GOOD ENVIRONMENTAL PRACTICE IN THE EUROPEAN EXTRACTIVE INDUSTRY: A REFERENCE GUIDE

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Preface

For some time now, and particularly since the early 1980s, a number of industries have been increasingly criticised, in some cases justiably so, for causing harm to the environment: the extractive industry was one of these industries in question. Despite the fact that quarrying in some form or other has been carried out since the Stone Age and counts - along with the procurement of food and housing - as one of the basic activities of human beings, people still tend to regard this kind of activity with distrust and fear its effects on the local environment. Although noise, vibration, dust and traffic are bound to occur if quarrying is to take place, the extractive industry has done a great deal to minimise the impact of quarrying on the environment and the resulting inconvenience caused to local residents.

It should be appreciated, however, that extractive activities are dependent on geology and the particular location of minerals. There is no way around this natural reality. It often obliges the operator to work minerals in far from ideal circumstances (e.g. in close proximity to residential areas or with possible environmental impacts), simply because there is no other economic alternative for producing these resources which are of fundamental importance to our society. As a result, the extractive industry operates under firm rules, guidelines and considerable self-discipline with regard to all of its activities. It has set itself high standards with regard to the protection of its workforce, to respect for the well-being of local residents, to respect for the natural environment and the restoration of quarry sites.

Quarry operators, either through voluntary agreements or through regulation, have been complying with an increasing number of measures to minimise a variety of harmful effects. These measures include, among others, Environmental Impact Assessment (EIA), permit procedures, restoration plans, investment in more technically advanced equipment, limit values for noise and dust, new roads to overcome traffic problems, etc.

All these measures, of course, have had an adverse effect on profitability, up to a point where an imbalance is occurring between environmental and business considerations. In this respect, it is important to appreciate that the added value of minerals, on a volume basis, is relatively low and that the structures required to produce them are heavy, most of them representing several hundred euros per tonne. Although investment is of course possible, it has to be reasonably proportional to the benefit obtained, and be planned over long periods of time, in order to allow for realistic financial returns and the sustainability of the activity. In other words, stability and long term policies are key aspects, which need to be taken into account when examining the extractive industry.

The extractive industry suffers from a low-profile, and sometimes poor, public image. There is a natural fear of the unknown and there is a need for better channels of communication to exchange information between the extractive industry, the authorities and the public.

One of the main aims of this Guide is to play a key role in this exchange of information. The Guide will attempt to explain how the extractive industry operates by using a series of "real-life" case studies, which illustrate a number of "good practices" employed by the industry. These case studies show how practical and cost-effective approaches to environmental protection are implemented. In most of them, the company concerned often went far beyond the regulatory requirements, simply because the option chosen was the best available under the prevailing circumstances. This attention to local conditions is a constant theme throughout the Guide. However, it is certainly not the intention of the Guide to prescribe operating standards or codes of practice. Rather, it is to illustrate the willingness of the extractive industry to achieve sustainable development in the context of a balanced regulatory environment.

The initiative of producing this Guide to good environmental practice arose from co-operation between the Enterprise Directorate General of the European Commission and the main trade associations of the sector: Cembureau, Cérame-Unie, EuLA, Eurogypsum, Euro-Roc, IMA-Europe and UEPG (see Annex 2).

The CTP (Centre Terre & Pierre), consultants in the field of quarries, processes and the environment, was engaged in the project to co-ordinate the work and to draft the Guide (see Annex 3).

Chapter 1
Scope and Structure of the Guide

The Guide intends to review the practices of the extractive industry, during all the steps of extraction and processing right up to the delivery of the material to the user. It also covers the maintenance and restoration of sites. What have not been included are the exploration phase or calcination processes, the latter currently being dealt with under the process of IPPC (Integrated Pollution Prevention and Control).

The term "extractive industry" can denote a wide range of products and processes. This Guide, however, covers the non-energy extractive industry of non-metallic minerals which in itself represents a large part of extraction in Europe. Every use of the term "extractive industry" in the Guide refers to this definition.

Finally, six key industries have been analysed: aggregates, cement, lime, dimension stone, gypsum and industrial minerals.

♦ The sector of raw **aggregates** produces hard crushed stone, sand and gravel in quarries of igneous rocks (volcanic included), sandstone and quartzite, limestone, workings of river and marine aggregates, etc. Aggregates are principally used in construction, for both buildings and civil engineering (roads, railways, bridges, etc.), or as a main constituent of concrete.

♦ **Cement** is mainly made of carbonate rocks and a mixture of clays, ashes, etc. This material is calcined before sintering at a temperature of 1400°-1500°C to form the clinker. The clinker is then milled together with small quantities of gypsum to form cement.

♦ **Lime** and dolomite are pyroprocessed minerals generally associated with large quarries of pure limestone, dolomite or chalk. In the calcined minerals industry, quarrying and crushing occur as integrated processes, the environmental effects of which are quite different from those of the manufacturing process which involves calcination [4].

♦ **Dimension stone** (or ornamental stone) covers various types of rock, such as marble and limestone, granite, sandstone and slate. These are used mainly for decorative purposes in building (e.g. floorings and claddings) and for funeral purposes [18].

♦ **Gypsum and anhydrite** are extracted from underground mines or open quarries and crushed before processing into stucco. Stucco is used to make products such as plaster and plasterboard.

♦ **Industrial minerals** include a number of minerals (kaolin, feldspar, calcium carbonate, talc, silica, clays, etc.) used as fillers or for their physico-chemical properties in a wide range of manufacturing, chemical and other industries. They are needed, for example, to manufacture paints, paper, glass, ceramics, detergents, drugs, etc. The characteristics of the final products are strictly dependent upon the base minerals. Although some physical processing is carried out, they are natural products, which basically retain the characteristics of the ores.

The main questions that this Guide sets out to answer are: *What is a quarry and in what environment does it operate? What are the main processes involved? What is the socio-economic importance of the extraction sector in Europe?* These questions constitute the backbone of the first part of the Guide. Each quarry has its own characteristics in terms of mineral properties, size and type of deposit, location, etc., and presents a specific picture. Bearing in mind both these general and specific viewpoints, the second chapter sets out to explain what quarrying is all about.

The third chapter of the Guide will, from a general point of view, consider the environmental impacts which can occur and the ways of mitigating them. It will show that these impacts vary considerably according to local circumstances and that an effective management approach has to be both flexible and adaptable.

Chapter 4 is dedicated to the restoration and aftercare of quarrying sites.

The best way to understand how an industry operates is through the use of "real life" case studies and achievements. These will be illustrated throughout the Guide, at the end of each section on environmental impacts. These case studies will present as wide a view as possible of both regulatory and voluntary ways of achieving sustainable extraction. These approaches are based on the respect of natural resources and the environment, on the attention paid to the welfare of local communities, and on the acceptance of the economic realities the extractive industry faces. These examples should obviously not be confused with a Best Available Technique approach.

In conclusion, the Guide is meant to help readers understand what quarrying is really about and to judge for themselves whether industry is behaving responsibly or not. It is hoped that it will be the starting-point for further initiatives in improving the working relationship between the extractive industry, society and the environment.

Chapter 2
The European Extractive Industry

2.1. Mineral resources in Europe

In the 1995 edition of the "Panorama of EU Industry" [56], Brian Coope, reviewing the non-energy mining sector, concluded that Western Europe's mining and quarrying sector is the most concentrated and active in the world. Furthermore, it makes a highly significant contribution to the economy and welfare of Europe's citizens.

What are the non-metallic minerals produced in Europe?

For the sake of clarity, one ought to make a distinction between two broad categories of minerals: those related to construction activities, and those related to other industries. Aggregates, cement, dimension stone and, to a large extent, gypsum, are destined for use in construction. Industrial minerals are used in a variety of other industries (even if some of the products also end up in construction), while lime is used in both categories.

What is common to all the minerals examined here is that, even if an ore-body is physically present in a particular location, the working of it might not be feasible due, for instance, to the fact that it is covered by too thick a layer of minerals with little or no economic value, or because customers are too far away. This then is an important paradox within the extractive industry: the mere existence of a mineral may, in itself, not be sufficient for its extraction since a number of non-geological parametres (e.g., technical feasibility, market proximity, etc.) must also be taken into account. In practice, the successful convergence of all these parametres rarely occurs, resulting, *de facto*, in an unexpectedly limited number of possible extraction sites. This, of course, is particularly true for rare types of mineral.

Aggregates are small pieces of rock the shape, size and nature of which are characteristic of the mineral from which they are produced. Many different minerals can be used to produce aggregates, including granite, basalt, porphyries, limestone, sandstone, sand and gravel, etc.

In some cases, these minerals are used directly as soon as they are extracted (sand, gravel, etc.), but more often than not they need to be further processed, usually crushed, in order to fit their intended use. Due to the diversity of minerals that can be used as aggregates, their availability is relatively widespread (see Table A).

Table A. Raw materials used to produce aggregates

Sedimentary rocks	Hard limestones, sandstone, red shale, river or fluvioglacial sand and gravel, also marine sand and gravel, etc.
Metamorphic rocks	Impure quartzite and marbles, black amphibolites, metamorphic shales, gneiss, granulite, etc.
Igneous rocks (intrusive & volcanic)	Porphyry rocks, some granite and diorite, syenite, anorthosite, gabbro, some basaltic rocks, andesite, etc.

Cement is also a major mineral-based material and is closely linked to extractive activities. Ordinary Portland cement clinker is produced from a mixture of limestone/chalk, clay/shale, marl, etc. (large deposits of these minerals are commonly found in Europe). Cement production is often located close to, or even integrated with, mineral extraction. Plants are frequently located close to carbonate rock, which makes up over 80% of clinkers. Several types of cement fulfilling different technical requirements are produced using different mineral mixtures. When mixed with water, cement forms a paste, which sets and hardens by hydration. After hardening, it retains its strength and stability, even under water. This hydraulic hardening is primarily due to the formation of calcium silicate hydrates [38]. Table B below is based on a plant with a clinker production of 3,000 tonnes/day (1 million tonnes/year), corresponding to 1,23 million tonnes/year of cement [4].

Table B. Proportions of raw materials used in the production of dry process cement

	per tonne cement	per year per Mt clinker
Limestone, clay, shale, marl, etc.	1.27 t	1,568,000 t
Gypsum and anhydrite	0.05 t	61,000 t
Secondary constituents (recycling)	0.14 t	172,000 t

Lime is a generic term which covers two main groups of products: i) high-calcium and dolomitic lime (quick or hydrated lime) used in industry and agriculture, and ii) hydraulic lime ($CaO < 85\%$), containing silica, used as a binder in construction [18]. Group i) is produced from high quality deposits of limestone, marble or dolomite. Group ii) is produced from impure deposits of carbonate rocks containing various grades of (calcium) lime. In both cases, the carbonate rocks are calcined between 900°C–1000°C (max. 1300°C) under oxidising conditions. Due to the specific nature of the basis materials required, the lime industry is centred in particular locations where limestone basins occur, the main ones being: the Meuse Valley in Belgium, the Düsseldorf-Wuppertal area in Germany, the chalk basins around the North Sea, and in the Seine Valley, the UK, Northern Italy, Spain, Denmark etc. [66].

Dimension stone is a generic term that covers the various natural stones used for structural or decorative purposes in building. Among the extremely diversified stones available, the more common commercial classes are ***marble*** and ***limestone*** (calciferous, dolomitic, serpentinous); ***granite*** (of igneous origin, containing quartz, feldspar, micas, etc. the grains of which are hard, integrated and crystalline); ***sandstone*** (formed from grains of sand bonded by a natural cement); and ***slate*** (schist with fissility plane and fine grains) [7]. Each producer or region has derived its specific commercial name from local varieties of rock such as: Carrara Marble, Petit Granit, Pierre de Bourgogne, Jura Marble, Solenhofen Plattenkalk, Granit du Tarn, Balmoral, Grès des Vosges, etc. Indeed, there are over 2700 recognised commercial names. As in the case of aggregates, these rocks can be classified according to their geological origin (see Table C):

Table C. Principle geological origins of dimension stone

Igneous rocks *(extrusive, volcanic)*	Granite and diorite, labradorite, gabbro, peridotite, porphyry rocks, dolerite, basalt and andesite, etc.
Sedimentary rocks	Limestone, dolomite and travertine, conglomerate and brechia, sandstone, onyx, alabaster, etc.
Metamorphic rocks	Marble, quartzite, shale and slates, metamorphic brechia, serpentine, gneiss, etc.

Gypsum is a relatively common mineral in sedimentary rocks with abundant distribution in thick beds, found for example in ancient volcanic regions where sulphur vapours have transformed limestone. It frequently occurs inter-stratified with limestone and shale and is usually found as a layer underlying beds of rock salt. Deposits of gypsum are primarily located in Germany, France, Spain, Italy and the UK.

Other countries either import gypsum or use synthetic gypsum [65]. Due to its thermal properties, 95% of gypsum is used in a calcined form: gypsum is ground and then heated until about 75% of the water has been driven off. The resulting material ($CaSO_4.½H_2O$) when mixed with water, slowly absorbs the water, crystallises, and thus hardens or "sets" [48]. Gypsum is also usually found in close association with anhydrite, an anhydrous form of calcium sulphate ($CaSO_4$). Over the last ten years, there has been a strong increase in the use of synthetic gypsum [121], primarily flue gas desulphurisation gypsum, or FGD gypsum, the properties of which are virtually identical to naturally-occurring gypsum.

The term **"industrial minerals"** covers a wide range of different materials. Their common denominator is that they are all used as functional fillers or as production aids by industry. They are generally milled into a very fine powder before use. The main categories included in this family are talc, calcium carbonate (ground and precipitated), feldspar, kaolin, ball clays, perlite, bentonite, sepiolite, silica, borates, etc. The mineralogical and chemical characteristics, as well as the particle-size distribution of the final product, determine the possible end-uses. Quality requirements are usually very precise. As the following section will show, the end-uses of these minerals are extremely diversified. The geological availability of industrial minerals depends on the categories considered: talc, for instance, is less common than silica sand. However, even for the categories which seem more common, the physico-chemical requirements are so high and precise that only a limited number of ore-bodies can be worked.

2.2. Main markets and socio-economic importance of the sectors

It is fairly easy to appreciate the importance of minerals in construction. Looking at any building, one can immediately recognise a number of minerals used virtually in their original form (e.g. aggregates, dimension stone, etc.). One only needs to take a second look to realise that other important parts of the building are entirely mineral-based (e.g. bricks, tiles, glass, concrete, etc.). Even the less obvious parts of a building consist of materials and products containing minerals, e.g. frames and pipes, insulating materials, plasterboard, paint, wallpaper and many others.

Looking at non-construction applications, which are primarily dependent on industrial minerals, lime and gypsum, the ranges of industries related to the extractive industry is virtually infinite. Practically all manufacturing industries use minerals as raw materials. Furthermore, minerals are used as processing aids in a number of production processes (e.g. limestone and dolomite as a flux in steelmaking, lime in sugar production, bentonite in oil drilling, sand in foundries, etc.), in healthcare (e.g. gypsum as an agent in tablets and as Plaster of Paris for casts and surgical bandages), and some are even used as consumer products (e.g. bentonite or sepiolite for cat litter). Moreover, minerals are increasingly used for environmental applications, e.g. water filtration, pH control, flue gas desulphurisation, etc.

Most people are unaware that minerals influence almost every aspect of our lives and figure at the very heart of our society and of its technological development.

Recognising this fact, it is not at all surprising then that minerals, and the extractive industry which supplies them, occupy a vital position in Europe's socio-economic structure. The following tables give an insight into the extractive industry itself (see Table D) and into the main industries using these materials (see Table E).

Overall, the extractive industry has an output of some 3 billion tonnes, with a value of about € 50 billion, and employs around 500,000 people. The main industries depending on these materials employ more than 4 million people and produce goods with a value of around € 700 billion. It is estimated that over 20% of the European Union's Gross Domestic Product is dependent in some form or other on the extractive industry. This part of the economy, and its contribution to Europe’s prosperity and welfare, clearly relies on a sustainable supply of these minerals.

Table D. Socio-economic overview of the European extractive industry

Mineral	Production 10^6 tonnes	Value 10^6 €	Employment	Main uses
Aggregates	2,700	22,000	200,000	Civil engineering, concrete production, etc.
Dimension stone	17	5,000	190,000	Structure and decoration of buildings, funeral materials
Cement	166	10,000	55,000	Mortar and concrete production
Gypsum & plaster	25	3,000	20,000	Plaster, plasterboard, cement production, moulds, food and drink-additives, etc.
Lime	22	4,000	11,000	Iron & steel industry, chemical industry, construction and construction materials, environmental protection, agriculture & forestry, sugar production, etc.
Industrial minerals	90	6,000	19,000	Paper & board, ceramics, china, plastics, rubber, glass, fibreglass, foundry, filtration, fertilisers, foodstuffs, drugs, cosmetics, etc.

Table E. Mineral-consuming industries.

Application	Value 10^6 €	Employment	Mineral content
Construction			
Concrete	38,600	290,000	100%

Aggregates for civil engineering			100%
Glass	26,800	250,000	100%
Ceramics	20,000	250,000	100%
Bricks & tiles	6,600	72,000	100%
Cement, lime and gypsum	38,600	292,000	100%
Stone production	5,300	71,000	100%
Non-construction			
Abrasives	9,300	69,000	100%
Rubber	31,200	300,000	Up to 50%
Plastics	95,300	835,000	Up to 50%
Paint	26,000	150,000	Up to 70%
Paper & board	43,000		Up to 30%
Ceramics			100%
Refractories			100%
Silicon & Ferrosilicon	25,000	3,000	100%
Foundries	30,000 ?		processing aid
Basic chemistry	154,000	595,000	Variable
Pharmaceuticals	65,000		Variable
Mineral filters			100%
Sugar			processing aid

More detailed information on markets and end-uses by sector is included in Annex 1.

2.3. The core operations of the industry: extraction, processing and production

Given the geodiversity of minerals, and the circumstances in which they are worked, there are many routes from the ore-body to end-uses. Mineral resources may be massive rocks in mountain regions or sand in alluvial plains, they may be close to the earth's surface or deep underground and they may be almost a pure material or a mixture, etc. As a consequence, processes and equipment have to be adapted to specific circumstances. Indeed, every quarry is unique.

Although it would serve no purpose to over-generalise, there are however some permanent features common to all the mineral types under review.

It is most important to point out that opening and running a quarry is a technically precise business. It is a demanding and costly process requiring competent management. First, the ore body has to be meticulously analysed and located (composition, location of the veins, size, amount of unwanted material, etc.). This is the work of geologists who, by drilling and other means of exploration, calculate the three-dimensional extent, quality and structure of the ore-body before extraction starts. If a site passes this first test, feasibility studies are then carried out. Finally, the applications for permit and planning are prepared. The operating and closing phases of the site must be planned, including restoration and aftercare. All in all, this preparatory work requires at least several years.

