in this industry, especially the solid particles, can be effectively separated at low costs from its entry into the atmosphere. However, the resulting problems should not be underestimated, especially when many factories are concentrated in one area. Fortunately, as a result of preventive measures and awareness, pollutants have been greatly reduced in recent years. Technological advances are one of the important reasons for this pollution reduction [13].

4. RESEARCH METHODLOGY

In this research, the contents of the policies and laws concerning the environmental priorities were examined as follows:

- Article 50 of the Constitution of the Islamic Republic of Iran.
- Economic and other activities that are associated with environmental pollution or irreparable destruction are prohibited.
- Clause 8-1 of General environmental policies (communicated by the Supreme Leader on 8/26/1394).

1-8- Low carbon industry, use of clean energy, healthy and organic agricultural products, and management of wastes and effluents should be prioritized by taking advantage of economic, social, natural, and environmental capabilities.

Followed by interviewing with 14 experts in this field, the basic concepts were extracted, and a thematic analysis method was employed to analyze the data. The interviewees were selected purposefully based on the snowball method. In this method, each expert introduces another expert, and the interview continues until the desired theoretical saturation is reached. During this process, those experts who had the necessary criteria were selected. These criteria were practical experience (i.e., executive experience in the field of industrial policy, especially in production), related field of study (management or engineering field concerning the Ceramics production industry), higher education (master's degree or doctorate), and acquaintance with the field of industrial policies. The characteristics of the mentioned interviewees are briefly listed in Table 1.

TABLE 1. Characteristics of the interviewees

Interviewees	Characteristics	Number
University professors	Faculty Members of the university-PhD Students in the fields of Management (preferably policy orientation) and Non-metallic Materials	5
Representative of the Islamic Council	Representative of the 10th term of the parliament and member of the 6th development plan compilation commission	1
Excellent managers	Managers of Ceramics production industries	2
Managers and senior experts	Relevant people working in developing production promotion policies-managers of Ceramics production industries	6

In the current research, according to the saturation approach, 14 experts were selected as the sample group. After interviewing 11 experts, the answers of the next experts became similar to those of the previous ones, and the content became repetitive until after the interview with the 13th expert, his knowledge reached theoretical saturation. However, in order to enhance the data practicality, the interviews continued until the 14th experience. Due to the qualitative nature of the theme analysis method, quantitative criteria and positivist approach were not used to control the validity and reliability of the present study; rather, as stated by Guba and Lincoln, the criteria of believability, reliability, verifiability, and transferability [14] were taken into consideration. Here, the following four procedures are used: doing the self-coding test [15], using independent coders, receiving feedback from the interviewees while providing a rich description, and recording the details of the investigations.

5. DATA ANALYSIS AND FINDINGS

By conducting the theme analysis, 172 primary concepts were extracted in the first step. In the next step, after coding the texts, 18 descriptive codes (basic theme) were finally extracted by combining the identified codes based on the degree of conceptual similarity. After analyzing the codes, 10 interpretive codes (organizing theme) were obtained and finally, two relational codes (overarching theme) were obtained through the final review. In order to validate the results based on the Delphi technique as well as the definition of the subject and required expertise, the members of the Delphi panel were selected in three stages through the judgmental non-random sampling method. The first round was done after extracting the primary components from theoretical texts and creating a semi-standard questionnaire. The questionnaire was designed containing two relational codes, five interpretive codes, and 15 descriptive codes. The respondents were asked to answer the question "How effective is each of the dimensions, components, and indicators in the model for evaluating the effectiveness of industrial policies related to production boom?". A five-point Likert scale was used to measure them. After completing and collecting the distributed questionnaires, the results of the first stage were analyzed. According to the opinions of the first round of the panel, three interpretative codes and four descriptive codes that had lower-than-mean agreement and importance were discarded and removed, and no new indigenous codes were added to the experts' suggestion. In the second round, Delphi, once the factors that did not reach consensus in the previous stage were removed, the questionnaire was given to the panel members again. The Kendall coefficient for the second stage questionnaire was 0.653 with the significance level of 0.05. In the third round, the questionnaire was again provided to the panel members. The Kendall coefficient for the third-stage questionnaire was 0.731 with the significance level of 0.05. According to Schmidt, the degree of consensus and unanimity of the members in the second stage, compared to the third stage, increased up to 0.078, and the growth rate of two consecutive periods is quite high. In addition, since the number of panel members is more than 5, a very small amount of W is considered significant; therefore, the repetition of Delphi courses was stopped. After collecting the experts' opinions and adding/subtracting some codes (with the Delphi method), two relational codes, five interpretive codes, and 15 descriptive codes were finally obtained and listed in Table 2.

