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BAUXITE RESOURCE EXPLOITATION IN GREECE vs SUSTAINABILITY

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Abstract

In the central part of Greece bauxite ore deposits are systematically exploited since more than fifty years, initially by a French industrial group and since few years by a Greek investment group. This "economical" activity uses the non renewable mineral resources of bauxite, non renewable energy sources, as well as significant amount of water and it exports to the environment pollutants and byproducts. CO_2, NOx, F, PAHs are diffused to the atmosphere, polluting the soil of the adjacent area. Big amount of red mud is deviated to the sea, covering an extended shelf area and parts of deeper marine areas. The aim of this work is to evaluate this "economic" activity using principles of the sustainability science. In its broadest definition, sustainability refers to the ability of a society to continue functioning into the future without being forced into decline through the exhaustion or overloading of key resources.

1. Introduction

Bauxite, the ore that contains a high concentration of aluminum hydroxide minerals, is the row material for the aluminum industry. Bauxites generally consist of mixtures of the minerals gibbsite [$Al(OH)_3$], boehmite, and diaspore [AlO(OH)], clay minerals such as kaolinite [$Al_2Si_2O_5(OH)_4$], quartz (SiO_2) and anatase and rutile (TiO_2). The worldwide bauxite reserves, the bauxite production and the alumina (aluminum oxides-hydroxides) production are given in Table 1. Greece is the largest bauxite producer of the European Union. Bauxite offers high concentration of Al_2O_3 and is the most important commodity of Greek aluminum mining industry. The exploitation of bauxite ores in Greece begun in 1925 in the Parnassus area (central Greece). The mineral industry of Greece is mainly export orientated, in order to meet the demand of the globalized mineral market.

At present time one company in Greece is activated in the elaboration of bauxite extracting pure alumina (aluminum oxide) and then from the alumina aluminum, the "Aluminum of Greece S. A., [AtE]". Bauxite exploitation activities are the driving (D) forces acting as pressures (P) for the environment. Space is needed, non renewable mineral resources as well as energy resources and big amounts of fresh water are used. These activities release significant amount of byproducts in the environment, climate gas emissions, inorganic and organic pollutants, bauxite residues, etc. These pressures are the factors changing the state (S) of the environment, impacting (I) the human society. Changes in the state of the environment and impacts on the human society trigger responses (R). Authorities, investors, citizens groups, non governmental organizations (NGOs), scientists, called together "stakeholders" have to establish a common language to plan, to meet decisions and measures, to reorientate the development priorities and to apply progressively the sustainability principles.

Table 1. Bauxite reserves (in million metric tones), bauxite production (in thousand metric tones) and alumina production (in thousand metric tones) [Reference year 1998] (American Bureau of Metal Statistics, Inc. Secaucus, NJ 1980, 1985 U.S. Geological Survey, Mineral Commodity Summaries, 1990–1998, modified)

Nr	Country	Bauxite Reserves	Country	Bauxite Production	Country	Alumina Production
1	Guinca	7,400,000	Australia	45,000	Australia	13,385
2	Brazil	3,900,000	Guinca	16,500	Un. States	5,090
3	Australia	3,200,000	Jamaica	12,606	Jamaica	3,411
4	Jamaica	2,000,000	Brazil	12,500	China	3,000
5	India	1,500,000	China	8,500	Brazil	2,756
6	China	720,000	India	6,000	Russia	2,300
7	Guyana	700,000	Venezuela	4,500	Venezuela	1,800
8	Suriname	580,000	Suriname	4,000	India	1,700
9	Venezuela	320,000	Russia	3,400	Suriname	1,600
10	**Greece**	**300,000**	Guyana	2,600	Irland	1,200
11	Russia	200,000	**Greece**	**2,500**	**Greece**	**750**

The aim of this work is to present this complicated net of human activities, behaviors and actions in the case study bauxite exploitation in Greece and to discuss if the logical DPSIR scheme (D=drivers, P=pressures, S=state, I=impact, R=response) can be introduced in the greek community as a whole and if the sustainability principles can find fruitful substratum in the Mediterranean country, called Greece.