Operations generally begin with the removal of the surface soil, known as the "overburden", which covers the ore-body to be worked. According to current practices, the topsoil is removed separately and carefully preserved so that it can be put back in place during restoration work. The overburden is used for mass restoration as foreseen by the restoration plans. When the mineral is a hard rock, the process is carried out by creating benches 10–20 metres high. These are designed to allow easy access for loading shovels and dumpers, or for the installation of conveyors. The rocks are fragmented by various means (drilling, blasting, hydraulic means, etc.) and carried away from the extraction face. The next stage of processing the rock varies according to the different extractive industries considered here. In some cases, e.g. for aggregates, the rock undergoes a preliminary crushing on the extraction site. The blocks may also be directly transported to a processing plant without pre-refining. In some exceptional cases, e.g. talc, the rocks are manually sorted in the quarry in order to separate out blocks of different quality.

Unless rock is to be used in massive form, as with dimension stone or with aggregates of several cubic metres destined for such uses as sea walls, the rock is generally crushed and graded by screening. The extractive industry has acquired a high level of technical ability to produce aggregates with different characteristics (size, form, purity, etc.), which is critical for even the most simple of end-uses.

Processing unconsolidated sediments, such as sand and gravel, usually does not involve crushing. It can be carried out simply by excavating the deposit, or dredging it if it happens to be underwater. The material is then transported away as is done with massive rock, or, in some cases, can even be pumped away.

In order to produce **cement** (in the dry process), carbonate rocks are mixed with clay, ashes and other materials. This material is pre-calcined before sintering at a material temperature of 1400°-1500°C to form the clinker. The clinker is then milled together with small quantities of gypsum to form cement. Various types of cement may be produced by adding other cement constituents to the mill such as fly ash, slag and limestone.

Apart from the blending, the preparation of **lime** (and hydraulic lime) is virtually identical. The pure carbonate rocks ($CaCO_3$) are calcined to form calcium oxide (CaO) at 900°-1300°C (1200°C for hydraulic lime) under oxidising conditions in high-energy kilns. Products are finally milled into powders and packed or stored in silos before delivery. For many applications, lime is subsequently hydrated or slaked to form $Ca(OH)_2$.

The degree of processing for **gypsum** is determined by its end use. Gypsum for use in cement production needs only to be crushed to 1.25 cm. Calcined gypsum for use in plasters is produced by heating crude crushed or ground gypsum to 250°C in kettles or rotary kilns. The resulting hemihydrate product is known as stucco and is used to make plasterboard, plaster blocks and builders plaster. When water is added to form a paste, the calcined material reabsorbs it and rapidly sets to form gypsum again.

Dimension stone occurs naturally as hard massive rock, such as marble, granite, etc. It is usually extracted from surface quarries, except for slate which can also be mined underground. Usually, rough blocks of dimension stone weighing 50 tonnes or more are detached from the massif by using both natural fractures and various techniques such as soft blasting, closely spaced drilling, diamond wires and blade cutting [7]. More recent techniques involve the use of high-pressure jets of water or hydraulic breakers. In dressing plants near the quarry or in specialised workshops, the blocks are directly dressed with gang saws, block-cutters, rotary disk saws, etc. and transformed into slabs or blocks of all shapes and sizes. Finishing includes polishing and cutting or carving by mechanical equipment or by specialised craftsmen.

The production methods of **industrial minerals** vary quite significantly depending on the nature of the minerals and/or their intended use. In general, the physico-chemical requirements are high, necessitating relatively sophisticated processing methods. The production of industrial minerals can be broken down schematically into five critical steps, as shown in the following diagram:

WASHING & SEPARATION ⇨ DRYING ⇨ MILLING ⇨ SIZE-SEPARATION ⇨ STOCKING & PACKAGING

During the washing and separation step, minerals are sorted on the basis of their relative density. Depending on the circumstances, only one or several of the fractions produced may be of interest. After drying, the minerals are milled into very fine powders. These powders then pass through size-selecting devices, which accurately sort the particles on the basis of their density, magnetic properties, etc. Some product grades have to meet a very narrow particle-size distribution, not ranging over more than a few micrometres. Blending between different grades may be carried out in order to fulfil end-user needs. The sorted material is then packed or stored in silos for bulk delivery.

Chapter 3
Managing the environmental impact of extraction activities

Every human activity has an environmental impact. Even the simple fact of writing on a sheet of paper with a pencil has an environmental impact: it generates heat. Depending on the particular circumstances, the environmental impact of a given activity can range from being of little significance to being extremely significant and the need to manage the impact varies accordingly.

Quite clearly, the extractive industry, by its very nature, is likely to generate a certain number of environmental impacts. It should be emphasised, however, that these impacts remain largely localised and do not have any wide-ranging effect beyond the immediate vicinity of the extraction site.

It would be misleading to believe that extractive industry operators have "carte blanche" to dig wherever and however they like. It would also be wrong to believe that prescriptive rules could apply in exactly the same way to all the different extraction sites in Europe. Managing this kind of activity requires a delicate balance between pre-set rules, adapting to local realities, and the initiatives of local quarry operators. Quite clearly, potential effects vary considerably according to the local environment, and this requires both a flexible and an adaptable management approach. In the preceding chapters, the complexities involved in developing an extraction project were described: geology, mineralogy, geography, markets, etc., are among the numerous parametres which need to be taken into account. In the relatively few cases where the project gets past this internal selection procedure, it still has to go through a formal authorisation procedure.

The authorisation procedure is the "open sesame" to environmental regulation, an integral part of any extractive activity. In the past, relationships between quarry operators and national authorities were guided almost exclusively by mining codes. These codes, where they still exist, continue to regulate questions of property and access to underground resources. Nowadays however, the extraction of minerals not only needs to satisfy the need for resources, but has also to be acceptable from an environmental point of view to society in general. The permit procedure thus becomes a complex and drawn-out process during which a project submitted by an operator goes through an impressive number of authorities, responsible for all types of environmental and other regulations. In many European countries, extraction permits are subject to enquiry and authorisation at two, three and sometimes four administrative levels, from local authorities through to national ministries. During this very long procedure (which can last 2-5 years!), the quarry operator often subdivides the project into several files one for each of the impacts and its corresponding authority, e.g. Natural Resources, Land Use or Environment Divisions, National River Authorities, Waste Regulation Authorities or Air Pollution Authorities, etc. In some regions, extraction is regulated by water management laws or landscape laws according to whether the ground water is affected or not by the working. The permits can also be different according to the kind of raw material, the kind of process or even the size and height of the plant! Throughout this consultation phase, the project is analysed, clarified and amended, until it is acceptable to all concerned departments. The positive aspect of this process is that generally it is highly interactive, often at a very local level. This increases the chances of the project being considered on practical rather than on theoretical grounds. The negative aspect is that, with regard to the increasing concern for the environment and the concomitant steep increase in regulations, the time needed to go through the whole procedure can be excessive (one example of 15 years exists [86]).

Although the EU Member States may still have slightly different approaches to it, the Environmental Impact Assessment (EIA) is becoming a widely used tool in the permitting process. As will be made clear in the rest of this section, the points of concern for the non-metallic mineral industry are usually environmental impacts of a temporary and localised nature rather than of major ecological significance. This certainly does not mean that more significant impacts do not occur, or that the effects of minor importance should not be dealt with. The commitment of the industry to sustainable environmental management is rapidly increasing as new environmental standards and instruments (e.g. the ISO 14000 Series, EMAS etc) are developed. In this respect, it is worth noting that one of the first industries registered under ISO 14000 in France, during the test phase of this standard, was a quarry producing calcium carbonate. It should also be pointed out that, according to current practices, extraction sites are more often creators of habitat variability and bio-diversity than the contrary. Quarry sites in Europe tend to become high-value ecological areas. There are also countless examples where they contribute to the well-being of local residents by being rehabilitated as natural spaces or leisure parks.

One of the difficulties of starting or extending an extraction operation is certainly its potential impact on local residents. Obviously, the less populated the area is, the better. Because of the numerous reasons already identified, it may however be that an extraction site is needed in a moderately or even heavily populated area. Reasons can be the exceptional quality of a given ore or the need to provide local industries (building, glass, ceramics, paint manufacturers, etc.) with the raw materials they need. In mitigation of any local environmental disturbance, it is important to emphasise that a quarry is a vital element of the local economy. This is particularly obvious in some rural areas where practically everybody is either working for the quarry or, for other companies, supplying the quarry or under contract to it. This "bottom-up" effect can even be observed in areas where the number of people directly employed by a quarry is more limited in relative terms. Bearing in mind the number of industries which rely on minerals for their production, there are areas the populations of which depend entirely on quarries. Drawing on the experience of quarry operators over the years, it appears that the people living close to a quarry generally suffer from what are limited and very specific effects such as dust emissions, noise from explosions, the start-up of engines in the morning, heavy goods vehicle (HGV) traffic, etc. Dialogue with the local population on these matters is critically important, since it allows the operator to take corrective action, and gives the local residents the certainty that their views are really being taken into account. Living together satisfactorily requires mutual respect and dialogue. This important aspect has been somewhat neglected in the past, although it now seems that the extractive industry and its neighbours are back on the right track. The emergence of local associations and groups allows constructive dialogue and facilitates the public consultation either required by the permit procedure, or initiated by the operator. The extractive industry has also become more transparent. While, for obvious safety reasons, day-to-day access to quarries needs to be restricted, open days and guided tours are increasingly organised, contributing significantly to a growing mutual confidence.

In the next sections, the principle nuisances an extraction site might cause will be looked at, as will the relevant regulations and voluntary practices. By using real examples, it will be shown how existing regulations combined with voluntary measures taken by operators, can lead to the successful management of a specific site. The cases reviewed will put into perspective why different approaches are needed to manage different extractive operations.

3.1. Noise and vibration

Firstly, a distinction should be made between permanent and intermittent noise; their origins are different and they create different sorts of disturbances. Typical permanent noises are those created by road traffic in large towns or along main roads. The noise usually produced by quarries and mineral processing seldom falls into this category, most of it being intermittent or even sporadic. Some permanent noise however might occur, e.g. from a shovel operating in the quarry or from a dust extractor or a conveyer belt. Processing plants also create some noise of this kind, but it is generally kept under control by means of insulation. As this low-level permanent noise is normally just a part of the prevailing background noise[1], it is relatively insignificant and usually well tolerated.

Intermittent noise is produced by specific operations: mainly blasting, but also the daily starting of engines, the loading of rocks into dumpers, the unloading into the steel entry chutes of primary crushers, etc. When it is not following a periodic cycle, or when the period is long, it could even be qualified as sporadic noise. To prevent and control this noise, well-managed quarries have taken effective measures such as screening mounds, special low-noise starters, rubber coating in dumpers and entry chutes, cladding of belt conveyors, enclosing of open plants, etc. The dimension stone industry has introduced new anti-noise and anti-resonance circular blades for the cutting of rough blocks and the setting of small pieces [104].

When considering the issue of noise, the density of the population surrounding the quarry is obviously a key factor. Population density in Europe ranges from 452 habitants per km^2 in the Netherlands to 16 per km^2 in Finland [72]. Concerns caused by the intermittent noise of quarries located in the relatively unpopulated rural territories of Scandinavia or the Mediterranean region are naturally less intense than in highly populated urban regions. Limit values imposed by local authorities reflect this fact. The maximum limit values for noise emission in European countries or regions varies between 50 – 85 dB(A)[2] during day-time and 35 – 70 dB(A) during evening and night-time. This range of values is completed by limits linked to land-use planning. In Germany, for example, the day-time limits in industrial, commercial, mixed and residential areas are 70, 65, 60 and 50 dB(A) respectively [102]. Many of the large mineral groups also have their own environmental

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[1] *At 50 m from a crusher in a closed plant, the level of noise is equivalent to the ambient noise of an office.*

[2] *dBA: Decibels measured on a sound level meter incorporating a frequency weighting (A-weighting) which differentiates between sounds of different frequency in a similar way to the human ear. A doubling of noise energy gives an increase of 3 dBA (e.g. 90 dBA + 90 dBA = 93 dBA).*

policies whereby they require their local operators to view the legal limit simply as a minimum requirement with a commitment to go beyond it if feasible.

Vibration from quarries usually results from the blasting which is required to break down the mineral or the rocks surrounding the ore. This step is required only in operations involving massive rock extraction. Blasting induces ground vibration and airblast overpressure. Some release of vibrational energy beyond the zone of rock breakage is inevitable. This unproductive energy however represents a small percentage of the energy of the explosive but, under certain geological conditions, can travel many kilometres before falling below background noise levels. Airblast overpressure is the superposition of a number of impulsive air pressures generated after detonating [16]. The resulting pressure pulse travels through the air as a sound wave. Atmospheric conditions, the terrain and the vegetation affect its propagation. Blasting is certainly an issue of concern for local residents, though more from a psychological point of view than a physical one[1]. Good blasting practice has important consequences for the profitability of an operation. It is thus one of the principle concerns in the quarrying of hard massive rocks. To optimise material recovery, the blast must fragment the solid rock into adequately sized blocks; they should be neither too big (necessitating costly and dust-producing secondary breakage) nor too small and dusty. To make the access of shovels and the loading of dump-trucks easier, the blast also needs to produce a sufficiently large pile at the foot of the rock face, well-sorted and not too jagged. Along the faces, benches need to be preserved and the surface of the rock face must be level and well cut in order to prevent rock from falling. Significant progress has recently been achieved in the quality of explosives, delay detonators, blast design and monitoring of blast sequences to prevent vibration and splattering. Quite clearly, blasting practice is an area where environmental and operational interests are entirely compatible and any progress is of mutual benefit to the industry and to the environment. In a number of countries, for example Belgium, training programmes on blasting are organised by extractive industry associations and directly sponsored by operators. In the dimension stone industry, the use of rock splitters in natural fractures diamond cutting wires tend to limit the use of blasting [104].

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[1] *Recent research shows that blasting will always have the potential to upset people but that well established quarries which have developed good relationships with local residents are less likely to attract complaints. Even if blasting is the second most important environmental concern (after dust), the complaints concerning blast-induced vibration are not the result of actual structural damage, but rather due to adverse human responses and fears of structural damage [53]. The vibration levels at which complaints were made varied significantly and, once the threshold of perception had been crossed (within the accepted damage criteria), the magnitude bore little relation to the level of resulting complaints [44].*

Vibrations, other than those from blasting, are generated by large primary crushers and plant screening equipment but if the foundations are correctly designed, vibration from crushing and screening operations can be greatly reduced.

The limit values for ground vibration applied to European quarries range from 2 to 50 mm/s (PPV), with an average of around 15-20 mm/s, and 90-140 dBL (OP) for the air overpressure[1]. For ground vibration, these limits are adapted to the frequency of the vibration and to the type of nearby building. For example in Germany, the PPV for a frequency < 10 Hz is 20 mm/s for industrial and commercial buildings and only 5 mm/s near residential buildings [102].

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[1] *Vibrations from blasting impact are measured in terms of peak particle velocity (PPV in mm/sec) and air overpressure (OP in dBL). The dBL logarithmic measure of sound level has two thresholds: 0 dBL is the threshold of normal hearing and 140 dBL is the threshold of pain.*

Case studies on noise and vibration

Noiseless starters for loaders and machines *Biblio. Ref. [33]*

Milieu Quarry(Belgium) – Limestone aggregates

Several quarries in the region of Tournai (Belgium) have been co-existing with local residents for years. Many quarry workers and other people live close to the quarries. Nevertheless, one of the important concerns of quarry operators is the problem of noise emission.

At one of these hard limestone quarries, producing 4 million tonnes/year of blocks and crushed aggregates, the intermittent noise was partly due to mining equipment working at the faces such as large dumpers and loading machines (Caterpillar 992C, 992D etc.).

To prevent this type of noise (particularly due to the daily start-up of engines), the quarry operator opted for the system of a noiseless starter. “Small” dumpers of 35 tonnes have been gradually replaced by others with a capacity of 85 tonnes. These are fully equipped with electronic and computing systems for better management of loading time, consumption, etc. All these specific measures of noise reduction directly applied to the quarry's loading and transport equipment have allowed for a considerable reduction of intermittent noise.

With other more classic measures, such as the building of earth mounds or the insulation of unloading stations at the primary crushers, the area is actually considered to be relatively quiet by local residents. Intermittent noise is not particularly excessive in comparison to the permanent background noise of major roads and highways crossing the surrounding urban areas.

Hydraulic hammers v blasting *Biblio. Ref. [61]*

Arstop Quarry (Sweden) – Granite aggregates

The reasons for encouraging the use of heavy hammers to replace explosives in quarries are mainly those of environmental regulations, but also of cost reduction. This new process of rock breaking with track-mounted hydraulic hammers, more traditionally used for secondary breaking of large blocks, is still poorly developed at the quarry face.

Due to the proximity of residential areas and taking advantage of a period of reorganisation, the managers of this quarry of granite for aggregates decided to substitute blasting by explosives with hydraulic hammers for breaking.

After testing different equipment between 1994 and 1996, the quarry opted for a new generation of hydraulic hammer that can break approximately 270-470 tonnes/hour of hard rocks at the face: the vibrosilenced version selected is also particularly silent (85 dB(A) when measured at distance of 10 m) and limits the vibrations in the massif. Even if production with this kind of equipment is relatively low (in comparison to blasting) and ideal for small to middle quarries, this new method is particularly environmentally friendly.

Above all, the adverse effects of blasting such as vibrations, sporadic noise and even the projections of stone are no longer experienced. Local residents and the local authorities are satisfied with the improvements.

If a "permanent" noise has been created by this new machine, others have also been avoided in the plant. Due to the quality of breaking (producing a homogenous granulometry between 200/400 mm) the subsequent operations of crushing have been simplified by the suppression of a jaw crusher.

The production of fine materials and dusts has been reduced from 12% to 2% ! … another plus point for the air quality around the quarry.
Finally, it was possible to simplify the subsequent project of restoration: new benches were only 5 m high compared to the traditional benches of 12-20 m generated by blasts. The future landscape of the quarry will be more level and less dangerous for visitors.
The manager of the quarry has announced a reduction of 55% in cost per tonne of crushed granite. Furthermore, it was possible to raise production from 600,000 tonnes to 750,000 tonnes. The increase in capacities and the reorganisation of the activities (with a new working time management) has opened up new perspectives for employment.

