Evaluation of the environmental performance of the natural stone industry based on sustainable indicators

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ABSTRACT

Environmental protection, economic prosperity and respect of the need for social equity promotion, constitute a prerequisite for any modern industry aiming to operate in a sustainable manner. The Natural Stone industry in Europe, a sector comprising mainly of SMEs, despite the fact that consists a dynamic extraction sector, often lucks the resources to apply novel techniques and management schemes towards achieving sustainable performance.

I-STONE, an EU Integrated Project funded by the 6th Framework Programme, is aiming to contribute in the improved performance of the Natural Stone industry. A primary project objective is the re-engineering of the stone production chain, in order among others to considerably increase its efficiency and productivity, and minimise the amount of stone wastes disposed. The present paper, resulting from the research conducted on environmental management within I-STONE, is focusing on the use of sustainable indicators as a tool for the assessment of the stone industry's performance. Based on Commission Decisions and reported studies, a list of indicators was selected and used within I-STONE, including environmental and socio-economic indicators.

A set of selected environmental indicators were quantified based on operational data of a number of Greek and Portuguese quarries examined as case studies. The analysis indicated that an integrated strategy, including the application of novel operation techniques and equipment, waste minimization and systematic environmental monitoring and reporting, constitute key factors for the sustainable operation of natural stone industry.

1. INTRODUCTION

Human civilization and especially the building culture worldwide are intimately related to natural and/or ornamental stones. The principal rock types used as ornamental stones are marble (calcareous stone), limestone and granite (siliceous stone).

The stone industry supply and demand is increasing internationally. The global primary stone production increased from 67.4 Mt in 2000 to 89.5 Mt in 2004 (ICAP, 2005). It is estimated that approximately 60,000 companies, mostly SMEs, are active in the European Stone Sector with more than 500,000 employees (OSNET, 2004). Italy, Spain and Portugal constitute the main EU stone producers, while Greece has a primary marble stone production of 2.1 Mt, representing about 7% of European quarry production

Despite the financial growth of the EU stone industry, there is a recognized difficulty to keep up in pace with technological innovations and breakthroughs in terms of equipment, production chain or adoption of holistic operational and environmental management strategies. Within this framework, I-STONE, an EU 6th Framework Programme, aims to transform the rather traditional stone sector into a modern, competitive and knowledge-based industry through the incorporation of emerging technologies. A primary project objective is the re-engineering of the stone production chain, in order to considerably increase its efficiency and productivity, and improve its sustainable performance.

2. SUSTAINABLE DEVELOPMENT INDICATORS, SDIs FOR THE EXTRACTIVE INDUSTRY

Extractive industry constitutes a sector significantly affected by the principle of sustainable development, focusing on the need to rationally develop mineral wealth, and to provide economic prosperity, environmental protection and social equity. Further development of certain sectors, like the natural stone sector, will create opportunities, including employment, transfer of skills and technology, development of local infrastructure and services and enhancement of national trade balance. However, parameters like the non-renewable nature of natural resources, increased energy consumption land take, potential impacts on soils and water, constitute main challenges faced by the extractive industry, indicating the requirement for a holistic approach and effective sustainable planning and operation.

The general international acceptance of the necessity for sustainability, especially after the Rio Summit in 1992 (Agenda 21), has triggered the effort for developing reliable indicators as operational tools for the evaluation of the sustainable performance of extractive industries (Adam, 2003). These indicators are based on environmental and socio- cultural parameters in addition to the economic ones. Their effectiveness mainly depends on their ability of being representative of complex, not directly measured situations.

3. INDICATORS TO ASSESS THE SUSTAINABLE PERFORMANCE OF NATURAL STONE QUARRIES

Several organizations are contributing in the development of Sustainable Development Indicators (SDI's) for the Extractive Industries (I-STONE, 2006). In these studies, SDI's are presented as a set of proposed environmental and socio-economic indicators. For the evaluation of the stone industry, a proposed list of environmental, social and economic indicators was initially identified within the present study. This list was developed after reviewing respective indicators established by various organizations, including: (a) Raw Materials Supply Group (RMSG), a group working on sustainability indicators for the EU mining industry published in 2004, (b) Sustainable Minerals Roundtable (SMR, 2003) covering U.S Mineral Resources Industry, and (c) Global Reporting Initiative (GRI) that developed Sustainable Performance Reporting Guidelines with a draft section for the

Table 1: Preliminary list of SDIs selected within I-STONE for the evaluation of the sustainability of the stone waste management schemes.