2. Bauxites ore deposits in Greece

The major bauxite deposits of Greece are geological formations hosted within carbonate rocks of different geological ages of the Parnassos – Ghiona geotectonic zone - Hellenides (central Greece). Three bauxite horizons (B1, B2, B3) are distinguished, intercalated with shallow-water limestones of the Upper - Jurassic to Middle Cretaceous carbonate sequences of the Parnassos – Ghiona zone. The (paleo)geographical distribution of the three bauxite horizons (B1, B2, B3) shown in Fig. 1 indicates a displacement of the formation areas from the NE place of the older B1 bauxite horizon to SW direction where the younger B2 and B3 bauxite horizons are formed (Petraschek & Mack, 1978). The bauxite reserves of Greece are estimated in approximately 300 billion tons (Papastavrou, 1986). The economically most important bauxite formations occur in the upper (B3) horizon, which expands over extended distances as continuous layer of 1–10 m in thickness. This horizon shows a pisolithic and/or oolithic texture and a red to red-brown color (Valeton et al., 1987). The mineralogical composition of the bauxite formations of the Parnasssos – Ghiona zone shows mainly boehmite or diaspore and in lesser amounts gibbsite, kaolinite, hematite, goethite (Valeton et al., 1987, Laskou, 2001, Laskou & Andreou, 2003). The average chemical composition of the bauxite samples is: 55% Al_2O_3, 20% Fe_2O_3, 3-5% SiO_2, 0.5-1.0% CaO, 2-2.5% TiO_2 and 10-14% loss of ignition. The average concentration of trace elements is: 450 ppm Ni, 700 -900 ppm Cr, 50-70 ppm Zn, 500-600 ppm Zr and 37 ppm Sr. (Valeton et al., 1987, Laskou & Economou-Eliopoulos, 2007).

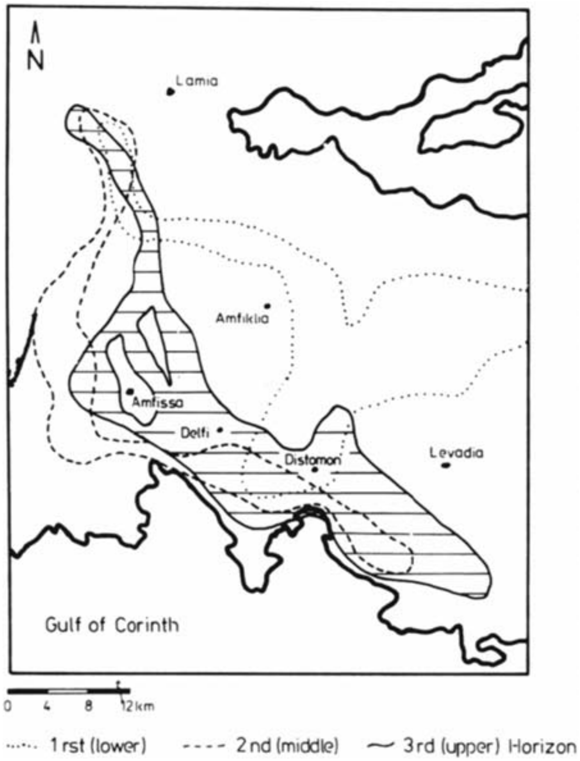

Fig. 1: Regional distribution of the 1st (B1), 2nd (B2), 3rd (B3) bauxite horizons in central Greece (Petraschek & Mack, 1978).

Greek bauxite offers high concentration of Al_2O_3, low of CaO, low loss of ignition and low humidity comparing to the largest bauxite exporters of the globe (Guinea, Australia, Jamaica, Brazil and China). However Greek bauxite has the disadvantage of high SiO_2 concentration, which makes it difficult to process (Laskou & Andreou, 2003).

3. Bauxites mining in Greece

Three bauxite mining industries are active at present time in Greece, the S&B industrial minerals S.A., Delphi Distomo S.A. and ELMIN S.A. with a total production of ~2.500.000 tons/year. Approximately 900.000 tons/year (year 2005) are directly as bauxite exported. The main export targets of Greek bauxite are European Union countries as well as Russia, Ukraine and Romania. The main domestic bauxite consumer is "Aluminum of Greece S.A." [AtE] subsidiary of the Delphi Distomo S.A., which consumes ~1,500,000 tons/year. The "Aluminum of Greece S.A."[AtE] produces alumina and aluminum. In the mining of bauxite the extension and shape of the deposits are determined by field geology studies and if needed by core drilling. After the fixation of the bauxite mining sites and the establishing of the necessary infrastructure, the bauxite is broken up, often with the aid of explosives, and removed with conventional earthmoving equipment. It is then transported to the clients.