An alternative to the backing-up warning systems of loaders and dumpers

Biblio. Ref. [111]

Rübeland Quarry (Germany) – Limestone for lime

Particularly in areas which are used for different purposes (in this particular case a lime works and employee housing), it is difficult to prevent the harmful effects of noise emissions. Consequently, state-of-the-art techniques are needed to help combat such effects. A noise problem that often occurs in such areas is the backing-up alarm signal of wheel loaders and dumpers. The acoustic devices installed on these large vehicles for safety reasons tend to disturb people living in the vicinity of the lime works, especially in the evening and at night. For this reason, comprehensive testing of alternative backing-up warning systems was done over the period 1995 to 1998. The objective was to reduce noise emissions whilst providing maximum protection of the work area of the large vehicles against unauthorised entry by other vehicles or pedestrians. At the same time the vehicle driver should be in a position to recognise danger when backing up and to avoid accidents and damage proactively.
During the trial period various systems using ultrasound technology and visual rear area surveillance, consisting of a camera and monitor, were tested. A rear view system consisting of semi-fish eye camera, picture recording and monitor produced the best results. For night operation, the system additionally features electronic twin flash lamps for visual rear area warning and additional headlights to improve visual quality. This technical combination is a real alternative to the acoustic rear warning and will minimise noise disturbance of the neighbouring population by large-size vehicles. The German Quarry Insurance Association gave a positive rating to this solution.

Common achievements to reduce noise and vibration

Biblio. Ref. [75]

Dürnbach Quarry (Austria) – Limestone for lime

The Dürnbach quarry producing 1,000,000 tonnes/year of limestone has applied standard measures to reduce noise and vibration: sheathing of the crusher and the loading in the plant, and, for the extraction operation in the quarry, blasting with shared column of blasting charge for the reduction of vibration. Millisecond detonators are used for blasting materials so that the air in the bore holes will reduce vibration.
In the next two years, two shafts will be erected in the centre of the quarry as storage and vertical transport system. The crusher is on the top of the shafts. Consequently, the amount of HGVs in the quarry and the distances from the loading place to the crusher will be reduced by more than 50%.

New blasting methods and hydraulic shovels to reduce noise *Biblio. Ref. [106]*

Gaurain-Ramecroix Quarry (Belgium) – Limestone for cement

This quarry of massive limestone is worked on a length of 750 m and has a total depth of 230 m under the surface level. Until now, explosives (irremite and An-FO) have been used to extract materials from the faces. Millisecond detonators and special stemming has allowed the production of a good level of fragmentation and minimisation of the impacts of blasting noise and vibration. Nevertheless, the faces have been moving closer to the nearest villages and are now at a distance of only 500 m. As each day two blasts of 20,000 – 25,000 tonnes are necessary to feed the cement and aggregates plants, investigations have been carried out to minimise the impact of blasting. A new blasting technique studied with the producer of the explosives has enabled the minimisation of the pressure peak by approximately 15%. In the field however, this improvement has been judged as insufficient.

A radically different method of extraction has been proposed by the quarry manager, to extract directly the rocks from the massif in the upper level of the quarry using a 1,200 horsepower hydraulic shovel of 255 tonnes. With a bucket of 12 m^3 and a penetration force of 1,100kN, this shovel will replace 15-20% of the drilling and blasting activities at the faces, mainly in the most sensitive upper level of extraction. These improvements will help reduce disturbance caused to local residents.

Measures to minimise local residents' fears with regard to noise and vibrations *Biblio. Ref. [111]*

Istein Quarry (Germany) – Limestone for lime

In 1983, the company obtained a permit to extract 700,000 tonnes of limestone per year from its new quarry for a period of only 10 years. During the initial stages, many objections to this operation were received from the inhabitants of a community located at a distance of only 300 m. Their main concerns were visual impact, vibrations during blasting and noise emissions.

The following parametres were fixed for large hole blasting which is necessary for the extraction of the raw material: maximum of 80 kg of explosive per drillhole, maximum of 6 drillholes per blasting activity, maximum height of limestone wall 20 m. The explosive charge in each drillhole is divided and activated by 2 millisecond igniters. These measures help to keep vibrations at a very low level.

The company uses 2 wheel loaders CAT 988 F and 2 dump trucks CAT (load capacity 50 t) to transport the raw material to the crusher. All equipment and vehicles meet the latest noise emission control standards. The crushing plant is fully encased with sandwich boards of high insulation value. The pre-crushed raw material is transported by conveyor belt to the screening plant over a distance of 1.5 km. This conveyor belt is encased and operates quietly.

The above measures helped to dispel most of the fears and concerns of the local residents. As a consequence, no objections were filed during the second permitting procedure, and in 1992 the company obtained a further operating permit for a 20 year period.

3.2. Dust

Dust occurs in processes like blasting, loading, transport, crushing, etc., i.e. any action where the ore is put into motion. The size of airborne particles ranges from a few micrometres to about 3 mm. The dynamics of dust generation is a complex issue. Dust produced in plants (by fine crushing, milling, screening, drying, etc.) is generally collected through exhaust ventilation systems which end up in filters. The dust collected from these filters may have to be disposed of, but in many instances, can be returned to the process cycle, or even sold directly as a specific product grade, as frequently happens in the industrial minerals sector. The composition of dust cannot generally be inferred *a priori* from the composition of the mineral from which it comes, but the amount of silica contained in dust deserves some special attention. Exposure to silica dust was an important health issue at the height of coal mining, this dust being responsible for the development of silicosis. The level and/or duration of exposure required to induce this pathology is however high, and outstanding progress has been made in occupational hygiene practices. If silica dust may still be an occupational hygiene issue, particularly in certain indoor situations, environmental dispersion of silica dust is not an issue of concern for health.

When looking at the issue of dust in the context of open air, in and around the quarries (where crushing is an important process), it is obvious that local climatic conditions greatly influence the level of generation and dispersion of dust: the working of quarries in a dry climate is more dust-generating than in rainy regions. In some regions of Southern Europe, long dry summers are responsible for conditions favourable (under windy conditions) to the local dispersion of dust, sometimes to the point of being problematic. On the other hand, such dispersion is fairly sporadic in Northern Europe where drizzle, mist and rain occur frequently. This concern for dust not only affects the extractive industry but also many other industries such as construction and agriculture.

Taking into account this parameter of climate, current dust emission limits applied in European countries and regions vary between 20 and 150 mg/m^3.day for ambient dust measured around quarries. The environmental impact of dust dispersion is mainly visual. From existing information, it appears that dust, which is not intrinsically toxic, has little influence on the surrounding biocoenoses[1].

In wet processes (screening and washing of crushed products) or during the sawing of dimension stone, materials are permanently dampened, to prevent dust emissions. Quarry operators have also developed ways of adapting the infrastructure and their operating

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[1] *Biocoenose denotes the integrated system of various life-forms (including that of human beings) living in a given place and in a given environment.*

practices which significantly reduce dust emissions: road surfaces, water spraying, decreasing settlement on stock piles, earth mounds and vegetation, enclosure of crushers, closed silo, etc. Substantial progress has been achieved in this area. The "white" landscapes seen in former times are now a thing of the past, due to the efforts undertaken by the extractive industry[1].

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[1] *Dust abatement investment represents 3-16% of the annual turnover of the cement industry [26].*

Case studies on dust management

New installation for dust control *Biblio. Ref. [31]*

Niederofleiden Quarry (Germany) – Basalt

In 1995, the Niederofleiden quarry of basalt, with a plant producing 650 tonnes/h of crushed aggregates, invested a total of € 7.7 million in a new installation for treatment (secondary crushing and screening), for storing in high hoppers and in a new loading station, with the aim of replacing the present one which, though modernised several times, basically still goes back to the 1930s. With regard to this modernisation, the quarry manager cited not only technical and economic reasons, but primarily environmental considerations for development of the totally new installation which incorporates integral computer control.

For example, in order to prevent dust emissions, the equipment for crushing and screening has been erected in a totally enclosed plant.

At the same time, a new BMD-Garant system provides dust suppression in the enclosed plant, using Lingenberg dust encapsulating technology with an absorption capacity of 245,000 m^3/hour.

The 12 new hoppers erected for a complete isolation of the chipping and crushing of stones have a total storage capacity of 6,000 m^3 and have replaced old external stockpiles.

Common achievements in dust management *Biblio. Ref. [112][113]*

GSM Group (France) – Aggregates

The GSM company producing aggregates has been planning its recent environmental programme year by year: 1993 for the audits of sites, 1994 for water management, 1995 for noise and 1996 for dust. For dust emission, the company has defined three measures that will be applied at all quarries: (i) setting up dust control with, for example, a weekly questionnaire about source emission and quantities of dust, (ii) asphalting of inside or outside roads (16 km in 1995 to mid-1996) and setting up of timer systems of spraying/watering of the inside track, (iii) investment in plants.

Between 1994 and 1996, industrial sites above ground have been equipped with systems of water micronisation. At Roussas, one of these sites exploiting where a pure but crumbly limestone is extracted, the anti-dust equipment has an air flow of 75,000 m^3/hour and allows a recuperation of 4-5 tonnes/hour of fine materials and dusts. This valuable material is stocked in a closed silo of 60 m^3 and sold as a filler in the building sector and other industries.

Asphalting of road and hose pipes *Biblio. Ref. [75]*

Dürnbach Quarry (Austria) – Limestone for lime

The Dürnbach quarry producing 1,000,000 tonnes/year of limestone has applied standard measures to reduce dust emission. One of the measures has been the asphalting of 30% of the roads. The crushing and screening plant is totally enclosed, and in the screening plant several places and transfer points are sprayed with hose pipes to minimise dust. In addition, asphalted areas near the crusher and the loading system are cleaned with a road sweeper.

Finally, an early warning and information system has been installed to reduce dust nuisance to local residents. It allows for the source of dust to be analysed and for prompt, remedial action to be taken.

Drastic reduction in dust *Biblio. Ref. [118]*

Rübeland works (Germany) – Limestone

The Rübeland works (producing limestone) has been entirely restored and reorganised, particularly to improve the quality of its environment. The view of the quarry and plants in 1991 shows that great efforts have been made. Since then, the former crushing, screening and milling plants have been rebuilt in a closed installation and the use of water has been generalised. Open-air stockpiles of limestone have been removed.

All the expected sources of dust have been fitted with filter systems. 10,242 tonnes of dust were emitted in 1989 (lime plant included) but, by 1997, the residual dust discharge was only 11 tonnes.

The Rübeland site has been validated by the EC Eco Audit Ordinance and certified in accordance with ISO 14001 of the Environment Management System.

Equipping a conveyor belt to reduce dust emission *Biblio. Ref. [128]*

Frechen Works (Germany) – Sand and gravel

Efficient measures to reduce dust emission near conveyor belts have been applied at the Frechen sand extraction site by a system of water circuits and guttering.

During the transfer of dry sands, fines and dust drift off the top level. The dust is dispersed by airflow and the observation of limit values becomes difficult. By building gutters (channels) under conveyor belts and by washing belts and gutters, the dust dispersion has been drastically reduced. The water, with low quantities of fines, sands and dust, is channeled to the rotary screen for washing operations. The fines particles are then returned to the water treatment installation where clean water is separated from mud.

A system of "global confinement" of silica dust *Biblio. Ref. [129]*

Capoulade Site (France) – Alluvial sand

The Capoulade alluvial deposit of sand (500,000 tonnes/year) near Rouen contains a high level of silica (92% approximately). To control the fine dust, a system of "global confinement" of the raw material has been installed at three critical points of emission: at the crushing-milling station, at the entry chutes and at the conveyors. The complete equipment has been set up in a hollow with an exhaust fan and dust is filtered by a sleeve filter. The removed dust is compacted in blocks (like "face powder") and redistributed on conveyor belts. This system is particularly efficient for very fine dust and has been validated by dust measurement at height source points: the values between 2–22 mg/m³ (with an average of about 8 mg/m³) have been reduced to between 0–2 mg/m³ after the installation of this system.

3.3. Visual impact

Among the potential negative aspects of mineral extraction, the visual impact of quarrying deserves special attention. Here, we need to consider sites the total surface of which normally range from 10 to 150 hectares, areas which are distinctly visible. In certain cases, the effect on the landscape can be significant and unpleasant to the eye. Generally speaking, the significance of the change is linked to the topography of the area and to the type of landscape and vegetation: a quarry in undulating moor is more visible than one in a flat wooded area. The overall visual impact of quarrying, however, should not be exaggerated. Many quarries in fact are not visible unless they are pointed out.

The importance of good design and effective landscaping to minimise visual impact has long been recognised by quarry operators. In flat and semi-flat areas, extremely good visual protection can be achieved through the creation of screening mounds, possibly in association with the planting of vegetation. Reducing the overall quarry surface through the rapid restoration of areas already worked is another means of reducing the visibility of a site. On this latter point, however, it should be appreciated that technical requirements must continue to be fulfilled. For some minerals, e.g. industrial minerals, the stability (or the specificity) of the material produced can, indeed, only be assured by blending different parts of the ore body. As a consequence, the different sectors in the quarry from which they are extracted have to remain accessible. This might require a wider working area than one would expect *a priori*. In other instances where the composition of the ore is less important, or where the ore is particularly uniform in composition, extraction work and restoration can proceed simultaneously.

In any case, visual impact is not easily discussed in absolute terms. Whether or not a quarry is unpleasant to the eye, beside the subjective dimension of the question, is very much a matter of integration into the surrounding environment. Physical screening, screen planting, landscaping and the use of existing features contribute to local surroundings [8].

Clearly, it is difficult, if not impossible, to measure visual impact quantitatively through standards and regulations. It is generally agreed, that the value placed on a certain type of landscape is a subjective issue and in some cases, for example, authorities have refused permits for landscape reasons, when, in fact, there is no opposition from local residents or environmental groups.

In fact, quarry operators are often obliged, through recommendations or regulations at the EIA phase or from the permit procedure, to plant trees to screen off processing plants, to respect maximum heights, to use available space in the quarries, to ensure adequate maintenance of the site and its exits, and to control piles of soil, whether recoverable or not. To assure these measures are implemented and that the visual impact of the site is well-managed, the authorities usually monitor progress on a regular basis, often with the use of photographic records. The developments of quarrying operations and ancillary activities may have a visual impact, generally understood as a loss of visibility and of quality of rural landscape. It is particularly the case for the quarries located in hills and mountains with their flanks in relief.

Good design and effective landscaping to minimise this impact are important for the corporate image of the quarry. For visitors and customers, the first impression given by the quarry is how well it is integrated into the surrounding area. It is particularly true in quarries of dimension stone where architects and contracting authorities are regularly invited to check the quality of stone at the face.

Case studies on visual impact

A quarry exit converted to resemble a farmhouse *Biblio. Ref. [50][117]*

Montmorency Quarry (France) – Gypsum

Located near the town centre of Bessancourt and near an air force base, the Montmorency quarry is an underground deposit in the heart of a well-preserved massif. During the construction of a highway access, a new exit for this underground quarry was provided for. The quarry manager took all the necessary measures to integrate the new developments into the landscape: respect of local architecture, noise prevention, traffic management, etc. A tunnel will minimise traffic noise and will be used by 380 HGVs/day (200 containing gypsum and 180 for the backfilling of underground galleries).

The new exit of the quarry, together with the offices and workshops, was moved to the north of the deposit, in open country with little urbanisation, recognised as a site of conservation. The project managers drew up an architectural plan with the buildings designed to resemble the traditional farmhouses of the region. The offices and workshops are being built at right angles to a "farm-yard" enclosed by a wall. The roofs and façades are being constructed with traditional materials. The buildings are being erected on what was once agricultural land thus avoiding disruption of local fauna and flora.

Furthermore, trees and bushes are being planted with the aim of creating a privileged site for animals and vegetation. The work began during Autumn 1997 and should be completed by the middle of the year 2000. The total cost of the operation for the company has been estimated at € 14.2 million.

A 30-year convention on landscape protection *Biblio. Ref. [30]*

Marquise Basin (France) – Limestone

In the Boulonnais region, five quarries exploit a 2,500 ha deposit of hard limestone representing an annual production of 8 million tonnes. The main problem of this deposit, due to geological reasons, is that 1 tonne of unrecoverable earth (shaly, sandy or argillaceous) occurs as overburden for every two tonnes of aggregates extracted. An original solution has been found for the storage of this large mass of earth. As it was not possible to put the overburden soils at the base of the quarry for a long period of time, an innovative 30-year landscape plan was developed by the quarry association to resolve this problem.

After a study of the local relief, landscape architects proposed erecting artificial hills (resembling the natural hills of the same height maximum 60m), slopes and elongation parallel to rivers and quarries. The project, proposed by quarry managers with the involvement of local associations, was approved by local authorities and communities after three years of study and discussions. Due to this, random mounding is a thing of the past and traditional roads and natural rivers have been preserved. To complete the quality of the landscape and to minimise visual impacts, a large number of trees have been planted on these hills.

A regional convention for 30-years has been agreed by all the participants. This convention will permit an ecologically and economically sustainable development of the industries and the tourist interests of the region.

Visual impact studied on computer through digital terrain modelling

Biblio. Ref. [79]

Siniscola Quarry (Sardegna – Italy) – Raw material for cement

To obtain a 20-year permit to work the site from the regional authority, a study of environmental impact (EIA) was developed.
Due to the high visual impact of the quarry (400,000 tonnes/year) on the landscape, the EIA was one of the first studies of environmental impact developed in Italy by means of digital terrain modelling on computer.
The landscaping studies have provided the basis for future restoration projects: a part of the quarry will be transformed into a nature reserve and another into a tourist area.

Agreement to reduce visual impact ***Biblio. Ref. [79]***

Brescia Quarry (Italy) – Raw material for cement

To reduce the high visual impact, an agreement with the local authority was signed covering:

- the restoration of the quarry which had been worked without explosives,
- a contribution to the local community for each tonne of limestone mined
- the control of vibrations by common consent with the local authority engineer.
- new restoration techniques have been developed to obtain fast growth of vegetation.

After the agreement, the company obtained a five year mining permit from the local authority with an extension option of five years .

Modification of extraction plans to screen off a quarry's activities ***Biblio. Ref. [79]***

Trieste Quarry (Italy) – Limestone

In the 1960s, the company modified its extraction plans for the limestone quarry to meet changing production and environmental needs, moving the extraction operations to the high plain in a position hidden from the view of city and the main road network.
The project involved some 20 ha and required the extraction of 11 million m³ of limestone with the formation of a large basin. The workings were connected by escarpments constructed at an angle of 38°-40°, a highly innovative feature for the time and one which has only recently been taken up again by a few project designers.
The environmental programme consisted of i) shaping the worked-out sections by blasting, ii) the levelling of the waste material, iii) the importing of topsoil and iv) the reforestation of the area. Black Austrian Pine was mostly used as this species had already been successfully planted in the 19th century for the extensive reforestation of the Carso area. This was integrated with deciduous planting (oak, manna-ash and hornbeam) with the intention that this should replace the conifers over the long term. The work undertaken to date has given positive results, and continues to be subject to technical refinements.
Acting on the request of the Region, and in the context of a request for permission to extract some 4 million m³ of residual limestone, the company recently entered into an agreement with landscape artists, forestry technicians and others for an amended programme which provides for a nature park designed to encourage mammals and birds into the woodland and to provide for their observation within a harmoniously reconverted landscape free of monotonous and artificial escarpments.