TABLE 2. Descriptive, interpretive, and relational codes extracted from the present research (researcher-made)

Descriptive Codes	Interpretation Codes	Relational Codes
Development of green spaces to the extent of the development of industrial places Green space maintenance and its effectiveness	Development of green space	Management of natural resources and green space
Use of clean energy Preventing environmentally destructive activities Encouraging environmentally friendly technologies Crimes for entities and persons who violate environmental affairs	Environmental Protection	
Installation of notification and fire extinguishing in industrial places Modifying production processes based on environmental policies Management and control of hazardous and flammable materials and explosions	Compliance with environmental requirements and standards	
Monitoring and controlling the extent of pollutants in industrial processes Air pollutants are under control Reducing the production of industrial pollutants Cleaning up the industrial pollutants	Industrial pollutants	Management of waste and pollutants
Separation of industrial wastes and determination of their duties Management and engineering measures to reduce waste	Effluent and industrial waste	

In order to measure the effectiveness of industrial policies based on environmental protection, it is necessary to check whether a valuable result has been obtained by implementing these policies [16]. Therefore, a survey was conducted with 200 managers, experts, and specialists related to the industry through a questionnaire.

It should be mentioned that it is possible to use the statistical indicators provided by the Statistics Center of Iran, the Central Bank of the Islamic Republic of Iran, and the Strategic Research Center of Expediency Council to directly evaluate the effectiveness of these policies. Nevertheless, there are doubts raised by the scientific community about these data and also some statistical indicators are calculated using artificial methods which lead to different results [16]. Therefore, to evaluate the effectiveness of these policies, the mentioned method was used. The results of this test will be discussed below. To implement statistical methods and calculate appropriate test statistics and logical inferences about research hypotheses; the most important action is to choose the appropriate statistical method for the research before any action. For this purpose, knowledge of data distribution has a basic priority. In this research, the Kolmogorov-Smirnov test was used to check the assumption of normality of the research data. The result of this test is shown in Table 3. Because the sig obtained for all variables is greater than 0.05, it can be concluded that the research hypothesis is rejected and the null hypothesis is confirmed, as a result, the data distribution of all variables is normal.

As shown in Table 3, in all cases, a significance value greater than 0.05 was obtained. Therefore, there is no justification to reject the null hypothesis based on the normality of the data. In other words, the distribution of the research data is normal; hence, the parametric tests can be done.

TABLE 3. Calculation of the Kolmogorov-Smirnov test

Components	**Number**	**Normal parameters**		**The maximum amount of differences**			**The value of the test statistic**	**The significance level of Sig**	**Test result (normal distribution)**
		Mean	Standard Deviation	Absolute	Positive	Negative			
Effluent and industrial waste	200	3.1250	1.31071	0.178	0.113	-0.178	1.178	0.445	✓
Industrial pollutants	200	3.1888	0.61875	0.143	0.086	-0.143	1.143	0.224	✓
Management of waste and pollutants	200	3.0375	0.90495	0.175	0.110	-0.175	1.175	0.125	✓
Development of green space	200	3.0683	0.78604	0.142	0.080	-0.142	1.142	0.127	✓
Environmental Protection	200	3.2183	0.69744	0.122	0.095	-0.122	1.122	0.075	✓
Compliance with environmental requirements and standards	200	3.1600	0.90332	0.147	0.088	-0.147	1.147	0.122	✓
Management of natural resources and green space	200	3.1255	0.46872	0.100	0.076	-0.100	1.100	0.113	✓

6. INVESTIGATING THE EFFECTIVENESS OF INDUSTRIAL POLICIES WITH THE APPROACH TO ENVIRONMENTAL PROTECTION

To measure the effectiveness of these policies, 14 interview questions were designed, considering the indicators identified for the indicators related to the research topic, in the form of a questionnaire in a five-point scale and then, the questionnaires were given to 200 experts in this field. Next, the collected data was evaluated using a one-group t-test. Table 4 also shows the results of the one-sample t-test to examine the current status of indicators for evaluating the effectiveness of industrial policies with the approach of environmental protection.