4. Bauxite industry in Greece

In Greece only one company is dealing with extraction of alumina (aluminum oxide) from bauxite and aluminum from alumina, the above mentioned "Aluminum of Greece S. A. [AtE]", which is sited in Antikyra bay, Gulf of Corinth. The "Aluminum of Greece S. A. [AtE]" was founded in 1960 and it started the production 1966. The first owner was PECHINEY (1960-2003). In 2004 "Aluminum of Greece S. A. [AtE]" was soled to ALCAN and ALCAN soled the company to MYTILINAIOS financial group (2005). The information about the history of the company, the procedures of alumina and aluminum extraction as well as about mineral ores and energy resources used, about byproducts accumulation and about future plans of the company, are gained from a recently carried out Technical Report of the "Aluminum of Greece S. A. [AtE]" company (Aluminum of Greece S. A. [AtE], 2007).

Extraction of alumina from the bauxite: Pure alumina (aluminum oxide) is extracted from bauxite by the Bayer process. In the Bayer process bauxite received from the mines is crushed, usually by a hammer mill to small particles and well blended. Lime (CaO) is added to assist in the extraction of alumina, to scavenge impurities, and later to enhance clarification. This mixture then flows to agitated storage tanks and is metered into high-temperature (~255°C) sodium hydroxide digesters (NaOH), where alumina is extracted from the bauxite as sodium aluminate ($NaAlO_2$). Pure alumina is then precipitated (by lowering temperature to 50-70°C) from the solution as a hydroxide [$Al(OH]_3$), filtered, washed, and then calcined to pure alumina (Al_2O_3) at 1100–1200°C.

Digestion	Precipitation	Calcination
$AlO(OH)+NaOH \rightarrow$ $NaAlO_2+H_2O$	$NaAlO_2+2H_2O \rightarrow$ $Al(OH)_3 + NaOH$	$2Al(OH)_3 \rightarrow$ $Al_2O_3 + 3H_2O$

This procedure leaves behind the impurities as an insoluble residue, mainly consisting of hematite (Fe_2O_3), titania (TiO_2), and silica (SiO_2). For the production of one tone of alumina two tones of bauxite are needed. The "Aluminum of Greece S. A. [AtE]" produces more than 750,000 tones alumina yearly.

The extraction of alumina from the bauxite is supported from two smaller industrial units:

a. The unit producing CaO (needed by the extraction procedure) from limestones coming from the geological formations exposed near the industrial field.

b. A unit producing thermal energy, needed also for the procedure. Using as energy resource imported crude oil.

Extraction of aluminum metal from the alumina: Aluminum metal is extracted from the alumina electrolytically by the Hall–Heroult process. In this process, the purified alumina is dissolved in an electrolyte consisting mainly of molten at ~960°C cryolite ($NaF.AlF_3$). Consumable carbon anodes are employed, producing carbon dioxide and carbon monoxide, which escape from the cell while the molten aluminum accumulates at the cathodic bottom and is siphoned out periodically. The aluminum produced is normally 99.6–99.9% pure. The typical impurities are iron, silicon, titanium, vanadium, gallium, and manganese, coming from the anode but also from impurities in the alumina. The "Aluminum of Greece S. A. [AtE]" produces approximately 170,000 tones aluminum metal yearly.

Uses of Aluminum: The market for aluminum comprises containers and packaging [foil, plastic, and paper laminants and pouches are used for packaging a wide variety of food and nonfood products] building and construction [doors and windows are generally produced], transportation [commercial and military aircrafts, use of aluminum in automobiles to reduce weight, in marine service, in space vehicles], electrical [high voltage electrical transmission lines], consumer durables, machinery and equipment.