3.4. Water

If minerals are important in our everyday life, water is even more so. Increasing consideration is being given to this vital resource, and quarry operators are among the first to do so.

In the preceding chapters, we have seen that extraction and production processes vary enormously, not only with regard to different types of minerals, but also to the different circumstances of extraction for a given mineral. This means that the treatment of water can vary considerably from one case to another. If, however, we are to draw meaningful conclusions, it is necessary to distinguish between groundwater, surface water and process water.

Groundwater, contrary to what one could be led to believe, is not contained in underground caverns. This water is indeed mainly interstitial water, contained in certain porous rocks, somewhat like in a sponge. As far as possible, operators try to keep the lowest extraction level of their quarry above the aquifer. The hydrogeological conditions, or the nature of the mineral to be extracted, however, do not always allow this to happen and extraction below the water table can also occur. Dewatering by pumping of the pure groundwater, by means of extraction boreholes drilled at chosen places around a quarry, not only facilitates the extraction, but also preserves water resources and allows for their rational use. In several countries, e.g. Belgium, in the quarry basin of Tournai, this disciplined approach by quarry operators has led to close co-operation with the suppliers of drinking water. The management of water abstraction, and its influence on quarrying permits, however remains a continuous concern to quarry operators. As is often the case, the groundwater pumped in the quarry may be little affected by the working of the quarry and, as far as possible, this water, the so-called pumping water, is fed back into the aquifer under strict quality control.

Surface water is critically important in mineral processing. Process water is usually obtained through surface water abstraction (either private or public) and water releases flow naturally into the surface water compartment. Furthermore, some mineral extraction is conducted underwater, by means of dredging. With regard to water release, strict rules apply all over Europe. It must be noted that the extraction of non-metallic minerals releases very few dangerous substances, the concern being more at the level of the physical characteristics of the water than of its chemistry. Standard measurement of the quality of water is generally based on three parametres: the pH, the TSS (Total Suspended Solids) and BOD (Biological Oxygen Demand). With regard to the latter parameter, one can note that the organic pollution induced by mineral extraction is extremely reduced, but that, on the contrary, the suspended solids content is significant due to processes involving water, i.e. cutting, washing, separating out of stones and mud. With regard to pH, its value in water is closely linked to the type of raw material and precise values are difficult to give. Depending on the characteristics of the water bodies, the thresholds applied to water effluents vary according to country, region and even to local circumstances. Maximum values for the three main parametres range from 20 to 100 mg/l for TSS, from 40 to 125mg/l for BOD, and from 5 to 11 for pH.

Accidental spillage can also be of concern in the context of surface water, mainly in relation to hydrocarburants used in quarries or plants. In order to prevent accidental spillage, the efforts of manufacturers and quarry operators have resulted in new technological advances. Standard oils, for example, used for hydraulic circuits of shovels and loaders are gradually being replaced by biodegradable ones in order to avoid long-term pollution in case of spillage [67]. Leakage-free areas are also being created to store hydrocarburants and hydrocarburant wastes. Pre-release treatment of waste water is a commonly applied rule, even creating situations where the quality of the outgoing water is better than that of the incoming water.

With regard to process water, the section in Chapter 2 on process description helps to appreciate the importance and diversity of water usage in the extractive industry. In a quarry, the ore is frequently cut or pulled down by water jet. Water may be used to transfer the extracted material from the quarry to the plant, in slurry form. It is often used to wash ore, in order to separate by-minerals from the main mineral body. It is also used for the fine separation of mixed minerals, on the basis of their relative density. It is used to transform quick lime into slaked lime. It is also used for sawing and polishing dimension stone and for preventing dust emissions. Some minerals, like calcium carbonate or talc, are even delivered to the customer in a slurry form. Mineral production obviously cannot be achieved without water. Most existing operations now employ closed-circuit systems: used water passes through sedimentation ponds before being returned to the process. This results in an extremely modest net consumption of water[1]. The resulting sludges are often fed back into the process or recycled as secondary products (e.g. limestone powder for agriculture and ceramics).

Water-related investments are certainly one of the significant items in the environmental accounting for mineral extraction. These investments generally have a "stepladder" profile, being related to the purchase and maintenance of water treatment and recycling equipment. The building of water treatment units represents, overall, a major investment.

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[1] *For example, the processing of one tonne of kaolin requires some 6m^3 of water, but up to 98% of this water is recycled internally and re-used.*

Case studies on water management

Improvement of water quality *Biblio. Ref. [137]*

(Sweden) - Talc

A talc producer based in Sweden works a steatite deposit in a mountain area. The blocks which, for example, are used for making steatite ovens, are sawn and polished using water as a cooling medium. For this process, water is pumped from an old flooded talc pit which is itself filled in by spring water rising from a nearby mountain. This spring water is also used as an additional supply for the plant. Before emerging, the water percolates through the mountain, known to be an ultrabasic structure (copper and nickel ore).

In co-ordination with the local environmental authorities, the quality of the water was tested at several points in order to check that the working was not endangering Än Lake, a downstream bird-nesting zone. It appeared from the measurement that the quality of the water which had passed through the old pit and the process was much higher than that of the original water. In particular, the content of copper and nickel was reduced by more than 60%. In this case, the talc slurry acts as a giant filtration system which protects the lake from the natural flow of poor quality water.

Recycling of process water *Biblio. Ref. [104]*

German industry - Dimension stone

During the extraction and setting of dimension stone, water is used intensively to cool the cutting and manufacturing tools and to drive abrasive agents and small particles produced by cutting and polishing. Even if there are no noxious additives in the water circuit, the fine particles of stones or metals (from tools) are prohibited in the effluent water or ground water.

The German dimension stone industry is particularly respectful of the low limits imposed by regulation. Expensive and efficient installations for regeneration and fine filtration have been installed in the quarries. The result of these investments is that currently 90% of the necessary process waters come from internal recuperation and recycling.

Protection of groundwater *Biblio. Ref. [111]*

Hahnstätten Quarry (Germany) – Limestone for lime

This company, extracting 1 million tonnes/year of limestone, has as its main products quicklime (mostly ground quicklime), hydrated lime, precipitated calcium carbonate and prefabricated dry mortar. The input for production is provided by a Devonian limestone deposit of highest purity (calcium carbonate content > 98.5%.). The width of the limestone bed is up to 200m. The quarry is about 30 ha in size and is bordered by public roads, a railway line and a river. In order to be able to use the high-quality limestone, the extraction had to be taken to a deeper level.

The limestone extracted is characterised by a high degree of karstification. This means, among other things, that the ground water easily finds ways through the rock. Directly adjacent to the quarry is a stream running through the karstified limestone for a distance of 1.7 km. The karstified caves provide an excellent connection to the quarry below. The flow velocity of the water is a yearly average of 2 m^3/sec, which can increase to 10-20 times this amount in times of flood. In periods of low rainfall the stream tends to run dry since the water runs into the quarry.

A solution therefore had to be found to seal the bed of the stream. The limestone extracted in the quarry was naturally covered by a layer of clay, which, after extraction, was used to seal the stream bed. Whilst this measure is cost-intensive, it has helped to stop the flow of the stream into the quarry and has helped to maintain the ecosystem of the running water.

Deacidification of a lake after quarrying *Biblio. Ref. [84]*

Kingslyme Norfolk Site (United Kingdom) – Silica sand

A silica sand producer excavates vast quantities of sand. The resulting large holes extend below the water table and so pumps are used to facilitate dry working conditions. When the excavation ceases, the holes fill with ground water to form lakes. The sand is worked until it becomes too rich in iron to be commercially useful for glassmaking. The iron is combined with sulphides in the form of iron pyrite which, on exposure to air, undergoes oxidation to produce sulphuric acid. The water in the newly formed lakes becomes very acid with a pH of 3 or less. There is an interest in using these artificial lakes for recreational purposes, including sailing and fishing. In their untreated state, the lack of biological productivity and unattractive appearance precludes such use. Treating the lake with lime would ameliorate the situation, but only temporarily and it was highly desirable to establish a self-regulating system.
The company has launched a research project in order to upgrade and stabilise this ecosystem. The principle is to apply a combined treatment, using lime, to raise the pH, and organic matter forming a uniform layer over the surface of the sediment. Decomposition of the organic material leads to reducing conditions, so that sulphate is converted to sulphide which is precipitated as iron sulphide. This reducing zone, situated at the sediment water interface, acts as a "chemical filter", removing sulphate as it enters the lake via the ground water. The large area of reducing sediment also prevents oxygen from coming into contact with the groundwater, thus slowing down, and eventually stopping, the production of sulphate. The organic matter also acts as a nutrient into the system and encourages primary productivity. This productivity leads to the accumulation of additional carbon, from atmospheric CO_2, which is continuously added to the lake and accumulates as organic-rich sediment. Photosynthesis is effectively used to combat acidification and a new balanced pH is established.
This principle has been applied at real size in the lake and a long-term monitoring of the effect has been put in place. So far, the results show a stabilisation of the pH and no side effect. The certitude that the ecosystem is self-sufficient and stable is not yet established. It has offered a real-size laboratory for developing a new environmental engineering technique, the interest of which extends much beyond this specific case.

Water supply management *Biblio. Ref. [136]*

Pöbenhausen Works (Germany) – Gravel

During the planning stage of this German plant of sand and gravel, a total water requirement of around 500 m³/h was calculated. If the patented industrial water recycling components are included, the water supply can be broken down as follows

- recycled industrial water — around 270 to 420 m³/h
- process water from the water clarification system — around 165 m³/h
- fresh water from the deep well — around 35 m³/h

The fresh water, representing only 7% of the permanent water supply, is pumped from a deep well and is only used to compensate for losses due to material discharge (residual moisture) and evaporation.
The process water used for cleaning the raw material is supplied in a continuous circuit with integrated water treatment.

3.5. Traffic

Once processed, extracted minerals need to be transported. Bearing in mind the relatively low added-value of most non-metallic minerals, transport and logistical issues are critically important for the sustainability of the business. As minerals are both bulky and heavy[1], it is often the case that the cost of transport exceeds the material and production costs. Some high-grade products need to be shipped overseas. Such movements generally correspond to minerals which can be found only in specific locations (e.g. borates), or to minerals (produced for example, at low cost in non-EU countries with little or no regulation) which can bear higher transport costs.

With few exceptions, minerals produced according to good environmental and social practices usually do not travel more than a few hundred kilometres from their point of extraction. Whereas some high-value types of marble can be exported all over the world, standard quality sand can rarely be transported more than 150 km to remain profitable. Road deliveries of cement generally do not exceed distances of 150 km and every time some aggregates are transported a further 50 km, it doubles their cost [38]. Road transport is certainly the most costly option and is therefore used as little as possible. Transport by barge is less costly, but the number of customers based on rivers or canals is limited. Rail transport offers an interesting option, but suffers from a lack of flexibility and reliability; it is also limited to large customers who have direct access to the rail network. Nevertheless, market strategies change and one increasingly finds large ships containing aggregates in European harbours. These suppliers of "virtual quarries" have a transport cost of only 0.15 €/tonne per day [69][2]. It would seem therefore that the transport of minerals is primarily a function of profitability.

Disturbance from traffic is due mainly to the transfer of minerals between extraction and processing sites or from the extraction site to the nearest port, inland waterway or railway station. The question may be asked why processing plants are not systematically located close to quarries. In fact, they are, whenever possible. However it sometimes happens that the topography of an area is unsuitable or that an unacceptable environmental impact could occur if a plant were to be built on or next to the extraction site. Moreover, in many types of extraction, the plant is surrounded by several separate ore bodies, which are sequentially worked over the life-time of the plant. The plant obviously cannot be demolished and re-built each time the extraction site moves a few kilometres away. In the industrial minerals, lime, gypsum and cement sectors, the processing plants are usually located near extraction sites or near highways, railways, inland waterways, etc. Low-

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[1] A common massive limestone has a density of 2,700 kg/m³.
[2] Cost estimated for an ore ship of 100,000 tonnes sailing 800 km/day.

impact transfer systems also use pipelines or underground conveyor belts. Nevertheless, in some rare cases, HGVs (heavy good vehicles) have to cross towns and villages and can be a source of annoyance or risk. The principle inconveniences of freight transport by road are noise and ground vibration, dust and dirt, visual effects, accidents and safety risks [103]. In the EIA of quarries, the potential traffic impact is always discussed with local authorities. Solutions may include an industrial road which diverts traffic from minor and congested roads, underground belt conveyors used in large quarries, or even cable transfer systems. For the delivery of processed material, which is generally sub-contracted to independent transporters, quarry operators generally impose load limitations, trimming, cleaning of HGVs and their wheels, spraying and covering of materials to prevent the spread of dust, and they make every effort to see that the owners and drivers of HGVs adopt a responsible attitude.

In some remote areas, quarry operators themselves have to build or repair roads and railways to transport materials. In such regions, local communities can gain long-term benefits from such infrastructure work. Once more, this demonstrates how important it is to develop dialogue with local authorities and local residents so that the particular extraction site is developed taking local circumstances into account.

Case studies on traffic management outside the quarry

Converting to shipment by rail

Biblio Ref. [45][36]

Torr Works and Glensanda Quarry (United Kingdom) – Aggregates

Since the mid-1960's, as part of an on-going action for more efficient transportation methods to reduce costs and improve competitiveness, the Foster Yeoman Company management decided to connect the quarry to the British Rail local branch line.

Currently, a massive 80% of the crushed rock product goes out by rail as this method is 30 times cheaper than transporting rock by road and can move ten times the volume of an HGV. Environmentally it is the sounder option as well: transportation by rail saves an estimated 50,000 HGV journeys a year! The development of this advantage over the years ultimately resulted in the rare decision to purchase 5 diesel-electric locomotives from the USA in 1984. These engines pull the heaviest trains operated by British Rail and can do the job of two classic locomotives. In fact, the quarry company became the first one to use privately owned locomotives on the national rail system.

Establishing a rail link between the rock face in the quarry and 17 rail depots, the activities have been progressively merged with other companies to form Mendip Rail, which supplies diesel-electric locomotives and wagons for the aggregate shipments of the shareholding companies.

Another quarry of the company also joined in the reduction of transport and environmental impacts with the only coastal superquarry of the UK. Using the “glory hole” method, the crushed stone is transported from the top of the mountain, 300 m down to an underground conveyor via a 3.3m wide vertical shaft. Rocks are conveyed through a tunnel 1.8km long to the treatment plant by the sea. Distribution occurs using company time – chartered self-discharging ships with a 37,000 or 76,000 load hauling capacity. The company, which began in 1923 as a small limestone quarry, now has a UK market share of 7% and promotes itself as a quarrying and transport company, as the success of the first enterprise is quite often dependent on the efficiency of the second.

An HGV tunnel for a mountain village

Biblio. Ref. [84]

Vipiteno Quarry (Italy) – Calcium Carbonate

A quarry located close to a mountain village caused heavy traffic (15–35 trucks/day) through the village, resulting in numerous complaints from the local residents.

The topography of the area did not allow for the construction of a bypass so the company decided to create a tunnel.

Starting in March 1995, the first 25 metres of the tunnel were bored by a specialist contracting firm, using cutters. The next 200 metres were done using explosives and advancing at 2 metre intervals. A large number of detonators together with very small quantities of explosive were used so that the vibrations were kept to a minimum, especially for a hotel overhead. Since January 1996, the work has been carried out by the company personnel, proceeding for another 100 metres on ground level (in fact, a 400m gallery as the tunnel is inclined). The asphalted and illuminated tunnel was officially opened in the presence of the local authorities in September 1996.

Some HGV noise however remained at the exit of the tunnel. So it was decided to lengthen the tunnel by 300 metres so as to connect it directly to the main road and thus avoid the village.

The final characteristics of the tunnel are: length 1 km, width 10m, height 6m, asphalted and illuminated. It has completely solved the problem of HGV noise.

Case studies on traffic management inside the quarry

Transportation of talc by a bucket and cableway system *Biblio. Ref. [84]*

Luzenac Quarry (France) - Talc

One of the most important talc quarries in Europe is located in the Pyrenees at an altitude of around 1,660 m. The processing plant is located in the valley leading down to the quarry, some 1,100 m lower.

About 400,000 tonnes/year of talc are extracted. To transport this ore to the plant, 16,000 HGV return trips/year (25 tonne HGVs) would be necessary, representing some 650,000 km (twice the distance from the earth to the moon). This would consume enormous quantities of fuel, emit greenhouse gases and generate heavy traffic disturbance.

The operator has built up a 5.3 km long cableway system, from the quarry to the plant. Each bucket carries 1.4 tonnes at a 4 m/s speed. Two or three shifts/day, from May to October, assure the complete transport of the ore extracted. The transport of the ore consumes no energy, since the loaded side descends by gravity (in fact, it has to be braked). It is silent and has minimal visual impact. Moreover, the system supplies, by way of a dynamo system, all the electrical energy required by the quarry.

Uphill transportation of limestone *Biblio. Ref. [111]*

Hahnstätten Quarry (Germany) – Limestone for lime

This company, extracting 1 million tonnes/year of limestone, has as its main products quicklime (mostly ground quicklime), hydrated lime, precipitated calcium carbonate and prefabricated dry mortar. The input for production is provided by a Devonian limestone deposit of highest purity (calcium carbonate content > 98.5%). The width of the limestone bed is up to 200 m. The quarry size is about 30 ha. Its area is limited by public roads, a railway line and a river. In order to be able to use the high-quality limestone, the extraction had to be moved to a deeper level.

With a difference in altitude of up to 40 m, the annual capacity of 1 million tonnes was transported by use of a single vehicle operating in two shifts. Moving the extraction to a deeper level would have required a second vehicle. This would have led to an increase of transport activity in the quarry, while at the same time increasing noise and exhaust gas emissions (the latter because of higher consumption of diesel oil). The company therefore planned the installation of a conveyer belt system which, compared to vehicular transport, has a considerably higher degree of efficiency. However, transport by conveyer belt is only possible when a primary crusher is installed at the lowest quarry level. Operating experience has shown that uphill transport by conveyer belt is not only more environmentally friendly, but also more economical.

3.6 Overburden

Two components of overburden result from the extraction process, the soils (topsoil and subsoil) and underlying material surplus to requirements, all resulting from stripping operations before extracting the main ore. The surplus material may additionally occur within the "pay mineral" in which case it is known as "interburden". Also, silts may be generated as a result of settling treatment of water used in washing or sawing processes [29].