Category	Indicator	Unit
Environmental	1. Specific volume of stone waste managed	t/m^3
	2. Indicative water consumption during treatment per tonne of stone waste	m^3/t
	3. Energy consumption	High/Low
	4. Chemicals/Reagents consumption	High/Low
	5. Use of dangerous substances (reagents, chemicals)	Yes/No
	6. Transport constraints (average transport distance from source to customers)	High/Low
	7. Environmental incidents (reportable)	Number
Economic	8. Overall indicative treatment and handling costs	High/Low
	9. Indicative capital costs of waste management facilities (if applicable)	€
	10. Indicative savings from landfill fees and rehabilitation costs	€
	11. Total R&D expenditure/turnover	%
	12. Profit making/Added value	High/Low
Social	13. Direct and indirect employment	Number
	14. Risk for accidents	High/Low

Table 2: Sustainability balance for different waste management schemes in the natural stone sector.

Waste management type	Sustainable consumption	Sustainable returns
Low input/Low output solutions	Low energy consuming, reduced set-up and operating costs. May utilise large quantities of material.	Low add-on value and profits, and minimal additional employment opportunities. Reuse of waste may not maximise the benefit of the material's inherent value.
High input/High output solutions	High energy consumption, potential for additional environmental impacts, high set-up, running and transport costs.	High add-on value and profits, additional employment created. Beneficial use more likely to maximise the material's inherent value; producing positive flow-on affects in other sectors (such as reduced extraction of virgin material).

Mining Industry.

Table 1 presents the list of the SDI's initially selected in this study for the evaluation of the sustainability of stone waste management schemes.

Various stone management schemes focusing on the beneficial use of wastes were assessed based on the above indicators. The schemes included on-site uses of quarry wastes in the as-produced state, uses of stone wastes requiring low processing (e.g. fill materials, armour stone, footpaths stone, paving and cobble stones, crushed aggregates, artificial topsoil material) as well as high input for processing waste (e.g. artificial stones and tiles, agricultural uses, coarse fillers, plastic and paper fillers etc.). Based on this assessment, there are a number of waste management schemes available for the sustainable use of natural stone waste, and whilst each solution is unique and should be assessed on its merits, certain generic conclusions can be drawn as outlined in Table 2.

From the above data it is seen that the initially proposed SDI's were usually not combined with an evaluation system, and/or a range of target values and significance factors, that would enable operators and stake holders to compare the performance of different operations, or to assess progress made with time.

Thus, in addition to the SDI's proposed above, the indicators provided in the Commission Decision 2002/272/EC "*Establishing the Ecological Criteria for the Award of the Community Eco-Label to Hard Floor-Coverings*", were used for the quantitative, and comparative evaluation of the stone industry performance. It is noted that this Decision includes, interalia, a matrix evaluating system specifically for the assessment of the stone quarrying (Lovera, 2003). The system comprises of nine (9) environmental indicators and their target values rates, ranging from excellent, to exclusion hurdle. These indicators are combined with a list of weight factors, setting their relative significance (Table 3). The above Eco-Label criteria were implemented by many different European organizations with varying degrees of success. Apart from the improvement of environmental performance other significant drivers for implementing the EU Eco-Label include the satisfaction of the customer requests, recognition as a market leader, improvement of international competitive capabilities and increasing access to public procurement.

4. APPLICATION OF THE ECOLABEL CRITERIA IN STONE QUARRIES - CASE STUDIES IN EUROPE

Within the present project, the above eco label criteria were used to assess the environmental performance of four stone quarries in Greece and Portugal, examined as case studies of the stone industry in Europe. Data for the Greek quarries (Quarries A and B) were collected from site visits of the ECHMES study team and co-operation with industry representatives. The data for the Portuguese quarries (Quarries C and D) were provided from CEVALOR, a partner of I-STONE, based on the environmental impact studies of the relevant operations.

Table 3: Ecolabel Indicators system and weighting criteria for the assessment of the environmental performance of natural stone industry, Commission Decision 2002/272/EC.

Indicator	Notes		5 (excellent)	3 good)	1 (sufficient)	Exclusion hurdle
I.1 Water recycling ratio	(Waste water recycled/ Total water exits the process) (m^3)		> 95	95-85	84-80	<80
I.2 Rehabilitation simultaneity degree	m^2 compromised area (quarry front + active dump)/m^2 authorized area (%)		<15	15-30	31-50	>50
I.3 Block recovery	m^3 commercial blocks/m^3 extracted material (%)	Marbles	>40	40-30	29-20	<20
		Granites	>50	50-40	39-30	<30
		Others	>20	20-15	14-10	<10
I.4 Natural resource appreciation	m^3 usable material /m^3 extracted material (%)	Marbles	>60	60-45	44-35	<35
		Granites	>60	60-45	44-35	<35
		Others	>50	50-35	34-25	<25
I.5 Working conditions of operating equipment	Total number of worked hours/yearly production (h/m^3)	wheel loader	<3.5	3.5-5.5	>5.5	
		excavator	<2.5	2.5-3.0	>3.0	
I.6 Air quality	Yearly limit value measured along the border of quarry area PM 10 suspended particles (μg/Nm^3)-Testing method EN 12341		<20	20-100	101-150	>150
I.7 Water quality	Suspended solids (mg/l) Testing method ISO 1996/1		<15	15-30	31-40	>40
I.8 Noise	Measured along the border of quarry area (dB(A) Testing method ISO 1996/1		<30	30-55	56-60	>60
I.9 Visual impact	Percentage (%)		0-10	>10-20	>20-30	>30