5. Bauxites exploitation activities and environment in Greece

5.1 Natural environment

The bauxite exploitation is a complicated human activity. It needs and it uses space, ore material resources, energy resources, water. The production procedure leads also to a huge amount of byproducts, which affect the environment and have significant impact to the humans health and the society. All the information on which is based this unit is the recently carried out Technical Report of the "Aluminum of Greece S. A. [AtE]" company (Aluminum of Greece S. A. [AtE], 2007).

Space: For the bauxite mining it is necessary to establish transport infrastructure in the mountains to reach the mining sites, which are changing the natural environment. The mining procedures result to harvesting of trees and local concentration of overburden, which are removed and set aside, contributing to environmental changes. No data are found about the area in which the mining activities are extended.

The industry itself occupied one field of 770,000 m^2, where the industrial plants are sited and a second field, in the same order of extension, where the employees of the industry are living. Both sites are plain areas near the sea, where olive trees were cultivated 50 years ago and are totally harvesting changed in industry field and residence area respectively. The company is owner of an expropriated 50 years ago extended area of 7,050,000 m^2.

Ore material resources: The "Aluminium of Greece S.A [AtE]" company obtains the bauxite mainly from the bauxite ore mining of the adjacent area (Delphi – Distomo S. A.) as well as a smaller amount imported from Africa (tropical bauxite). In the year 2006 the "Aluminium of Greece S.A [AtE]" consumed more than 1,760,000 tones bauxite.

Use of limestones for the production of CaO: The company uses yearly more than 125.000 tones of limestones (production of ~62,000 tones/year lime).

Energy resources: Table 2 gives a breakdown of the energy required from the "Aluminum of Greece S. A. [AtE]" to produce aluminum. The energy for mining and refining comes from fossil fuels. Crude oil is used also by the Beyer process (refining the ore) as well as by the Hall-Herout process (smelting). From Table 2 it can be seen, that smelting consumes ~90% of the total electric power. The company obtains the energy required from the National Energy Network of Greece in a tariff significant lower than this of the normal electricity consumer.. The sources covering the electricity requirements of the "Aluminium of Greece S. A. [AtE] are showing in Table 3.

Fresh water use: Water is commonly used throughout the aluminum industry for cooling, clearing and dissolving purposes. The "Aluminum of Greece S. A. [AtE]" consumed in the year 2006 ~4,000,000 m^3 water to cover the industrial requirements and 225,000 m^3 as potable water. The company gains this water quantity through exploitation of the ground water of the area.

Byproducts:

Climate gases emissions: The "Aluminum of Greece S. A. [AtE]" produces as byproducts climate gases emissions. The annual emission of CO_2 is more than 1.000.000 tons. The emission of CF_4 is ~8.2 t/y (CO_2 equivalent ~53.300 t/y), ~0.05 kgr/t Al and of C_2F_6 ~0.8 t/y (CO_2 equivalent ~7,500 t/y), ~0.005 kgr/t Al.

SO_2 emissions: The total SO_2 emission reaches~16,000 t/y, having as the main source the bad quality of crude oil, which contain ~2.7 – 3.00 % S.

Table 2. Energy required for the production of Aluminum of the "Aluminum of Greece S. A. [AtE]".

	Electrical energy MWH/year	Thermal energy Crude oil t/year	Thermal energy Diesel m^3/y
Mining and transportation of bauxite			~480
Refining ore (Bayer process)	~200,000		~250
Smelting (Hall–Herout process)	~2,300,000	~231,456	
Electrolysis [2.200.000 MWH/year]			
Other [115.000 MWH/year]			
General requirements	~10,000		
Total	~2,500,000	~231,456	~730

Table 3. Sources covered the electricity requirements of the "Aluminum of Greece S. A. [AtE]".

Total electrical energy required	~2.500.000 MWH/year
Covered by: Coal burning (lignite) Hydropower Renewable energy sources	50% 50% 0%

NOx emissions: The total NOx emission reaches ~1390 t/y, having as source the thermal energy resources.

Fluoride emissions: The total (gaseous and particulate) emissions of fluoride from primary alumina electrolysis plants of the company "Aluminum of Greece S. A. [AtE]" reaches ~270 t/y, making 1.65 kgr/t Al. Measurements carried out from the company in atmospheric particles show the presence of fluoride in distances more than 8 km from the industry. Indicative values of fluoride in the atmospheric particles are following:

0-2 km distance from the industry ~800 μg/week,
2-4 km distance from the industry ~80 μg/week,
4-6 km distance from the industry ~27 μg/week,
6-8 km distance from the industry ~20 μg/week,
>8 km distance from the industry ~8 μg/week.