While awaiting use in quarry restoration or as embankments in civil engineering works, overburden is generally employed at the quarry to construct anti-noise and dust barriers or screening mounds. In some cases, depending on their mineralogical characteristics, soils and overburden are also used by other industries for aggregates, bricks and ceramics, etc. In the dimension stone industry, only 30–70% of rock ends up as finished product [104]. The rest, either rock not meeting decorative quality standards or processing scrap, is recycled as secondary materials for building blocks, aggregates, or even as industrial minerals. With regard to the fine materials produced, for example, by limestone quarries, some are used in agriculture as carbonated fertiliser while some are used in the manufacture of precast concrete. Production fines can be used as secondary materials.

Most countries do not define surface soils, overburden and production fines as "waste", which indeed they are not. More often than not, it is strongly recommended to use these soils and other overburden for restoration work. Even if restoration might consist of the partial filling in of the hole left after extraction, this process should not be confused with landfilling. Many quarry operators sort the topsoil containing the biomass to prepare further planting. Although this good practice is becoming a legal obligation in some European countries or regions, others still consider soils and overburden as solid industrial effluents, which lead to these natural materials being taxed as "industrial wastes" [82].

A good number of case studies in Chapter 4, which deals with site rehabilitation, also involve the management of soils and overburden.

Case study on soils and overburden management

Tipping practices and the creation of heathland *Biblio. Ref. [84][85]*

Cornwall & Devon (United Kingdom) – China Clay Industry

The UK china clay industry (kaolin) has a history of more than 250 years in Cornwall and Devon. It has influenced the landscape up to a point where it has now became a part of the cultural heritage of the area. Tipping practices have evolved over time; traditional conical tips have been progressively replaced by engineered benched tips which can be revegetated.

Several studies have been carried out on hydroseeding techniques and machinery, crop growing, heathland trials, forestry trials, etc. They culminated in a report by the Department of the Environment on "Landscaping and Revegetation of China Clay Waste", which became a new standard in restoration practices.

The value of heathland areas is very important in this context. Restoration of the existing tips involves, for example, reprofiling, heathland trials and traditional Cornish style fields linking to adjacent farmland. A project has been developed with two companies, English Nature, the Mineral Planning Authority, and National Heritage, to manage, recreate and increase the UK's resources of heathland areas. Matched funding and commitment to this project by the china clay companies are crucial and mainly involve landscaping and preparing waste tips for heathland re-creation.

3.7. Biodiversity

Although industrial development can cause negative impact, more often than not the extractive industry creates new and diverse habitats. This is, for example, true in regions where intensive agriculture or population density has put pressure on nature, and where animal and vegetal species seek refuge in former quarries and, even in well-managed, active quarries [12]. To a certain extent, quarries can compensate for the disappearance of the original habitats, generating diversified biotopes for rare species of amphibians, reptiles, insects, birds, flowers and plants [35] – one such example is a simple quarry face with benches and terrils representing 12 different biotopes [132]. Sparse vegetation found on dumps and gravel terraces of quarries, pools and marshy areas, tyre tracks and clay depressions, nesting sites along disused faces, new varied undergrowth on earth mounds, calcareous grass, etc. all can represent valuable habitats. This biodiversity is recognised as such by a number of botanists and ornithologists: quarries, even when active, are regularly visited by naturalists eager to photograph rare species of orchids, nesting night-birds, etc. The fact that even active quarries are such a source of biodiversity is undoubtedly a sign of good management practice.

Many habitats of high conservation value are directly dependent on underlying geological substrata which may be a valuable mineral resource. As these habitats cannot be conserved in situ, habitat conservation through relocation is the best available means of mitigating the loss of the ecosystem. This consists of the removal and subsequent replacement, usually in a new location, of a complete collection of plants and animals with the aim of maintaining the conservation value of typical habitats (heathland, woodland, coastal, bog, fen, aquatic and grassland). The minerals industry has set the standard in relocation and will continue to improve the technique, defining the best practice and developing a valuable tool which has the potential to reduce conflict between industry and conservation interests [107]. This is, of course, a radical method used only for outstanding habitats, and it would be meaningless to apply it in every case. In many instances, quarries simply result in the replacement of one habitat by another, often a richer one, or by a temporary disruption of the original habitat.

Case studies on the management of biodiversity

Artificial cliffs created for sand martins *Biblio. Ref. [12][99][100]*

Frasnes Quarry (Belgium) – Limestone for lime

For several years, a group of migratory sand martins has rested in valuable mound of ground-limestone located along a basin in the 65 ha limestone quarry of Frasnes in the Fagne Basin of Belgium. As the company had planned to sell this material, the problem of this nesting place required serious examination. Since, in fact, a decrease in the population of sand martins has been observed in Belgium as in other European countries, the quarry managers carried out a pilot project with the help of an association for nature conservation ("Les Bocages").

The objective was to ascertain the value of the mound of ground-limestone to the martins so that an artificial cliff could be created in a less active part of the quarry. The cliff was constructed in January-March 1991. Once the martins arrived (end March), they were diverted from the original mound by aluminium foil strips and attracted to the new location by tape-recorded calls and specially created tunnels. Despite the presence of other suitable cliff faces, a good colony of some 80 pairs was established by 20 May. The artificial cliff face needs cutting back each year to prevent the clogging up of the holes and the resulting material is returned to the base of the cliff. Roofing has been placed over the face to reduce the ravages of the weather and the face is divided into two zones for nesting in alternate years, which cuts down on the work needed to maintain the cliff face. Martins have nested each year on the new face with great success; 377 pulli have been ringed (in 1994). The quarry workers have become increasingly interested in "their" birds and in the other flora and fauna with which the quarry is well endowed. The project has received the Eurosite Award 1993 "Creation of New Habitats".

Another rare species exists in another quarry of this company. Great horned owls species have been resting in the cavities of the old quarry faces without been disturbed by quarrying work. The quarry managers have arranged for the quarry access to be monitored to assure their safety.

A quarry operator is called upon to create a lake *Biblio. Ref. [122]*

John Wilson Lake (United Kingdom) – Aggregates

A gravel pit in Norfolk that yielded more than 60,000 tonnes of much-needed material for the aggregates industry and created local employment has won a top environmental award. The restoration site is described by an independent expert as "an idyllic, tranquil masterpiece and a jewel in the landscape". By working closely with the land owner, from planning to completion, John Wilson, one of Britain's top coarse fishing experts and angling journalist has helped the quarry operator to deliver the best of both worlds. The project makes optimum use of valuable mineral resources while creating a natural habitat that is "brim full" of wildlife, including coarse fish, water birds, indigenous mammals, rare aquatic insects and 30 varieties of water lilies.

This successful partnership between landowner and aggregates producer is thought to be the first of its kind in the UK in which the extraction process was designed specifically to meet planned after-use requirements, in this case coarse fishing. It may also establish a blueprint for the future, not just for the mining and quarrying industry, but for coarse fishing too.

The site was formerly an overgrown heathland area of six acres partly blighted by pitfallen land which was the result of emergency wartime extraction of gravel in the

1940s. It had few, if any, birds nests or active wildlife. A small, three-quarter acre fishpond, which, almost 50 years after the completion of wartime extraction, had returned to a more natural environment, first attracted John Wilson: "The property was attractive in many ways but most importantly it had significant potential for improvement," he says. "I envisaged a ten year programme to create a larger aquatic environment as well as developing the site into a haven for the maximum possible variety of wildlife. Where necessary, and where possible, we would also give nature a helping hand reducing the restoration period from around 50 years to five or six and producing a finely balanced ecosystem to which all elements, fish, birds, plants, trees and insects would contribute and in which all would prosper."
John Wilson had approached his local branch company with details of his plans and an invitation to investigate the presence of commercially extractable reserves of gravel on the site. In short, if the company could profitably extract the material then, in return for digging a new 1.56-acre pond and landscaping the site, in line with John Wilson's precise plan, he would actively encourage acceptance of the plan by local authorities. The results of the investigation were positive and, backed by the full support of the man who was both the landowner and the only near neighbour to the site, planning was duly granted. The company then extracted 60,000 tonnes of gravel, using a dragline to dredge material from below the water table (thereby creating the pond) and a wheeled loader for loading out to on highway tipper trucks.
While the mineral extraction was taking place in line with John Wilson's layout and plans, John was busy planting trees, shrubs and water-borne plants such as lilies, as well as working closely with the machine operators to ensure compliance with the original plan and the correct interpretation of drawings. Indeed, by the time the gravel reserves had been recovered, all planting work had been completed, and several thousand new plants, including several special species for the pond had been used. As well as 30 varieties of lilies, there were nine types of evergreen trees, nine of deciduous trees, and 30 varieties of willow trees. Next came stocking the lake with coarse fish. Some 25 different types of fish were introduced in a combination carefully designed to ensure a balance between predator and prey and to take account of the levels of other food in the environment to establish a healthy and sustainable habitat.
It has been pointed in this project that "What we have done here is to take the concept to a new level deciding in advance what will be the after use of the site, before a stone is turned or planning permission applied for. This makes permission much more likely to be granted and means, in effect, that the objective of the extraction process is to create the desired environment for leisure and/or wildlife rather than simply to retrieve valuable mineral resources".

Peregrine falcons prosper in quarries *Biblio. Ref. [124]*

Extractive Industry quarries (Ireland) – Limestone an aggregates

In Ireland, the population of the peregrine falcon is growing in seven regions, all of which have a common denominator—the presence of quarries. Of the 35 quarries counted–half of them are still being worked–14 have peregrine falcons nesting in them.

Biodiversity of flora in gypsum quarries *Biblio. Ref. [92][94]*

German Gypsum Association - Gypsum

In the context of a research contract awarded by the German Association of the Gypsum and Gypsum Wallboard Industry, studies were carried out on the development of vegetation sequence in 15 gypsum quarries.

It emerged that many small-scale structures developed, which are determined by, among other things, quarrying, beds, geomorphology. Because of different microclimates, hydrologic balances and nutrition conditions, this can result in a very diverse biotope mosaic. In addition, different sequence stages develop because of the time factor. The existence of a total of 350 plants was demonstrated for the quarries studied. The lowest for any quarry amounted to 136 and the highest 294. The plant numbers are also certainly dependent on the size of the quarry. In relation to the fern and flowering plants found in the Federal Republic of Germany, the presence of almost 12% of all species could be demonstrated. In accordance with the various conservation regulations and categories of endangered species at both Federal and State levels, 90 species of these are protected.
In addition to the plant species, the different plant categories were also recorded. These increase within a time span of 30 years from the cessation of quarrying, but after this period, fall drastically when the plant cover becomes thicker and woody plants appear. The sequence generally ends on the terrestrial surfaces with a number of trees appearing. Besides plant species and categories, many protected biotopes also develop in the quarries, such as open and low-nutrition rock formations, block and debris heaps, verge categories in hot, dry sites, as well as different aquatic biotopes.
From this study of vegetation development in gypsum quarries various recommendations can be made for recultivation or natural rehabilitation: before actual quarrying, biotopes can be created temporarily by shifting the plant and soil cover. Diversity should be maintained in quarries, no topsoil should be brought in and the natural sequence should be given priority.

A nature reserve in a gravel pit — *Biblio. Ref. [74]*

Faverney Quarry (France) – Alluvial aggregates

The idea occurred to the Faverney quarry operator to create a nature reserve in a gravel pit still being worked (220,000 tonnes/year). He has always done his utmost in the planning of open spaces and in integrating both sites being worked and sites no longer in use into the surrounding environment.
The new nature reserve has in fact been integrated into a large local authority project aimed at discovering nature and it has been linked with other leisure projects in the vicinity.
Furthermore, the nature reserve has become a visiting centre where information and education is provided to students and others.

3.8. Cultural heritage

In some cases, the conservation of sites occurs due to the safekeeping of local archaeological and historical heritage.

There are numerous examples of archaeological discoveries made by geologists and other workers during the first phases of prospecting and overburden removal: ancient buildings, Roman villas, large collections of helmets and arms, tools from medieval times, prehistoric bones, ancient log boats in alluvial deposits, etc. This has become so important that some operators organise information seminars with the help of archaeologists. Their objective is to inform workers and engineers about the history of their regions and on the emergency measures used to protect archaeological discoveries. When an ancient object or building is discovered, the authorities are always informed and meetings are usually organised with specialists to decide if a systematic excavation of the site is necessary or not. In some countries, the examination of an eventual "archaeological risk" is necessary during the Environmental Impact Assessment [120].

Case studies on the conservation of cultural heritage

Discovery of late Neolithic bones during the stripping of overburden

Biblio. Ref. [49]

Langford Quarry (United Kingdom) – Sand and gravel

In September 1995, the Trent & Peak Archaeological Trust was informed that four human skulls and some animal bones had been discovered during sand and gravel extraction. The skulls were spotted by the dragline operator, who stopped working and informed the Langford Quarry manager, who in turn immediately relocated the quarry operations further along the working face. It was clear from discussions with the quarry's staff that the skulls were found below the working face, so the scree below the face was investigated and several more pieces of bone were recovered.

Following the discovery, an exploration investigation was carried out for the Trust with funds provided through the quarry's Company Estates Surveyor. The area of extraction had been stripped of overburden, which comprised some 2 m of alluvial silt, to expose 4-5 m of clean sand and gravel. Studies will show that the bones have a calibrated date of 2350-2030 BC (late Neolithic-early Bronze Age). Although skulls are often recovered from major river systems in Britain and Europe, this is the first systematic excavation of such a deposit and one that will fuel the ongoing debate about the treatment of the dead during the Neolithic-Bronze Age.

According to the UK Planning Policy Guidance note 16 (1990), the conservation of an archaeological site through its detailed recording by excavation and prior to its destruction is acceptable. Negotiations were therefore commenced to raise the necessary funds for archaeological excavations prior to quarrying. This resulted in a partnership of funding between the quarrying company and the Environment Committee of the County Council, with help in kind from a University and from archaeological societies. These agreements were possible because of the responsible attitude of the staff of the quarrying company.The considerable inconvenience of working around the area for some six months over the winter so that excavations could be undertaken was acknowledged, as was the support and help of all the quarry staff. This positive side to quarrying, in addition to all its economic benefits, is important at parish, district and county levels. Such actions will help to ensure local and national support for the future quarrying needs of local communities.

The quarrying company was commended for the BP Award at the British Archaeological Awards in Cardiff 1996.

A 3500-year-old boat discovered during extraction

Biblio. Ref. [97]

Shardlow Quarry (United Kingdom) – Aggregates

The quarry operators unearthed the remains of a Bronze Age boat at their Shardlow Quarry near Derby (UK). The 3,500-year-old find, still carrying some of its cargo of quarried stone, was exposed by floods on the nearby river Trent. Archaeologists have described the 10m long boat as a 'spectacular find of national importance'.

Made of oak, the log boat contained five large blocks of Bromsgrove sandstone, up to 1 m in width, and several others were spilled alongside. They are believed to have been quarried from a sandstone outcrop some 2 km up river.

The boat has been cut into sections and moved to the quarry yard for protection. Decisions on its final resting-place have yet to be made.

Roman treasure in a sand and gravel quarry ***Biblio. Ref. [127]***

Xanten Site (Germany) – Aggregates

One of the major economic activities of the Lower Rhine is the extraction of alluvial aggregates. Some of the ancient alluvial terraces of the river are affected by the extraction of gravel. Frequently, fossils and archaeological pieces are discovered due to the enthusiasm and watchfulness of the quarry staff. The sand and gravel quarries of the Xanten region have always yielded up individual pieces and fragments like the Wardt-Lüttingen Roman silver cup exhibited in the Bonn Museum. Nevertheless, at the Xanten-Wardt site, the archaeological finds of excavation works were particularly exceptional: the archaeological survey includes 300 metallic pieces mainly of Roman origin that were unearthed between 1982 and 1992. The collection includes simple nails as well as helmets, metallic kitchen vessels, ceramics, etc. With the much appreciated support of quarry operators and workers this significant collection will become a permanent exhibition at the regional museum, with a particularly educational emphasis on the civil and military life during Roman times in the region.

3.9. Other

For some time now, quarry operators have come to understand that they have a major role to play in the issues relating to their socio-economic environment. The development of good practices has shown that the extractive industry is particularly attentive to problems not necessarily linked directly to the environment but certainly important for public opinion: the quality of management, information and educational interests, services and amenities for local residents, the preservation of resources and energy are examples. The aim of this short section is to present some success stories in this area.

Case studies on various topics

An information booklet prior to application for planning permission

Biblio. Ref. [13]

Rochester Works (United Kingdom) – Raw materials for cement

In 1972, this cement company applied for and received planning permission for an extension to its quarry. Fifteen years on, the consented minerals were nearing exhaustion and supplies of high carbonate chalk were due to run out completely in 1992. Vital planning permission was sought for an additional 20 years of chalk reserves to be worked to enable the company to maintain production levels. After enquiry, it was proposed to develop a new quarry in a well-conserved country valley covering an area of 43 ha.

An informative booklet of 14 pages, suitably entitled "Why a quarry in Dean Valley?", was published and distributed widely to local communities and interested local residents.

In this educational document, the responses to understandable fears were given: a plan of progressive extraction followed by restoration; a system of underground conveying to limit traffic; a comparison of views of the valley with an artist's impression depicting the same valley after restoration and showing, as the main difference, just a slight lowering of the valley floor; statistics on new employment in the area, etc.

The project was announced before formally applying for planning permission so that everyone had the opportunity to discuss it with the company. This was due to the fact that the company was firmly committed to the need for community involvement where its activities were likely to affect local amenities.

Conservation of natural gypsum resources

Biblio. Ref. [89][92]

European Gypsum Industry – Gypsum

The production of FGD (Flue Gas Desulphurisation) gypsum in power plants has made available a raw material identical to natural gypsum in both specifications and quality standards. All European political and industrial organisations and institutions, e.g. EUROGYPSUM (Association of European Gypsum Industries), ECOBA (European Association for Use of the By-products of Coal-fired power stations), EURELECTRIC (European Grouping of the Electricity Supply Industry), the OECD and the European Union agreed in their understanding of FGD gypsum as a product [89]. Today, more than 8 million tonnes of FGD gypsum goes toward supplying the total European demand for gypsum of about 30 million tonnes. There are also certain positive effects such as the increased usability of geologically low-quality natural gypsum and the preservation of natural gypsum resources.