According to the questionnaire scale, which was a five-point Likert one, the basis of the decision was considered on a score of 3. As Table 5 shows, regarding natural resources and green space management indicators, the t statistic calculated 3.816, 3.110, and 2.514 in the indicators "with the implementation of industrial policies, green space has been developed to the extent of the development of industrial places", "with the implementation of industrial policies, there is a written program for the maintenance of green spaces and their effectiveness", and "using environmentally-friendly fuel materials is promoted by implementing industrial policies", respectively, which is significant at the 0.05 level. A comparison of the mean of the dimensions (3.1600), (3.2650), and (3.2050) with the expected mean (score 3) shows that these three components are valid from the experts' viewpoint and confirmed with 95 % confidence.

In relation to other indicators of natural resources and green space management, the t statistics calculated for the indicators "environmentally destructive activities are prevented by the implementation of industrial policies", "environmentally-friendly technologies are encouraged and promoted by the implementation of industrial policies", "with the implementation of industrial policies, crimes are attributed to units and persons who violate environmental affairs", "with the implementation of

TABLE 4. The results of the one-sample t-test considered to examine the current status of the indicators used for evaluating the effectiveness of industrial policies with the approach to environmental protection

Components	Expected Mean=3						
	T	Degree of Freedom	Significance Level	Mean	Mean Difference	95 % Confidence Interval Meaning of Differences	
						Lower Limit	Upper limit
With the implementation of industrial policies, green space was developed to the extent of the development of industrial places	3.816	199	0.041	3.1600	0.16000	-0.0137	0.3337
With the implementation of industrial policies, there is a written program for the maintenance of green spaces and their effectiveness	3.110	199	0.002	3.2650	0.26500	0.0970	0.4330
Using environmentally friendly fuel materials is promoted by implementing industrial policies	2.514	199	0.013	3.2050	0.20500	0.0442	0.3658
Environmentally destructive activities are prevented by the implementation of industrial policies	1.349	199	0.179	3.1250	0.12500	-0.0578	0.3078
Environmentally friendly technologies are encouraged and promoted by the implementation of industrial policies	0.169	199	0.866	3.0150	0.01500	-0.1604	0.1904
With the implementation of industrial policies, crimes are determined for units and persons who violate environmental affairs	0.650	199	0.517	3.0600	0.06000	-0.1221	0.2421
With the implementation of industrial policies, fire alarms and extinguishing systems have been installed in industrial places	0.997	199	0.320	3.0900	0.09000	-0.0880	0.2680
With the implementation of industrial policies, dangerous and hazardous substances ignition, and explosion are under control	1.576	199	0.117	3.1400	0.14000	-0.0352	0.3152
With the implementation of industrial policies, the production processes have been modified based on environmental policies	-0.274	199	0.784	2.9750	-0.02500	-0.2048	0.1548
With the implementation of industrial policies, the extent of pollutants in industrial processes is monitored and measured	2.009	199	0.046	3.1800	0.18000	0.0033	0.3567
With the implementation of industrial policies of air pollutants in places industrial is measured	2.769	199	0.006	3.2250	0.22500	0.0647	0.3853
With the implementation of industrial policies, the production of industrial pollutants has decreased	2.790	199	0.006	3.2500	0.25000	0.0733	0.4267
With the implementation of industrial policies, industrial wastes are separated and assignments are determined	2.970	199	0.003	3.2650	0.26500	0.0890	0.4410
With the implementation of industrial policies, managerial and engineering measures are taken to reduce waste	0.586	199	0.558	3.0550	0.05500	-0.1300	0.2400

industrial policies, fire alarms and extinguishing systems have been installed in industrial places", "with the implementation of industrial policies, dangerous and hazardous substances ignition, and explosion are under control", and "with the implementation of industrial policies, the production processes have been modified based on the proposed environmental policies" were not significant at the 0.05 level, and their mean was not different from the expected mean (score 3). According to the experts, these indicators have had a moderate impact on the effectiveness of industrial policies with an environmental protection approach. In the indicators of waste and pollutants management, the t statistics were calculated 3.1800 for "with the implementation of industrial policies, the extent of pollutants in industrial processes are monitored and measured", 3.2250 for "with the implementation of industrial policies of air pollutants in places industrial is measured", 3.2500 for "with the implementation of industrial policies, the production of industrial pollutants has decreased", 3.2650 for "with the implementation of industrial policies, industrial wastes are separated and assignments are determined", and 3.0550 for "with the implementation of industrial policies, managerial and engineering measures are taken to reduce waste", which were significant at the 0.05 level with their mean higher than the expected mean (score 3).

Therefore, according to the experts, they have had a great impact on the effectiveness of the industrial policies with the approach of protecting the environment.