Benz (a) Pyrene emissions (BaP emissions): From the industry an important quantity of PAHs (PolyAromativHydrocarbons) is emitted in the atmosphere. Measurements carried out from the company in atmospheric particles show concentrations of total PAHs fluctuating from 5 -9 mg//m^3 (measurements of 2006). Data available for Benz (a) Pyrene emissions of the company "Aluminum of Greece S. A. [AtE]", show concentration from 0.05 – 0.5 mg/m^3. PAHs and Benz (a) Pyrene are emitted in the atmosphere by paste plants, anode plants and primary smelters.

Bauxite residue deposited: The bauxite residue materials are defined as the materials remaining after the extraction of the alumina. It has a brown red color and a mud texture. The "Aluminum of Greece S. A. [AtE]" company produces an amount of approx. 700,000 t/y of this byproduct. All these amounts of red mud are canalized to the sea in a depth of 110 m and a distance from the coastline of 2.200 m. In the red mud discharge area the submarine topography is totally changed. A number of six lobes on the shelf area are formed with an elevation from 7 m to 37 m. Through gravity mass movements a part of these deposits are moved to the deeper zone of the marine area (depths of 700 – 800 m). Indicative chemical composition of the red mud is showing below.

Fe_2O_3	40-46 %	SiO_2	7-12 %
Al_2O_3	14-25 %	Na_2O	2.2-2.7 %
CaO	8-14 %	TiO_2	6.0 %

The area covered from the red mud shows high heavy metals concentration. Using as reference sample a pre-industrial sample of a core of the red mud area the enrichment factor of some heavy metals is calculated. The enrichment factor for Cr is 44, for cobalt 11, for Ni 29, for As 64 and for Pb 25 Data stem from a report of the"Aluminum of Greece S. A. [AtE]", based on studies carried out from the Hellenic Center of Marine Research (HCMR).

Spent pot lining and Hazardous waste deposited: The quantity of spent pot linings from electrolysis pot rooms deposited after removal of materials for reuse and recycling reaches 104.244 t/y, the amount of hazardous wastes deposited reaches 12.212 t/y (year 2006).

5.2 Social environment

The "Aluminum of Greece S. A. [AtE]" gives in its report (Aluminum of Greece S. A. [AtE], 2007) the information that provide a safe workplace for employees and gives emphasis on the prevention of accidents in the workplace. However no data are available for the Lost Time Incident (LTI), the number of lost time accidents, the fatalities and the employee exposure and health assessment.

6. Bauxites exploitation viewed under the sustainability framework

6.1 The European programme of Aluminium for Future Generations – The "Sustainable Development Indicators (SDI)"

The interest groups related to bauxite exploitation have to be committed to navigate all their activities following the general principle of the sustainability, i.e. "meeting the needs of the present, without compromising the ability of future generations to meet their own needs". This means meeting the needs of modern society by

- taking seriously into account that bauxite ore resources and energy resources used, are not renewable and fresh water quantity is limited,
- reducing the environmental impact,
- demonstrating social responsibility towards employees, customers, local communities and society as a whole.

The European Aluminium Association (EAA) and its member companies, through the Aluminium for Future Generations programme, developed 34 measurable "Sustainable Development Indicators (SDI)" to be systematically tracked and transparently reported by the European aluminium industries, on a dynamical process and a future pathway towards sustainability. Sustainability is more than just an initiative it is a philosophy that have to run right through the industry influencing every activity and decision.