Significance factors

If	Weight	Indicators	are multiplied by
The quarry is is located in notified sites of importance (e.g. NATURA 2000 network areas etc.)	W1	I.2, I.6, I.7, I.8, I.9	0.3
Land use potentialities is Classes I-II	W2	I.2, I.7	0.3
Land use potentialities is Classes III-VI-V			0.5
Land use potentialities is Classes VI-VII-VIII			0.8
Population density is >100 hab/km^2	W3	I.2, I.6, I.7, I.8, I.9	0.5 (0.6)
Population density is 20 to 100 hab/km^2			0.7 (0.84)
Population density is<20 hab/km^2			0.9
The quarry interferes with surface water-bodies (average flow<5 m^3/s)	W4	I.1, I.7	0.5

Greek Quarries A and B operate block processing facilities; quarry A, constitutes part of a vertically - organized activity where almost all the extracted material are beneficially exploited. More specifically in quarry A, in addition to marble blocks, processing, facilities produce marble dust, calcium carbonate filler, dry mortars and inert materials, using as feed the extraction and processing wastes. Portuguese quarries C and D are related with marble and granite extraction respectively. Quarry C in Portugal includes both quarrying and processing facilities. The production consists of commercial blocks, slabs, flooring and covering. Portugese Quarry D produces granite blocks and operates a processing plant for the production of cubes and paving stones

Based on economic data for the period 2000-2004 (ICAP, 2005), Quarries A and B are included in the four major Greek stone industries active in Greece and Balkans with an annual turnover exceeding 6.0 M€, and a net profit margin around 20%. Greek quarry B is located in a region where approximately 54% of the Greek marble is produced. The annual turnovers of Quarries C and D average 3.5 M€ and 1.0 M€, respectively, whereas their production is exported by 94% and 80%, respectively. The above economic indicators reveal healthy production activities, with essential contribution to national economy and employment.

The Ecolabel criteria listed were employed in Table 4, to assess the environmental performance of the examined Quarries in Greece and Portugal based on the respective operational data, where available.

5. DISCUSSION

Based on the data presented in Table 4 for selected Greek and Portuguese quarries, a number of conclusions can be drawn regarding the natural stone industrial practice and its environmental performance. Firstly it is noted that the matrix evaluating system set by the Commission Decision 2002/272/EC constitutes part of the EU Eco-label award scheme, a voluntary scheme that manufacturers/stone industries apply within the framework of promoting cleaner, more sustainable production.

It is seen that the target values set for a number of indicators for excellent, or good performance, are quite stringent and in cases one-order of magnitude higher than the operational data recorded. More specifically regarding the Water Recycling Ratio (I.1) in all quarries examined the values recorded, ranging between 10-50% were significantly lower than the values of 80-97%, set for satisfactory to excellent performance. This deviation may be attributed to the operating conditions prevailing in a quarry in a dry-hot climate. Regarding Rehabilitation Simultaneity Degree (I.2) further improvement in the design of extraction is needed for the quarries to comply with the targets set by the Decision 2002/272. This deviation may be attributed to the fact that extraction in stone deposits is commonly performed at different benches in parallel, rendering rehabilitation of exhausted slopes prior to commencement of work in a new one practically impossible. Consequently, the quarrying practice needs to be reconsidered in order to improve rehabilitation rates.

Block Recovery (I.3) is a parameter that mainly depends on the physical and mechanical characteristics of the stone deposit, the extraction method and the equipment used. In the four case studies examined and especially in marble quarries, block recovery remains at low levels when compared with the Eco-label criteria. These data are in agreement with published data, where it is reported that current quarrying activities can produce up to 95% waste material (OSNET, 2004). However, the overall stone re-

Table 4: Ecolabel indicators application in selected Greek and Portuguese quarries.