Table 5 shows the results from the evaluation of the components of the effectiveness of industrial policies with the environmental protection approach. According to the results of the one-sample t-test (Figure 1) and exploratory factor analysis, the current situation is as follows: the components of sewage and industrial waste with the value of t = 3.567, environmental protection t = 4.427, and compliance with the environmental requirements and standards t = 2.505 are significant at the 5 % error level ($P < 0.05$). Therefore, the null hypothesis that there is no difference between the observed mean and community mean (3) is rejected, and it is concluded that there is a significant difference between the observed mean and community mean (3). Therefore, the components of "effluent and industrial waste", "environmental protection", and "compliance with environmental requirements and standards" were approved by experts with 95 % certainty. However, in the components of "industrial pollutants" and "development of green space", a comparison of its mean with the expected mean (score 3) does not show a significant difference that these two components have a moderate level of credibility according to experts.

TABLE 5. One-sample t-test results to check the current status of the research components

Components	Expected Mean=3						
	t	Degree of Freedom	Significance Level	Mean	Mean Difference	95 % Confidence Interval Meaning of Differences	
						Lower Limit	Upper Limit
Effluent and industrial waste	3.567	199	0.000	3.2125	0.21250	0.0950	0.3300
Industrial pollutants	1.349	199	0.179	3.1250	0.12500	-0.0578	0.3078
Management of waste and pollutants	4.314	199	0.000	3.1888	0.18875	0.1025	0.2750
Development of green space	1.229	199	0.220	3.0683	0.06833	-0.0413	0.1779
Environmental Protection	4.427	199	0.000	3.2183	0.21833	0.1211	0.3156
Compliance with environmental requirements and standards	2.505	199	0.013	3.1600	0.16000	0.0340	0.2860
Management of natural resources and green space	3.787	199	0.000	3.1255	0.12550	0.0601	0.1909

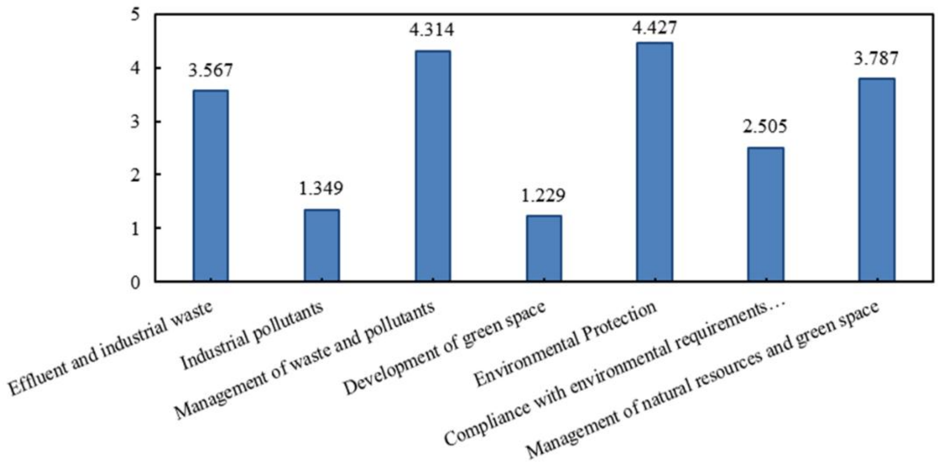

Figure 1. T-test results graph

7. CONCLUSION

According to the evaluation results, in the case of implementing industrial policies in the Ceramics production industries, despite the development of the green space to the extent of considerable increase in the areas of industrial places, proposal of a documented plan for the maintenance of the green spaces and their effectiveness, and extensive use of environmentally-friendly fuel materials, serious crimes have not yet been considered for units and persons who are recognized violators in environmental affairs, hence incapable of deterrent. Although fire alarm and extinguishing system were already installed in some sensitive industrial areas, there are still other vast areas that have not been covered yet. In addition, some reports denote that some dangerous and flammable materials and explosion are not fully under control and supervision. Although some of the production processes were modified based on environmental policies, there are still a number of processes that are not aligned with environmental policies and requirements. In terms of the pollutants and industrial wastes management, it should be noted that the production level of pollutants in industrial processes is not accurately monitored and measured, and the amount of pollutants caused by industrial production has threateningly increased in some cases. Moreover, industrial production wastes are not completely planned, segregated, and determined. In short, although some measures are currently being taken to reduce the amounts of waste and effluents from industrial production, these measures are not effective enough, hence the need for further considerations.

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