The success story of the acceptance of this raw material began with the comparison of natural gypsum and FGD gypsum and the evaluation of the health aspects by Beckert et. al. in 1991 [90]. The investigations showed that the differences between the two raw materials are, from a health point of view, insignificant with regard to chemical composition and to the content of trace elements. The results of the analyses demonstrated that FGD gypsum can be used for the production of building materials with no risk to health. The continued use of FGD gypsum will remain an important task for the European gypsum industry in the future, as is already the case for the German gypsum industry [91]. This is because of the increased volumes of FGD gypsum which will be produced in the EU and in the countries of the former

Eastern Bloc due to the stringent legal provisions concerning the desulphurisation of flue gases in the burning of fossil fuels.
Particular attention has therefore been paid to FGD gypsum from lignite combustion, especially since, due to the development of new refining processes, this can now be produced in the same quality as FGD gypsum from hard coal. At the same time, efforts have been made to improve the use of FGD gypsum from both technical and economic points of view. As a consequence, Germany, the European country with the highest FGD gypsum production, was able to cover over 50% of its overall gypsum consumption with synthetic gypsum in 1998 [138].

Internal audits and management *Biblio. Ref. [84]*

European Talc Group - Talc

As in many other industries, one of the biggest European talc producing groups has designed and implemented a comprehensive environmental management system. It includes two levels: a corporate level and a production site level.
At corporate level, an environmental co-ordinating body was set up. In each production site, a manager (generally the technical director) and a co-ordinator were appointed to manage the environmental issues. Each company of the group has a written environmental policy and annual objectives.
The originality of the structure lays mainly in its implementation, which is based on an internal auditing system. A team of twenty auditors, drawn from the different subsidiaries, was constituted, on the basis of company technical specialists having the suitable skills to deal with the specific problems of each operation. The auditors were trained by external consultants on environmental audit techniques. A pilot audit was carried out in 1996 and, since then, 7 - 8 sites are audited annually.
The audits are planned and conducted by two auditors and by the group co-ordinator. The auditors are chosen according to their skills, excluding auditing of their own site. The audit starts with an interview of the managers. Their answers are double checked at lower management levels and with on-site personnel. All findings are recorded, checked, analysed and presented to the plant manager at the end of the audit. This is generally an opportunity for interesting and lively discussions. The audit report is then drafted and all the auditors' findings are then integrated into the company's management programme, with a view to corrective actions (with a degree of urgency rated according to the real or potential seriousness of non-compliance or of the risk involved). A follow-up meeting is organised within the following six months. Each site is audited about once every two years.
The experience shows that these audits are efficient tools for developing action plans and the improvement of company management systems. The good results are obviously related to the strong commitment of the different levels of management in the system, and to the fact that the auditors are really specialists of the sector. This process will be further extended to health and safety management.

Collaboration with local authorities and local residents *Biblio. Ref. [79]*

Guidonia Quarry – Raw materials for cement

When the quarry was near closure, the local authorities decided to build new housing very close by. Consequently, after contacts between the company and the authorities, a new restoration project was planned together with local authority engineers. It included:
- the building of an amphitheatre,
- the preparation of a helicopter landing pad,
- the laying down of vegetal earth on the quarry for fast vegetation growth.

The plan showed the willingness of the company to respect the needs and wishes of local authorities and local residents, and it received a permit for 20 years to work a new site.
A European prize for the environment was awarded to this project in 1988.

Actions undertaken to respect an urban and tourist area *Biblio. Ref. [84]*

Kerbrient quarry (France) – Kaolin

The quarry is located in a very sensitive urban and tourist area. In order to limit the impact of the site, two main actions were undertaken.
First, from the beginning of the working, a 500m long and 5m high embankment was constructed. It was planted with local vegetation for optimal integration into the surrounding landscape. The achievements were twofold:

- the quarry is no longer visible from any of the surrounding roads,
- the noise generated by the quarry is under control, the noise level inside the quarry being lower than the surrounding ambient level.

The quarry is located some 4 km from the plant where the ore is processed. In order to prevent HGV traffic going through the local town, an underground pipe was installed. The product undergoes a primary treatment on the extraction site and is then suspended in water. The resulting slurry is then pumped to the plant for final treatment. This was possible because the ore needed anyhow to be suspended in water for processing. The treatment of the ore has in this case been partly delocalised, while maintaining the main treatment steps in the central plant.

An education resource pack for a better understanding of the rural environment *Biblio. Ref. [32]*

A Quarry Products Company (United Kingdom) – Aggregates

In partnership with the Countryside Foundation for Education, the company has launched "A case for the countryside", a national education resource pack designed to increase Britain's 11-14-year-olds' understanding of their rural environment.
The pack was produced after it came to light that, despite National Curriculum reforms, a serious imbalance remained in the amount children are taught about the economical, social and environmental importance of rural life. The pack communicates different aspects of land management and can be related to subject areas such as mathematics, design and technology, science and geography.
In addition, two cross-circular units offer opportunity for personal and social development. One of these units is a simulation of a planning application for quarrying sand, designed and supported by the company, which encourages school pupils to consider rural land use management in a series of role-plays.
It is expected that the pack, which consists of teachers' notes, pupils' workcards, videos and aerial maps, and is based on five locations in different parts of Britain, will be used in around 800 schools nation-wide.

Quarrying on a seasonal basis to allow tourist activities *Biblio. Ref. [64]*

Milos Islands companies (Greece) – Industrial minerals

The 150 km² "mineral island" of Milos (Aegean Sea), with a 1994 production of 1,792,050 tonnes, accounts for 26% of Greece's total industrial minerals production, a great deal of which is exported to other EU countries. The minerals include barytes, bentonite, kaolin, perlites and pozzolan and also sulphur, silica, clay, feldspar, gypsum and newly discovered deposits of diatomite and zeolite. With an optimistic outlook for the major consuming industries of construction, chemicals,

paper and steel, producers on the island would appear to be in a relatively healthy position.
However, the Milos economy is also dependent on tourism and as such there is a groundswell of local opinion demanding effective site rehabilitation, which could pose a potential threat to the future growth of extractive activities. However, to counter this possibility, the companies active on Milos have recently undertaken restoration works on several of the island's inactive sites.
One company quarrying barytes has rehabilitated three disused sites and waste areas and another has carried out work on some of the areas around its mines. Two large companies linked to the cement industry, have restored the depleted parts of their pozzolan deposits. Rehabilitation work has been undertaken by the whole sector on the island.
The most significant result is that most of of the companies now work on a seasonal basis in order to avoid any conflict with the island's flourishing tourist trade.

Sewage works for local residents *Biblio. Ref. [114]*

Kruibeke and Ermitage quarries (Belgium) – Aggregates and clays

In the area of two of its quarries, the Gralex company has given the municipal authorities two development sites to establish an artificial basin and purifier marsh in these fields with the aim of treating domestic water and sewage from urban zones, where main sewers do not exist yet. A field has been placed at the municipal authority's disposal by the company, to create an artificial marsh permitting the setting of sewage near the quarry and plants of Kruibeke. The embankment works have been carried out by the quarry operator as well as the supply of 600 m³ of Argex (expanded clay produced by the company) necessary for the biological reaction. The municipal authority has provided the waterproof material and 850 reed plants. The work undertaken is as follows:
In the immediate vicinity of the production plant, on the outskirts of Kruibeke, there are several houses which are too remote to be connected to the main sewer. As European directives state that sewage water from all houses has to be treated, the Kruibeke municipality and the company worked together to devise a solution which would meet these directives: a reed-bed filtration unit.
How does it work? The waste or sewage water is first fed from existing channels into a settling tank of 10m³, where solids such as twigs, leaves, silt and faeces can sink to the bottom. This "pre-purified" water then flows into a 10m³ pumping tank, from where it is pumped into the reed-bed. This 100m long, 2m wide ditch combines reeds and Leca pellets to purify waste water in an ecological sound manner.
Reeds have roots which are a superb filter for waste water and research has shown that a specific reed variety, Phragmites australis, delivers the best results for water purification, due to its resistance to drought, frost and salt, as well as being pH-tolerant. They also place very little demand on the soil in which they are planted. Here 1,800 one-year old reeds of this variety were planted in biodegradable pots.
Leca pellets function both as a vegetation layer and as a drainage layer. Furthermore they form an excellent basis for bacterial growth. Therefore they were used as a substrate over a total area of 200m². The bottom of the reed-bed slopes at 3.8%, from the pumping tank side to the far side and is coated with an impermeable foil. The layer of Leca pellets has a horizontal upper surface. The depth of the pellets varies from approximately 0.5m on the pumping tank side, to about 0.8m on the far side. The slope of the bottom is essential for the gravitational flow of the water. The waste water is filtered as it seeps through the Leca layer, and is caught by the impermeable foil which leads the purified water to an existing brook.

The project started end October 1996 and was carried out in a remarkably short period of time. The rough draft and agreement was completed in November, as was the planning application. The survey of the site's elevation took place in December. In early January 1997, the excavation for the tanks and installation of the pipe work started, and the excavation of the reed-bed ditch commenced. The impermeable foil was installed in early February, and the reed-bed was filled with Leca pellets end February. At the beginning of March, the reed-bed was irrigated with clean water for the first time, and reed planting started on March 18th. Finally, begin June waste water was pumped into the reed-bed for the first time. Since then, purified water from the reed-bed has been fed into the neighbouring brook.
At another extraction site of the company near the quarry of Lessines, the company has opened the site to the local community and undertaken civil engineering work to facilitate the planting of reeds necessary for the decomposition of organic material. The annual maintenance is done by local associations and important repair works by the quarry workers (such as dike maintenance, etc.).

Good relationship with local residents ***Biblio. Ref. [116]***

Clee Hill Quarry (United Kingdom) – Aggregates

The Clee Hill quarry management places great importance on maintaining a good relationship with the local community. The majority of the workforce live in the village of Clee Hill or within a eight-kilometre radius. The company supports as many local projects as possible. Recent examples include the donation of land for a picnic area, the supply of foundation materials for two local village halls, and the supply of rockery stone for a toposcope. Also, three school parties, totalling some 100 pupils, visited the quarry during May 1998 and in June, the quarry welcomed members of the public to a special "open day".

Chapter 4
Quarry restoration and aftercare

In or near a typical extraction site, there are two distinct areas: the extraction area itself (e.g. a quarry or an alluvial site) and the processing plant area, which has a more industrial character. When the site is closed down, the plant is always dismantled for further use or recovery.

The way an extraction site is restored depends largely on its disposition. In the case of hillside or mountainside quarries (with flank in relief), site restoration is mainly based on its ultimate integration into the landscape, the stability of its rock faces and the control of rain water discharge. For "hollow tooth" quarries (in flat areas), the main points to watch for are the possible flooding of the quarry, the control of groundwater and the management of soil and other overburden [37]. In both types of quarry, trees are usually planted around the disused sites to complete the landscape integration (for example, the French gypsum industry planted 52,000 trees on 54 ha in 1996 alone [134]). The restoration of worked alluvial deposits is based largely on the conservation of specific aquatic ecosystems and on maintaining a hydrogeological equilibrium. Due to their method of producing in large cubic blocks and not in benches, the jagged rock faces that occur in dimension stone quarries are difficult to reintegrate into the natural landscape, even with trees planted along ridges and hillsides. These quarries are usually small, making it difficult to create agricultural land by backfilling [104]. Efforts are nevertheless made to restore rock faces (e.g. by reshaping the sharp cliffs with earthworks) and to facilitate the progressive reintroduction of local fauna and flora. Undersized blocks left scattered around closed quarries are increasingly being used as aggregates. However, in all cases, technical solutions for site restoration depend on two conditions being fulfilled: the agreement of local authorities and a sustainable cost of restoration.

For the general public and for local authorities, landscape conservation is of growing importance. A large quarry, whether it is located in a rural area or near an urban agglomeration, can no longer be closed down without a minimum of restoration. In most cases, restoration needs to be planned at the early stages of the site project and, in some cases, the way the quarry is worked depends on the type of restoration foreseen. For example, if the site is to be restored for agriculture, the greatest care must be taken even before extraction begins, namely at the stage of soil stripping and overburden storage. The techniques of backfilling, landforming and natural drainage and restoration of soils are also very important [29]. The quality of a restoration project (estimated at 1,500 – 6,000 €/ha) aimed at nature conservation is a permanent concern for quarry-operators: the planting of rare or local vegetal species closely matching existing ones, the reintroduction of bird species, the creation of nature-oriented leisure areas, and others [13] [119] [133]. In all kind of projects, the problems of soil recultivation are carefully studied [126]. Other restoration projects beneficial to society at large include golf courses, industrial parks [125], amphitheatres, sports grounds, etc.

In many countries, there are increasingly specific requirements for restoration, although these are usually pragmatic in terms of terracing, mounding, tree planting and lake formation. Generally speaking, restoration plans need to be reviewed every year [73]. Authorities in an increasing number of countries require financial bonds or taxes to ensure restoration is achieved in practice [70]. If typical requirements todate have been the restoration of forestry and agriculture, local authorities are now increasingly asking for alternative after-uses such as conservation of wildlife, or the creation of public open spaces, etc. [79]. In Northern Europe, some countries require reinstatement of sand and gravel pits to farmland or recreational use, and even special restoration as fishing lakes and birds sanctuaries [80]. Sometimes, the professional trade associations have their own industry-agreed guidelines for implementing restoration, and in many regions or countries, these groups make awards for "best practice" restoration to encourage quarry operators and to provide recognition of good practice.

In other areas, landscaping carried out for disused quarries has become an integral part of the local cultural heritage, which itself is protected.

Case studies on site restoration

Awards for restoration and renaturisation *Biblio. Ref. [110][131]*

European Aggregates Association - Aggregates

In March 1998, in the Palace of the European Parliament in Strasbourg, UEPG (the European Aggregates Association) honoured for the first time nine companies of the sector with the UEPG Restoration Award, a certificate for exemplary performance in the field of renaturisation and restoration of former extraction sites.

These awards in Strasbourg were a tangible demonstration of the advances made in restoration practices in Europe. In Scotland, for instance, a former gravel pit was turned into a model nature protection area "Birnie Loch", in which over 100 species of birds found their habitat.

A different idea was presented by an extraction site of England, which was turned into a spacious recreation area for water sports, rugby, soccer and golf. In Wales, a disused quarry was blended naturally into the hilly Welsh countryside through landscaping and horticulture.

Companies from France have also been given awards for their exemplary performance in the renaturisation of a river landscape and the large-scale restoration of former gravel and sand pits with flora indigenous to the region.

Two certificates of honour were also presented to Spanish companies: one award was bestowed for the renaturisation of arid land, turning it into a green zone, and another was granted for restoration by landscaping, including the planting of thousands of bushes and trees.

The eighth certificate went to a Swedish company in the sand and gravel industry. In its case, while extraction operation continued, a site was remodelled and replanted in harmony with the surrounding Southern Swedish moraine countryside of hills and lakes.

Lastly, a special prize was awarded to a Swiss company for its performance in restoring the estuary delta of the mountain river Reuss by redepositing sludge and fine grain sand drawn from the processing water of the extraction installation.

It has been demonstrated that close co-operation with the relevant local authorities, with local environmental protection organisations, and with the support of scientific institutions, were of decisive importance for these achievements. The President of UEPG sounded a warning, however, about the increasing amount of regulation targeted at the extraction industry: "What we have seen here today goes to show the variety of ways and means for achieving restoration. Topography, geology, fauna and flora from Scotland to Gibraltar vary enormously. Trying to regulate and generalise restoration plans and operations is counter-productive; local conditions vary greatly and so do approaches to restoration. Over-regulation and over-standardisation cannot be beneficial for the environment; on the contrary, it could prove to be rather damaging."

A typical example of biodiversity in a former extraction site *Biblio. Ref. [123][134]*

Haut-Saint-Martin Site (France) – Gypsum

Haut-Saint-Martin is a former gypsum extraction site of 25 ha in the region of Paris. Closed in the seventies, the site has been entirely restored since 1993 with the aim of promoting its fauna and flora heritage and of improving its reintegration into the natural environment. The biodiversity of the site is particularly remarkable:

45 species of nesting birds have been recognised on the site and 16 others on the approaches to the site. During winter or summer, 18 additional non-nesting species

are present on the site. 11 mammal, 3 amphibian and 3 reptile species are also present at Haut-Saint-Martin. Several special species of insects are of great biological interest: 5 species of dragonfly, 8 species of orthoptere, more than 20 species of butterfly, 4 rare species of scarab, etc.
This diversity of animals is linked to the diversity of natural environments: 8 special vegetal environments have been created, from the aquatic zones to marl grass or quickset hedges, woods, etc. These environments contain more than 220 species of vegetation from very rare types of flower to common trees. The site is particularly adapted to test different kinds of soil or plant management: testing has been carried out on calcareous grass with natural harvesting by sheep, etc.

Nature reserves for bird *Biblio. Ref. [68]*

Taupes and Barbey quarries (France) – Alluvial sand and gravel

The Taupes and Barbey quarries, separated from each other by only a few hundreds metres, have been rehabilitated with ecology in mind. Two new wetlands (of 25 ha and 35 ha) have allowed the influx of a rich population of migratory waterfowl and nesting birds. The richness of the sites and the ornithological interest in them, have led to their registration as a ZNIEFF (Natural Zone of Interest for Flora, Fauna and the Ecology).
In the main basin of the Taupes quarry, various habitats have been created: 12 small sandy islands as a nesting site (an area of 5700m²), shallow zones (sandbanks and mud banks) as a feeding ground for waders and waterfowl, smooth banks with reed beds, belts of diversified vegetation, etc. In 1994, one year after the closure of the works, 113 species of birds were spotted on the sites: common and little terns, gulls, black-winged stilts, tufted ducks, little ringed plovers, great reed warblers, etc. The breeding of 5 very rare species in the Ile-de-France was one successful consequence of the project.
In the Barbey quarry, a lake of 35 ha also contains 3 ha of shallow water and 3-4 ha of smooth banks and five big islands (two of them have been planted to assure the quality of landscape and three have been constructed with ground material to allow the nesting of terns). The new shores of the lake are in fact 4 km long representing an increase of 60% compared to the original straight line bordering the quarry. Steps have been taken to assure the inflow and outflow of underground water and to maintain water quality through the use of steep banks with no additional topsoil cover.
Between 1991 and 1994, 118 species were recorded, with 17 species of swans, geese and ducks and 15 of waders (sandpipers, snipe, plovers), gulls and terns. In November 1994, 1,500 birds were counted. For fulfilling the three objectives of the project (landscape quality, water quality and increasing the ecological potential of the site), the company received the second prize of the "Landscape and Environment Award”, conferred by the General Council of the Seine-et-Marne Department, in 1993.

A new life for a quarry and its surroundings *Biblio. Ref. [76][108]*

St-Pietersberg Quarry (The Netherlands) – Limestone for cement

Since 1926, a major cement company has been giving the St-Pietersberg quarry near Maastricht a new face. A face that is still changing and which, when quarrying ceases, will one day be reflected as a nature reserve in the waters of a marl lake. Although this prospect still seems far away, considerable effort is already being expended on the preparatory work both in and around quarry. Walls are being finished and slopes created in line with the most recent development plans.