INDICATOR	Quarry A in Greece		Quarry B in Greece		Marble Quarry C in Portugal		Granite Quarry D in Portugal	
	Value	Score	Value	Score	Value	Score	Value	Score
I.1 Water recycling ratio (%)	<10	0	<10	0	50	0	50	0
I.2 Rehabilitation simultaneity degree (%)	69	0	98	0/Exclusion	77	0	33	1/Sufficient
I.3 Block Recovery (%)	7	0	20	1/Sufficient	5	0	50	3/Good
I.4 Natural resource appreciation (%)	97	5/Excellent	20	0	90	5/Excellent	90	5/Excellent
I.6 Air quality – PM10 ($\mu g/Nm^3$)	-	-	-	-	18	5/Excellent	19	5/Excellent
I.8 Noise (dB(A))	-	-	-	-	41	3/Good	38	3/Good

covery can be significantly improved with the subsequent processing phases where significant percentages from the usable portion of the extracted material can be recovered (Montani, 2004). In the case of the Greek marble Quarry A and Portugese marble Quarry C , block recovery averages 7 and 5% respectively resulting in a large volume of waste material production. Optimization of the equipment used, which is a subject of a parallel study within the I-STONE project, can contribute substantially in obtaining block recovery values, above 20% set by the examined Commission Decision. Moreover, in the case of Quarries A, C and D, low block recovery is effectively counterbalanced by the 90 % recycling of the extracted waste material, used as the feed in processing plant (i.e. crushing, grinding, etc.), to produce high added value material for other applications.

According to the environmental indicators set by Commission Decision the performance of quarries regarding air quality and noise is assessed based on monitoring of PM10 emissions and noise level in dB(A), respectively at the quarry boundaries. Water quality is assessed based on monitoring suspended solids.

The target values for the air quality indicator – PM10 are within the range set by the Council Directive 1999/30/EC of 22 April 1999, where the limit value for PM10 in ambient air on annual basis is 40 $\mu g/Nm^3$.

No air or noise monitoring data where available or the Greek operations. The data systematically recorded in the examined Portuguese quarries, regarding air quality and noise, indicated that the quarries performance was either good or excellent. Use of modern equipment and application of preventive measures for the elimination of dust emission and noise production, can result in improved environmental performance of the stone quarries, recorded with monitoring.

With respect to indicators I.5, number of equipment working hours, and I.9, visual impact of quarrying operations, no data were available for the examined case studies. Indicator I.5 is directly related with the equipment emissions and energy consumption, and thus its monitoring is critical for the assessing of the eco-efficiency of the extraction process. The proposed method for the quantification of the quarries visual impact, could provide the basis for further discussion amongst the various stake holders to reach general acceptance.

To further quantify the relative significance of the environmental impacts stemming from quarrying operations it is noted that all four quarries examined were not located close to environmentally sensitive sites, (as defined in the Decision), the land use potential is low, the population density either <20 or 20-100 hab/km^2 and there is no interference with surface water-bodies. Thus, the available indicators values were multiplied with the lowest significance weights, and the overall result presented the performance of the examined quarries

6. CONCLUSIONS

A number of environmental, social and economic indicators are developed internationally to assess the sustainable performance of the extractive industry. Following a review of available indicators, a set was initially employed for the qualitative evaluation of stone waste management schemes. Subsequently in the present study a number of eco label indicators proposed in the Commission Decision 2002/272/EC, "*Establishing the Ecological Criteria for Awarding Ecolabel….*" were used to quantitatively assess the environmental performance, and impacts of four Greek and Portuguese stone quarries, producing marble, quarries A,B, in Greece, C in Portugal, and Granite, Quarry D. All quarries examined were main stone producers, with profitable operations, employing personnel from the local community. Assessment of available operational data demonstrated that regarding the % Natural resource appreciation criterion, three out of the four quarries examined had excellent rates, ranging between 90-97%. For indicators such as Water recycling ratio, and Rehabilitation simultaneity degree, additional measures need to be taken to improve quarries performance. However it is also proposed that for these specific criteria, the target values set by the Decision need to be further examined versus the prevailing climatic conditions at Mediterranean countries, and the best attainable practice of the sector. Low block recovery recorded in two operations, resulting in increased waste production, can be mitigated to a great degree with the beneficial use of quarry waste material for the production of medium or high added value alternative products. When monitoring data were available, quarry operations regarding potential impacts to atmospheric and acoustic environment were classified as excellent and good, respectively Moreover, systematic monitoring and recording of critical environmental parameters, such as air & water quality, or noise and parameters as working conditions of operating equipment, is required in order to identify the main areas of extraction activities where additional preventive, or mitigation measures need to be applied. Considering that the examined quarries play essential role for local and national social and economic development, improvement of environmental performance would act synergistically for achieving sustainable development goals.

From the present study it was also concluded that the stone producers in cooperation with regulators, permitting authorities and other stake holders should foresee to employ certain sets of indicators for the systematic evaluation, prevention and mitigation of the quarrying potential impacts. Indicators like many of the ones listed in Commission Decision 2002/272, combined with target values, and relative significance weights can be used by the stone industry for their environmental reporting, in order to optimize their operation and gain the acceptance of the local communities.

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