Shortly to mention the 34 measurable "Sustainable Development Indicators (SDI)" are related to the

-production [SDI 01.Total Production Alumina], -policy and management efforts (SDI 02. Sustainability mission statement; SDI 03.Plant certification, (ISO 14000, OSHAS, etc)], -competitiveness [SDI 04 Aluminium use per capita; SDI 05. R&D expenditure (R&D investment/year); SDI 06 R&D persons employed; SDI 07 Value added], -revenues and investments [SDI 08 Total revenue; SDI 09 Capital investments], -employee development and relations [SDI 10 Training performance (~hours for job training/person/year); SDI 11 Wage level; SDI 12 Total number of employees], -community relations [SDI 13 Community expenditure (for social, cultural, sports, and others); SDI 14 Community dialogue; SDI 15 Community health initiatives], -health and safety [SDI 16 Lost time incident rate (lost time accidents), SDI 17 Total recordable incident rate; SDI 18 Fatalities; SDI 19 Severity rate; SDI 20 Employee exposure and health assessment], -resource use at global level [SDI 21 Bauxite area mined; SDI 22 Mine rehabilitation rate], -resource use at european level [SDI 23 Energy consumption (electric energy/tonne of product in kWh), (other energy/tonne of product in MJoule); SDI 24 Renewable electric energy in %; SDI 25 Fresh water use (m^3/tonne of product)], -emissions [SDI 26 Climate gases emissions (in kilogram of CO_2 equivalent per tonne produced); SDI 27 Fluoride emissions. (in kilogram per tonne produced); SDI 28 BaP emissions (Benz a pyrene emissions/tonne produced); SDI 29 Bauxite residue deposited (kgr/tonne of alumina produced); SDI 30 Spent pot lining and Hazardous waste deposited (kgr/tonne of alumina produced), product life cycle [SDI 31 Use phase; SDI 32 Aluminium recycling; SDI 33 Life Cycle; SDI 34Recycling material flow].

6.2 The Greek programme of Aluminium for Future Generations – The "Sustainable Development Indicators (SDI)"

The only one aluminum company in Greece, the "Aluminum of Greece S. A. [AtE]" produces ~750,000 tons per year alumina [SDI 01], while the European total production (in 2005) reached the amount of 6.786.000 tons. 50% of the produced aluminum and 20-25 % of aluminum products are exported mainly in Europe. Unknown are the policy and management efforts of the company related to the sustainability mission statement of the company [SDI 02] and the plant certification, (ISO 14000, OSHAS, etc [SDI 03]).

The competitiveness indicators for the "Aluminum of Greece S. A. [AtE]" show 15,5 kg aluminium per capita [SDI 04], while for Europe the indicator is 24,2 kg/person, No data are found about the R&D expenditure (Research &Development investment/year) [SDI 05], R&D persons employed [SDI 06], Value added [SDI 07]. No data are found about revenues and investments [SDI 08], [SDI 09], employee development and relations [SDI 10], [SDI 11], [SDI 12], community relations [SDI 13], [SDI 14], [SDI 15], health and safety [SDI 16], [SDI 17], [SDI 18], [SDI 19] [SDI 20], resource use at global level [SDI 21], [SDI 22]. In the above mentioned "Sustainable Development Indicators" [SDI] we can add the total number of employees [SDI 12] reaching ~1000 persons.

Some important "Sustainable Development Indicators" [SDI] are calculated from the author for the production activities of the "Aluminum of Greece S. A. [AtE]", related to resource use at European level and the emissions (Table 4). The electric energy consumption in kWh per ton of product [SDI 23] reaches the value of 14.706 kWh (for Europe 804.7 kWh, data for 2005). The calculation of the production of primary aluminum of 170,000 tons/year is taken into account. No renewable electric energy is used from the company [SDI 24]. The fresh water used (m^3/tonne of product) [SDI 25] reaches the value of 23.5 m^3/tonne of product (for Europe is 12.7 m^3/tonne of product, data for 2005).

For the emissions the "Sustainable Development Indicator" [SDI] for the climate gases emissions is calculated (in kilogram of CO_2 equivalent per ton produced) [SDI 26]. The 1,000,000 tones of CO_2

Table 4. Sustainable Development Indicators of the European Aluminium Industry.