Continuous research is also being carried out into fauna and flora, and management of the sections that are already finished is benefiting from the latest scientific knowledge.

In 1967, the company and the local authorities made a careful assessment of parts of the St. Pietersberg that were irreplaceable. These areas remained outside the concession and were designated as a protected natural monument. Only three years later, the company transferred 65 ha of this site to their provincial government, including an historic castle and farmstead. In a new plan, prepared with authorities and experts, the accent has shifted from recreation to conservation.

In the south-east section, where part of the landscape has already been redeveloped, the D'n Observant hill (what used to be a mound formed with materials from the marl deposit) has become a natural site: with the substitution of planted non-native trees by local species of trees and shrubs, the remodelling of slopes, etc.

There are now limestone grasslands at the foot of the hill on the quarry's slopes which have already been excavated. They form the habitat of a special and rare collection of plants.

Within a few decades, the marl quarry will have been transformed into a nature reserve with a marl lake, occupying in fact only a small part of the area. If necessary, the lake could be used as a drinking water reservoir. Together with the neighbouring limestone grasslands, the marl lake (former extraction sites) and other local site, the D'n Observant hill gives a clear idea of how the St. Pietersberg site will look in future.

In addition to its achievements with respect to the ongoing restoration programme, the company has played a part in the natural, cultural and living environment of the areas through the creation of a well-frequented forest, the restoration of a ruined castle, the financial resources to create a playground and a small animal zoo, etc.

The new life of the quarry and its surroundings received a strong recommendation at the European Year of the Environment event.

Research into grass cultivation

Biblio. Ref. [102]

Schelklingen Site (Germany) – Raw materials for cement

This company has developed an original research project in one of its quarries located in Baden-Wurttemberg. This consisted of using cut grass to encourage vegetation growth by spreading it over the floor of a closed-down quarry. This procedure involved first mowing surfaces where suitable vegetation was growing, then collecting the cut grass and subsequently spreading it across the surface to be restored to its natural state. In order to protect germination, the grass counteracts high soil temperatures. The moisture of the soil is retained much longer, and the air humidity under the grass is higher. The grass maintains this protective function for at least 1 to 2 years. Corresponding tests on the following substrates were carried out at the quarry: raw soil substrate (unchanged quarry site), mixed substrate (screen residue and excavated material), excavated material. The development of vegetation on the different trial surfaces can be described as follows:

The raw soil accommodated numerous varieties of grass typically found on rocky soil and oligotrophic grass land of high continuity, but characterised by a virtually complete absence of grassland varieties.

On the mixed substrate, the share of oligotrophic grassland varieties decreased sharply from the 5th year of development. The grass varieties typically found on rocky soil largely disappeared as well, whereas the surface area covered by grass varieties typical of meadows continued to increase.

The varieties of grass typically found on rocky soil and the oligotrophic grass land were hardly detected at all on excavated material. Other varieties commonly growing on meadows were predominant.

With regard to effectiveness, it can be stated that 50 to 60% of the species established on the areas from which the cut grass was taken were introduced and naturalised in one single mowing process.
The costs incurred by such a process range between a minimum of 0.43–0.61 €/m² (without site preparation) and a maximum of 1.36–1.87 €/m² (including distribution of substrate and further measures). In contrast to that, the costs occurring for recultivation for agricultural or forestry purposes, amount to between 1.02–3.07 €/m².

Restoring a Mediterranean ecosystem *Biblio. Ref. [34]*

Artimes Quarry (Greece) – Hard limestone for cement

Due to the fact that the Artimes Quarry lies in a natural and touristic Mediterranean area, many efforts have been made, during the restoration phase, to preserve the original landscape and to protect the natural Mediterranean ecosystem. First of all, 400,000 tonnes of unsuitable material was transported to near the plant in order to create earth mounds of 10-12m high and 1500m long. These mounds were covered with fertile planting soil, and trees such as Eucalyptus and Acacia were planted. These tree barriers were created to protect the surrounding area from noise and to improve the aesthetic appearance.
In the quarry, the method adopted was by open pit with vertical levels of 10m and 6.5m width. The excavation near the final level is done by mechanical means (with no blasting) in order to avoid any disturbance that could affect the plants or the soil on the planted levels. The surface soil layer of the quarry, removed to expose the main limestone deposit and now used as top soil, has been placed along the sharp faces to form a smooth slope towards the foot of the level so that water does not flow away.
A plant-nursery with a capacity of 40,000-50,000 plants per year has been created to revegetate the new faces recovered by these soils. In addition to an automatic water supply system, the plants have been fertilised and structurally supported during 4 years. The variety of plants and the use of soil from the area allows the self-multiplying and reappearance of local flora and fauna (more than 11 plant species, 6 special species of flowers and 15 species of birds and animals).

Integration of a site into a nature reserve for freshwater birds *Biblio. Ref. [74]*

Chambéon Quarry (France) – Alluvial aggregates

In the 20 ha site of Chambéon, 200,000 tonnes/year of aggregates have been excavated in the high water bed of a river. It is located in the Forez plain (also named the Ecopole of Forez), a 150 ha nature protection area about 6 km from the Loire river.
At the initiative of the most important regional association for nature protection, and with the help of quarry operators, this “ecopole” or ecological site has been created to reconstitute a natural wet environment and to recreate the necessary biotopes to allow the settlement of the 50 species of nesting birds already recorded in the surrounding zone of the plain.
A rest centre and an observation post have been built and informative walks are organised.
This “ecopole” constitutes one of the biggest nature reserves for freshwater birds in France.

Example of quarry restoration using trees *Biblio. Ref. [74]*

Bernières-sur-Seine Quarry (France) – Alluvial sand and gravel

The Bernières-sur-Seine alluvial sand and gravel quarry annually extracts 2,000,000 tonnes of raw materials on 360 ha. The first steps that were taken in the restoring of the former area of extraction (particularly well coordinated with the working of the site) were to return it to its former identity and landscape. 50 ha of lakes and 110 ha of well-timbered woods were created using a large variety of trees: deciduous trees such as oak, maple, alder, chestnut, birch, acacia, etc. and conifers such as maritime pine, laricio, cedar, etc.

The quarry operator himself was responsible for the digging work. The floor of the quarry required important work before remodelling; particular attention was paid to the topsoil, and calcareous powder was used as a soil improver.

Additional work was carried out by the quarry team to smooth off and remodel the shores of the lakes and the former embankment.

Creation of lakes fitting in with the landscape *Biblio. Ref. [74]*

Autrey Quarry (France) – Alluvial silica

With the aim of rehabilitating the Autrey site of 60 ha (200,000 tonnes/year) and of preserving the appearance of the landscape, a project was developed to create several lakes appropriate to the surrounding landscape. The following steps were taken to achieve a coherent morphological landscaping:

- Profiling and cutting of basins of different forms,
- Non-linear remodelling of shores,
- Particular attention to the original and local fauna and flora: firs, picea, alders, willows, birch, oaks.

The project will be carried out in different phases with progressive development of the fauna and flora.

Restoration of a quarry in a karst area *Biblio. Ref. [92]*

Appenrode Rüsselsee Quarry (Germany) – Gypsum

The duty to recultivate and restore used quarries has become a fundamental tenet of the company's philosophy. The principle of leaving behind no wounds, not even scars, after the intrusion into nature due to the extraction of raw materials situated near the surface, is also actively applied through specific measures in the South Harz region, at the Appenrode Rüsselsee quarry. As anywhere where intrusions into nature occur, there existed a considerable potential for conflict between economic operators and environmentalists.

Due to the increasingly acrimonious debate, the company representatives proposed that the original opponents of the extraction activities should join them to find a solution to the apparently unsolvable problems. This resulted in a pilot project.

Together with representatives of the local municipality and of the nature protection agencies of the district as well as with interested members of the public, the projects have been successfully worked on and led by an engineering office since the middle of 1996. This is the first time such an exercise has been carried out in the South Harz region.

In the meantime, in addition to the modelling of the total quarry area, i.e. the actual start-up through to the final design after extraction, there are three reports available on the results of compensatory actions undertaken. Some extracts from these reports follow:

"At the foot of the gypsum quarry there is an outstanding landscape feature of a small valley, the so-called Rüsselsee. It is situated at the edge of the quarry and is

no longer disturbed by extractive activities. In the 1996, the nature census of the area observed excellent living conditions for many animal species in the area of the Rüsselsee valley, and a great variety of them were registered: i.e. nine types of snails, six sorts of beetles, 146 species of butterflies, seven species of amphibians and one kind of reptile as well as more than 50 types of birds in the immediate surroundings of the quarry.
In the meantime, the restoration measures which had already been undertaken resulted in a further improvement of the habitat of fauna and flora in the day-to-day quarry operations. This pilot project proves that a sensible compromise between economic and environmental interests can be reached on the basis of pragmatic cooperation of all parties involved. This is ultimately in the interest of maintaining Germany’s economic success."

A reserve for nature and education *Biblio. Ref. [79]*

Ceretto Quarry (Italy) – Sand and gravel for concrete

In Ceretto, in a river bed enclosure area, extraction activities (600,000 tonnes/year) have been underway since 1970 under a stratum of sand and gravel with a surface area of 75 ha.
In 1989, the company policy gave the go-ahead for a restoration project through the creation of a recreational Botanical Reserve destined for public use, and for nature. The guidelines for designing the area were developed together with nature protection organisations.
The idea was to create a "Living Botanical Catalogue" recounting the history of vegetation from its origins until man’s activities in the landscape. The catalogue, the pages of which are displayed at various locations in the Reserve, can also be found in the "Documentation Centre" located in the Reserve.
Another area of activity sees the breeding of "Avelignese" horses, agrestic turkey cocks and rabbits, Langhe sheep and alpine chamois goats.
The pages of the Botanical Catalogue on the Reserve are the following: The riverside wood; Natural Habitat and Country Trees; the "Tiphaeto" Cane Thicket; the Piedmontese Cold Habitat; Plain Resinous Plants; the Arboretum; The Natural Lake; The Moorland and Hill Woods.
The roads inside the reserve are unmetalled and limited to agricultural and excavation vehicles only. Access to the parking area is located near the asphalted public road of the former port. The Ceretto Reserve promotes naturalist and environmental education through free, guided visits. Visits are foreseen for an aquatic ecosystem culture providing different levels of academic use (from nursery school to high school). The basic elements include:

- A trip of two hours which visits the most characteristic points with direct and specific observation of the riverside wood, the marsh, the pond and the quarry lake;
- A visitors' centre where there are various posters explaining environmental issues and nature protection;
- A small "Agricultural/Horse-rearing Centre" where it's possible to observe certain domestic animals (horses, Langhe sheep, ducks, etc.) and exotic animals (peacocks, tibetan goats, etc.).

A donation of forest to the public *Biblio. Ref. [95]*

Tarnow Quarry (Poland) – Limestone for lime

For several years, this company has tried to minimise the impacts of quarrying on the landscape, hydrological systems and local vegetation. By improving mining

techniques and the systematic restoration of soils, the quarry operator has set out to overhaul his approach to environmental management. The working of the quarry does not alter the natural flow of water due to the depth of the water table.
From 1997, after the cessation of quarrying activities, the operator has restored a total surface of 42 ha into forestry. Of this, 31 ha have been transferred to public ownership via the Directorate General of Domanial Forest.
The worked out quarry surface has been covered by the strippings and residual products. After this, the area has been planted with 2-3 year old trees previously transplanted. The trees with a well-developed root system are placed in 0.3–0.5m wide holes which are filled up with top soil. The varieties of deciduous trees usually planted include maple, ash, alder, rowan, oak and birch.

Realisation of terraces and hydroseeding

Biblio. Ref. [79]

Roashia Quarry (Italy) – Limestone for Cement

The limestone, from a quarry in Roashia (active since 1965), is quarried by blasting using a descending series of horizontal benches. The benches have a height of 15m and a distance from wall to quarry-edge of 8-8.5m, giving an average gradient of the overall quarry face of 55 degrees.
With the collaboration of the authorities, the restoration has been carried out with satisfying results. The project consists of piling up, on each bench or ledge, loose material to a height of 3-4m against the wall. A flat part is formed at the top of the embanked material so as to provide a path for access and also to halt any falling stones from above. Water flow regulation is obtained using surface channels. The accumulation of water for the benefit of vegetation is facilitated by slightly rising gradients towards the wall. The embankment is formed of a base of coarse filling using limestone left on site, a foundation stratum comprised of fine local siliceous aggregates to fill up irregularities and smooth the surface and finally a stratum of fertile earth suitable for the grass sod surface. The substratum thus formed allows a supply of moisture to be accumulated for the stable establishment of vegetation even in summer drought periods, with a continuous and capillary moisture transfer to the upper strata.
The operating plan is the following: barring of the upper wall of the bench to remove loose rock, levelling and grading the floor of the bench, establishing the slope of the piled material to create a stable gradient of 30 degrees and finally sowing a mixture of seeds of local and perennial grass species (e.g. 40gr/m^2) by means of hydroseeding. The hydroseeding is carried out at an interval of one/two seasons. The seeds are enriched with organic/mineral fertilisers and by a special bonding/stiffening agent of organic origin.
The embankments of material are usually made in an irregular way with random height and gradient variation so as to create an irregular shape of the restored faces. Following hydroseeding and after one or two seasons, planting of wild hazel, Cytisus, Sorbus etc is carried out to prepare the ground for the establishment of local arboreal growths. This operation allows the grass surface and the arboreal growth to be exposed to view in a greater way thereby obtaining a continuity of landscape between the area and the natural bordering slope, thus recreating a naturalised and pleasant landscape.

Case studies on incremental restoration during the lifetime of a quarry

A restored quarry integrated into the environment *Biblio. Ref. [79]*

Sarche Quarry (Italy) – Raw materials for cement

The original quarry was opened in the 1960s and occupied an area of approximately 40 hectares. As part of the cement works programme, the quarry was intended to provide for the extraction of 10-11 million m³ of material, with a dozen or so extraction sites located next to each other with a difference in height of 10 metres.
However, the particular geology of the site, with a clay strata present, resulted in landslips and the consequent need for safer working conditions. As a result, the excavations were moved to the higher levels in the late 1970s, and at that time, efforts were made to minimise the serious environmental impact the quarry was having in an area of great tourist importance.
This was made possible because:

- the old faces were temporarily restored during the excavation work on the upper levels,
- the worked-out faces were profiled by blasting with escarpments at approximately 35°, and the waste material was levelled,
- topsoil was laid on these escarpments and grasses and shrubs were sown. Once the soil had been consolidated, tree planting followed.

The integration of the reclaimed quarry has been further enhanced by the creation of a new road infrastructure on abandoned land, replacing the old and inadequate roads connecting the villages on the surrounding hills.
The environmental reclamation work is continuing, and should not present obstacles to the extraction of the remaining 5 million m³.

A ten year programme to restore a large open-pit quarry *Biblio. Ref. [57]*

Vaujours-Caubron Quarry (France) – Gypsum

The important programme of restoration for this disused open-pit gypsum quarry (135 ha) was started in 1995 and should be completed by 2005. It has been subdivided in two main phases: backfilling of the excavation by inert materials and vegetalisation of these spaces with grass, timber, orchards and ponds.
Between November 1994 and July 1996, 1.3 million m³ of earth was used to backfill the Vaujours-Caubron quarry. After that, it was necessary to reshape the topography and to reconstitute the surface soils.
To the north of the quarry a network of wet ditches and ponds have been created to drain the field and to give the landscape a more attractive perspective. Consolidated marns were used to ensure the ponds did not leak.
To the south, the old site of excavation was backfilled by a thick plant-soil that was worked and prepared before planting. Following the zones, a belt of diversified vegetation was prepared.
Ten species of graminaceae and leguminous plant were planted to recreate grasslands with the aim of promoting growth of a spontaneous flora especially adapted to this surface soil.
The children from the nearest village planted 300 trees on the 18,000 that have been planted for this project. Six species of tree (oak, ash, maple, wild cherry, birch) selected for the timbering, were bordered by bushes such as viburnum, dogwood, hazel tree, etc. An orchard with apple trees, plum trees and aquatic plants for wet lands complete the scenery.

The restoration project was carried out on 76 ha between 1994 and 1998. A further 60 ha will be restored between 1998 and 2004.

Restoration of benches in an open-pit quarry ***Biblio. Ref. [77]***

Ebensee Quarry (Austria) – Raw materials for cement

When the benching of limestone (for cement) was finished, the Ebensee Quarry's team subdivided the bench heights of about 18 m into smaller heights. The bench edges, bench lengths, slopes of benches, etc were also built in different ways. After this preparation, the variable benches were covered with topsoil, humus, rootstocks, etc. These local materials, carefully separated after ripping, came from the overburden works that were necessary before extraction and benching (the total surface area of the site was 20 ha).

After a certain time, the quarry's team coloured the bench faces with a special mixture consisting of water, a dispersion, a grey colour and additives of different seeds. The next step was to replant the prepared area with grass, pastoral alder, spruce and other species.

The aim was to restore about 40% of the quarry using these methods.

Incremental restoration during the lifetime of a quarry ***Biblio. Ref. [84]***

Boudeau quarry (France) – Quartz pebbles and silica sand

This quarry exploits a sandy-clay ore-body containing quartz pebbles (300,000 tonnes/year). The overall plan was designed in order to allow simultaneous working and restoration of the site.

The working area is maintained at less than 4 ha and the "active area" (from clearing of vegetation through to replantation with trees) does not exceed 15 ha.

The working is carried out in basins of limited size, about 10m deep. Once the working is completed, the basin is used to collect the clay mud resulting from the washing of the ore-body during the process. These clays progressively fill up the exploited basins. The amount of carrying water released in the basins with the mud was minimised by introducing a cyclone concentration of the mud at the outlet of the process. The water is recycled in the process.

The complete drying of a basin occurs in 2 to 3 years, mainly through evaporation. For final restoration, the overburden material is put back in place and is eventually covered with the vegetal earth, which was carefully kept for this purpose. The final remodelling of the soil is carried out in harmony with the local topography.

Depending on the initial vegetation on the site, it can be rapidly converted back to agricultural use (e.g. one area has already been used again for cereal production three years after starting the working), or it can be planted as a forest. Forestry research has been carried out, with the support of specialised institutions support, in order to optimise the plantation, both from ecological and forestry points of view. It resulted in the development of mixed forests of pine and chestnut trees.

The unique aspect of this case lies mainly in the rapidity with which the site was returned to its initial use.