SDI Nr	"Sustainable Development Indicators" [SDI] European Aluminium Association	Europe 2005	AtE
	RESOURCE USE AT EUROPEAN LEVEL	804.7	14,706
SDI 23	Energy consumption (electric energy/tone of product in kWh)	45.7	0%
SDI 24	Renewable electric energy in %	12.7	23.5
SDI 25	Fresh water use (m^3/tonne of product)		
	EMISSIONS		
SDI 26	Climate gases emissions (in kilogram of CO2 equivalent per tone produced)	134	5,294
SDI 27	Fluoride emissions. (in kilogram per tone produced)	0.96	1.65
SDI 28	BaP emissions (Benz a pyrene emissions kgr /tone produced)	1.11	-
SDI 29	Bauxite residue deposited (kgr/tone of alumina produced)	706	~ 800
SDI 30	Spent pot lining and Hazardous waste deposited (kgr/tonne of alumina produced)	12.8	15.4

Source: European Aluminium Association: Sustainability of the European Aluminium Industry 2006

corresponds, according to US Environmental Protection Agency (http://www.epa. gov/RDEE/energy-resources/calculator.html) to approximately 900.000 CO_2 equivalent and gives the SDI 26 indicator ~5.300 kilograms of CO_2 equivalent per ton produced. The European middle value is 134 kilograms of CO_2 equivalent per ton produced (Table 4). The fluoride emissions indicator [SDI 27] is calculated in 1,65 kilograms per tone produced (the European middle value is 0.96 kilograms per tone produced). No significant data were available for the Benz-a-pyrene (BaP) emissions indicator [SDI 28].

The bauxite residue deposited indicator [SDI 29] is ~800 kgr/tonne of alumina produced (the European middle value is 706 kilograms per tone produced). The spent pot lining and hazardous waste deposited indicator [SDI 30] is calculated in 15.4 kgr/tone of alumina produced (the European middle value is 12.8 kilograms per tone produced).

No data are found for the product life cycle, use phase [SDI 31], aluminium recycling [SDI 32], life cycle [SDI 33] and recycling material flow [SDI 34].

6.3 A plan for the aluminum industry in Greece based on the sustainability principles is needed

As it is mentioned above, at present time one company in Greece is activated in the elaboration of bauxite, the "Aluminum of Greece S. A., [AtE]". These activities are the driving forces (D) acting as pressures (P) for the environment. Space is needed, non renewable mineral resources as well as energy resources and big amounts of fresh water are used. These activities release significant amount of byproducts in the environment. All these pressures are the factors changing the state (S) of the environment, impacting (I) the human society. The changes in the state of the environment and the impacts on the human society trigger responses (R). Authorities, investors, citizens groups, non governmental organizations (NGOs), scientists, called together "stakeholders" have to establish a common language to plan, to meet decisions and measures. The "Sustainable Development Indicators" [SDI] shown in Table 4 indicate that the company has to change exploitation and elaboration practices in order to converge the company SDIs towards the European SDIs.

A reorientation of the development priorities and the progressively application of the sustainability principles gain importance in this procedure. The spiral D-P-S-I-R scheme is a logical tool to be applied. The only question remaining open is if the greek society is mature to participate in those procedures.

The companies, mainly the "Aluminum of Greece S. A., [AtE]" and the public authorities related to the mining and industrialization of bauxites have not any plans and any politicies for the management of the unrenewable resources. For the protection of the environment no important measures are undertaken. The public services in local, regional and central levels are totally manipulated from the industry interest group. The scientific community of the most of the public services, research centers, universities, generally does not react to this situation. And if some scientists try to search the state of the environment in the area near the industry activity, the entrance in the industry field is forbidden (research team from the University of Patras). Even worse is the situation for researchers from the Hellenic Center of Marine Research (HCMR), who announce results of their measurements (Anagnostou & Hatjianestis, 2009). They are confronted with justiciable measures from the company, carrying out this procedure in "harmonical" collaboration with directors of the Research Center. Small citizen groups and initiatives as well as Non Governmental Organizations are the only "healthy" part of the greek society.

The company spends efforts for communication with local communities and authorities and some money to gain a positive resonance from the local community with expenditures for social, cultural, sports and other community activities and to form also a citizen revetment against the pressure of the Non Governmental Organizations and the citizen initiatives.

7. The way out

The educational and scientific research communities have to find the way first to emancipate themselves and then to play the leading role for the society, which is permanently in crisis (economical, societal, cultural). Managing the environment is not simple. Managing the natural resources, protecting the function of the nature, giving priority to the biodiversity, solving the survival problems of many human communities, all these are questions waiting for answers. Integration and participation are showing the way out.

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