Incremental restoration ***Biblio. Ref. [98]***

Kavala quarries (Greece) – Marble

The company began planting trees in its quarry Nr 1 in 1971. At the beginning, there were a number of problems, but they were overcome and now the restoration of the quarry site is progressing in a satisfactory way. Furthermore, there is a plantation of trees and bushes covering 60% of the company’s needs. In the near future, areas around the quarry that have not been restored yet will be fully planted and only the site undergoing extraction will remain for ultimate restoration.

Currently, there is a crushing plant next to the quarry which operates permanently, with full installation of filters where surplus material is transmitted from the extraction area and transformed into marble aggregates and powder. It is estimated that over 80% of the surplus material will be recycled with no need for storage.
The company has published a book called "Marble and the Environment", describing the experiences with regard to the working and restoration of the quarry. In Quarry Nr 2, the same company has been implementing an environmental reinstatement programme since 1987.
The increase in the use of the raw material was achieved by means of a crushing plant with full installation of filters for marble aggregates and powder production.
In the near future, the port installations next to the quarry will come into operation and the quantity of materials sold in Central and North Europe markets will be increased.
Also, the volumes of surplus material will be considerably reduced and reinstatement work will progress to the next level. In 1991, for example, a park with kiosks, benches and a small church was created on the upper level of the quarry.

Restoration of a settling basin — *Biblio. Ref. [101]*

Moha Quarry (Belgium) – Hard limestone for lime

The place called "Valèche", located on the perimeter of the large Moha quarry belonging to the same company, had been used for the extraction of hard limestone up to 1972.
This 5 ha site had been transformed into a settling basin for the purification of process waters produced by the washing of stones in the plant. The banks of the basin have been progressively heightened as the sediments reach the upper limits of the basin. The site was decommissioned in 1975. The particular characteristic of the site is that, even if the area of water is important, the stony cliffs of the faces have been preserved for their aesthetical and biological interest.
Now, the restoration work carried out by the company has transformed the basin and its vicinity into a natural wetland through the:

- Planting of various species of trees and bushes along the banks and cliffs: poplars, larches, willows, fruit trees, etc.,
- Monitoring of the vegetation and its natural regeneration in order to maintain biodiversity,
- Monitoring and cleaning of bulrushes and reeds to prevent the clogging up of the stretch of water,
- Checking for leakages to maintain the water level.

Over 15 years, these measures have created a natural wetland of great value in terms of landscape and biological environment.

Case studies on the restoration of sites for tourism

Restoration for use as a wine storage and tourist attraction *Biblio. Ref. [96]*

Portel Quarry (France) – Gypsum

Opened in 1807, the underground gypsum quarry of Portel in the Corbières wine area of Languedoc-Rousillon ceased operations in 1992.
Near the coast and the A9 motorway, the quarry is remarkably well-positioned. It is close to major tourist locations such as Narbonne Plage, Port la Nouvelle, Port Leucate and Port Barcares, as well as being in the middle of the Corbières Maritimes wine area and only 5 km from the African game reserve of Sigean with 350,000 visitors a year.
Contacts were made with UCCM (Union des Cooperatives des Corbières Maritimes) to look at the potential of the site for the storing and the ageing of wine. In addition to its good location, the ambient temperature of 15°C, the high hygrometic level of 80% humidity (due to an underground lake) and the spacious galleries, made the Portel mine an ideal place for wine storage.
A € 457,000 programme of work was carried out by the company. It included the hiving off of the 524m of galleries to be used, the cleaning-up and reinforcement of these galleries, the closure of the ventilation wells and the preparation of the "old mine" area.
The overall objective was to make the site completely safe for visits by the public.
For their part, the UCCM invested € 1,220,000 to turn the site not only into storage for 30,000 litres of wine in barrels but also as a tourist attraction with a wine-tasting room, a reconstituted Gallo-Roman villa and a mine museum.

Restoration as a golf course *Biblio. Ref. [105]*

Altendorf Quarry (Germany) - Gypsum

The Altendorf golf course is located at approximately 3 km of Eckenförde and 1 km of the Ostsee shore. Initially created in a national park of very old oaks, the 60 ha area contains an old quarry of 14 ha worked to a maximum depth of 15m between 1939 and 1983.
When the quarry ceased operating, it was decided to incorporate the site into a golf course. Some of the steep slopes have been flattened and others have preserved their original appearance. On the floor of the old quarry, three stretches of waters have been created in the golf course. Planting has been carried out and vegetation preserved in other parts of the old excavation works: small sloping sections have been planted prior to them growing their own vegetation naturally and old oaks overhang the north side.
In this way, a good variety of vegetation is developing along the faces including shrubs and trees. The greens are regularly sprinkled, mown and treated with fertilisers. Some rarely mown wild spots of sparse shrubbery surround them.
The general appearance of the site is pleasant and the old quarry is unrecognisable. The site is a real pleasure for golfers who can play on an unusual green with diversified vegetation, all the while surrounded by unspoilt nature.

When quarry-operators are also wine producers *Biblio. Ref. [111]*

Istein Quarry (Germany) – Limestone for lime

In 1983, this company obtained a permit to extract 700,000 tonnes of limestone per year from its new limestone quarry for a period of only 10 years. During the initial discussions many objections to the project were received from inhabitants of a

community located at a distance of only 300m. One of the main concerns of the local residents was the visual impact on the landscape.
Once the operating permit for the new quarry was obtained, the old quarry was closed down and restored. Along the walls of the disused quarry about 2 million m³ of earth were deposited to create shallow slopes. By this means, a surface of about 30,000m² was obtained which was mostly planted with vines. This measure was hailed locally by various media as an excellent example of successful site restoration. The positive side effect is that the company now not only produces lime and limestone products, but also a superior-quality wine.

The rehabilitation works of a harbour *Biblio. Ref. [74]*

Beinheim Quarry (France) – Alluvial sand and gravel

The former extraction site of Beinheim occupying a zone of 70 ha (400,000 tonnes/year of alluvial sand and gravel for concrete and civil engineering) is located close to the major river Rhine and directly linked to rivers via an open wet dock. In fact, the extraction site now under water constitutes a part of an important river harbour.
In the harbour zone, the rehabilitation works have mainly consisted of the construction of banks and of protection against flooding.
At the request of the local authorities, the quarry operator has carried out special work in order to create small islands for the nesting of herons. A local team of nature specialists now scientifically monitors these ecological sites. The rehabilitation of the harbour now allows the anchoring of pleasure boats in addition to the usual commercial boat traffic.

A typical example of restoration as lakes for public use *Biblio. Ref. [78]*

RÆrdal Quarry (Denmark) – Chalk for cement

The chalk pit in Rørdal is an open quarry intensively worked. The quarrying has changed the landscape totally, and it is too optimistic to believe that, when the quarry is closed at some future date, nature itself will be able to restore the site and make it a natural part of the surroundings without help from man. In 40 to 50 years, this chalk pit will be worked out, and, at that time, it will cover an area of 404 ha.
Over the years the company has readjusted and replanted the area, but in addition to this, a detailed plan has now been established to ensure that the area is given the recreational facilities that will enable it to live up to its future name: the Rørdal Lake Park. The guidelines for its establishment are within the framework of the regional plan worked out by the County, and also comply with the municipal plan.
The lake will become a pleasant leisure area for the next generation. The park will offer new attractions to all North Jutlanders and it is expected to include an open-air theatre, large green areas with a variety of plants (for walks, relaxation or fishing) and a lakeside marina for pleasure sailing. All around the lake, one will be met by the steep chalk slopes like those lying along the shores of local fjords, and which are a characteristic feature of the North Jutland landscape.
The project also outlines the condition in which the quarry must be left by the company when extraction work stops. The slopes will usually be left by the operator in straight or broken lines, and therefore, to make the park form a harmonious entity with the natural surroundings, it is suggested that the slopes and the lake are re-shaped with more gentle curves. Some sections will remain as they are left by the excavation machines, while others will be given different shapes and planted.

The planted ramps will give access to the different heights of the sloping banks. Where there are outstanding formations of special geological interest they will remain as they are, as part of the unregulated area.
It is planned that the restoration of slopes will take place in stages and that each stage will take five years.

Swimming and windsurfing in a former sand pit ***Biblio. Ref. [105]***

Wesel Quarry (Germany) – Sand

In the vicinity of Wesel (Ruhr) a very large sand pit (215 ha) was worked until 1993. Due to the proximity of the town and the available spaces for parking, the old sand pit has been restored into a leisure park with restricted zones reserved for nature preservation.
The zone of 215 ha has been divided into lakes (178 ha for swimming, diving, windsurfing, regatta, etc.) and shores or islands (37 ha planted with 100,000 bushes or with grass along the shores).
This very popular leisure zone attracts up to 30,000 visitors during the summer.
On the other side of the lake the landscaped shores have been so conceived as to divert the visitors from the nature reserves: footpaths lead away from the lake, separation is assured through many small marshy or bushy zones, etc. Small islands that have been left to natural development have become nature reserves for birds and nesting sites have been created for particular species such as terns for which nesting is increasingly difficult along the Rhine-river.
Ornithological observations show that of the 62 indigenous species of birds recognised, 11 were classed among the country's endangered species. The same applies to the 28 migratory bird's species of which 21 are exceptional. For this reason, the former quarry operators have granted funds to build an observation post that directs and concentrates the visitors as far away as possible from the ecological zones. Embankments have also been erected to prevent flooding by the river Rhine into this new leisure and lakes area.

Chapter 5
Conclusions

The aim of this Guide is to inform rather than to draw any detailed conclusions. It is up to readers to draw their own conclusions. It is enough if the Guide has simply succeeded in clarifying what quarrying is all about.

Looking back at the Guide and, in particular, the case studies, it is evident that the planning, opening, managing and closing of a quarry are all part of a technical and precise business. It involves heavy investment requiring a long-term perspective for both management and the regulatory authorities. Regulatory and other constraints imposed in increasing numbers and in a haphazard fashion inevitably lead to frustration and can only have an adverse effect on economic and social development, two important pillars of sustainable development.

A close look at the activity of mineral extraction reveals an important paradox. Minerals occur in a relatively limited number of suitable locations. However, those minerals still need to be extracted because they are vital to industry and to people's lives. This basic reality, of course, runs contrary to the "not in my backyard" attitude invariably taken by local pressure groups.

Since the dawn of time, quarrying has been, and still is, one of humanity's basic activities, vital for its survival. Neolithic quarries supplied, in a managed fashion, the stones necessary for tools and weapons. Thousands of years later, in today's world, mineral extraction contributes significantly to the EU's economy and to the welfare of its citizens. Accounting directly and indirectly for over 20% of EU GDP, it certainly cannot be considered as a marginal activity. Although this importance in no way justifies irresponsible, non-sustainable behaviour, it cannot be disregarded in the inevitable debate on sustainability that precedes any extraction activity. The industry has suffered far too long from a bad image and from ignorance and it would benefit all parties concerned to understand and appreciate more fully the essential nature of minerals.

Of course, recognising the importance of minerals does not mean that everything is fine in the industry even if it were possible to remove the burden of constraints to which the industry is subjected. There is no doubt that making holes in the ground, often extremely large ones, causes important environmental impacts. However, from the examples reviewed in this guide, and they are examples taken from the non-energy, non-metallic mineral sector, it does seem that these impacts do not cause any wide-ranging harmful effects. What impacts they have are local and limited in time.

We also need to examine another paradox. Overall, the non-energy, non-metallic extractive industry contributes substantially to habitat variety and to biodiversity. Initial reaction to this is: “Well, nature should have been left alone in the first place.” Of course, in a world where minerals were not needed this would be the perfect answer. However, in the real world, where extraction activity is inevitable, further reflection shows that temporary impact and inconvenience can eventually lead to permanent and real environmental improvements. Quarries indeed have temporary lives, ranging from a few months to 30 years on average. In many cases, particularly where the surrounding areas have, in the meantime, become urban, industrial or agricultural zones, quarry restoration does indeed create sites of conservation. These would certainly not have existed if a quarry had not been opened there in the first place. Furthermore, the habitats recreated by restoration are often richer than the original ones. There are even examples of situations in the Guide, where the quarry site operator had difficulties in coping with the enthusiasm ecologists expressed for the habitats created during the active life of the quarry. Even some of those quarries, where no rehabilitation measures were taken during or after their active lives, have managed to become sites of ecological interest. However, the industry recognises that the chances of ending up with a site of ecological quality are much greater when the site is managed to that end both during and after the life of the quarry.

The situation is rarely straightforward. It would be as naïve to maintain that opening a quarry is always good for the environment as it would be to maintain the contrary. Obviously, there are eco-systems which are irreplaceable and which should not be touched for whatever reason, even those of major socio-economic importance. Other eco-systems might be less unique, particularly if, in the end, they can be recreated or replaced by a similar or even better system. Finding the right balance is an extremely difficult task, mainly due to the large element of subjectivity required in any decision.

An apparently simple solution to this problem would be to physically separate the respective interests i.e. by “freezing” some areas for nature protection and others for mineral extraction. This would, however, prove unrealistic. Nature is dynamic and cannot be “frozen”. The extractive industry cannot isolate areas of critical mineralogical importance from the outside world. The best way forward lies in an open dialogue which, with as few as possible pre-conceived ideas on either side, would try to arrive at well-balanced local solutions.

The local conditions and the specific nature of each project form the critical parametres of any decision. European or national regulations are often unnecessary or irrelevant. This is not a call for complete deregulation so that industry can do what it wants. Throughout the Guide it is apparent that although access to resources is still being regulated by mining codes, environmental and social conditions are now being covered by numerous separate regulations. In other words, far from being deregulated, the extractive industry is probably today one of the sectors with the most environmental controls. The most effective way of dealing with this complex situation would be for regional and local authorities to manage all procedures and authorisations, although it would not be simple to allocate the various responsibilities.

The extractive industry needs to be able to operate on a level playing field based on the recognition of the essential role it plays in everyday life. It is not the anti-environment monster that some would label it. It has come very far in integrating environmental concerns in its management practices and will continue to improve these practices, hopefully with the support and assistance of the people whose criticism of the industry is based on a lack of awareness of what industry has already done and what it intends to do.

This dialogue should be helped by the fact that mineral extraction is the industry most widely and deeply implicated in the socio-economic tissue of our society. Mutual knowledge and trust will provide the best way of arriving at intelligent solutions, designed to take into account the concerns and expectations of all parties concerned.

We trust this Guide will facilitate and contribute to such a dialogue.

Annex 1
Markets and end-uses

Minerals pervade almost every aspect of our lives and are at the very basis of our society and of its technological development. The uses of minerals are numerous and range from concrete to sugar: 200 gr of limestone is necessary to produce 1 kg of sugar; 700 kg of sand and 300 kg of carbonates are used to make 1 tonne of glass; 15,000 tonnes of aggregates to build one kilometre of TGV rail track; 650,000 tonnes/year of calcium carbonate are used by the European PVC industry [55], etc. The construction of a house would be impossible without minerals and in 1997, a total of 1,900,000 dwellings were completed in the European Union. In fact, total 1995 European output of construction, chemical and industrial minerals (in the broadest sense of the term) was valued at over € 20 billion compared to less than € 15 billion in the U.S.A.. In Chapter 2, this economic importance was briefly examined. The objective of this annex is to give more detailed information, sector by sector[1].

The Aggregates Industry

The economic importance of the sector of crushed stone and sand and gravel for construction is characterised by its large output: over 2,5 billion tonnes in the European Union in 1995, representing 31.5% of world production. Except for the Low Countries which is covered by recent sand or clay sediments, almost all European regions can claim to have some deposits of hard rock worked by way of open quarries or river beds and banks. For marine aggregates, the United Kingdom (20 million tonnes in 1995) and The Netherlands and Denmark (6 million tonnes) number among the major European producers. At respectively 7%, 13% and 18% of their national aggregates production, these relatively small quantities are mainly destined for local use or, for example, to mitigate the cost of building and maintaining polders and artificial islands. Belgium (with 8%) and France (with 1%) are smaller producers but with known reserves [68].

A new activity of the aggregates sector is the treatment of mineral waste from demolition. The extractive industry tends to have the best know-how for the difficult process of crushing, washing, screening, and recycling of demolition waste.

In Germany, for example, 50 million tonnes/year of recycled aggregates are used compared to an annual production of 650 million tonnes of stone, sand and gravel [10]. In

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[1] *Further statistical and qualitative information can be obtained for the EU Minerals Yearbook published by the Enterprise DG of the European Commission, available on : http://europe.eu.int/comm/dg03/publicat/emy/index.htm.*

the United Kingdom, the use of recycled materials is forecast to rise from 32 million tonnes/year in 1992 to 55 million tonnes/year by 2006 [22].

The European aggregates industry constitutes a major sector of the economy with a total production of more than one billion tonnes of gravel, sand and quarried stone, providing some 190,000 jobs. Although the number of direct jobs is limited, the number of jobs indirectly dependent on the aggregates industry can be arrived at by applying a factor of 2.4. This gives a total of about 650,000 jobs, excluding the construction industry [17] which is difficult to estimate. This figure is, however, probably under-estimated: in France, for example, while the cement and aggregates industries provide 21,500 jobs, the concrete and concrete components producers (using cement and aggregates as "raw materials") employ 28,000 people in 1,700 enterprises [41].

In 1998, the association UNPG-IAURIF[1] published a study on the local socio-economic impact of about 20 quarries of alluvial aggregates located in the Ile-de-France region. It was shown that extraction in this region generates the equivalent of one indirect job for one direct job. The direct employment includes those jobs directly performed by the quarry team i.e. production activities (extraction and treatment), maintenance of production tools (equipment and engines), quality control, commercial and administrative functions, etc. Using these direct employment figures as a basis, the study identified the equivalent indirect employment (Table F).

Table F. The aggregates industry and indirect employment (case of Ile-de-France)

Transport of materials (waterways or roads)	64,7%
Production operations (earthworks, restoration)	15,0%
Functioning (tools, fuels, …)	6,5%
Maintenance	5,3%
Investment	4,9%
Commercial activities	2,7%
Services, consultance, etc.	1,2%

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[1] *Union Nationale des Producteurs de Granulats (French Association of Aggregate Producers) - Institut d'Aménagement et d'Urbanisme de la Région Ile-de-France.*

The Cement Industry

Cement is also a major mineral industry, playing a key role as a basic material in both building and civil engineering. It is mainly used for concrete: a natural material made by mixing sand, gravel and water with cement as hydraulic binding agent [35]. Since 1824, modern concrete based on Portland cement is present in all aspects of our life. Cement plants are generally located near large deposits of hard limestone or soft chalk found all over Europe. European countries have cement industries with capacities of up to 34 million tonnes/year.

World production of cement has grown steadily since the early 1950s. Recent growth in world output of cement (1.4 billion tonnes in 1995) is due to increased production in developing countries, particularly in Asia, China and Japan which now has 60% of the world production versus only 12% for the European Union and 5% for the USA. In the European Union, total 1995 cement production was at 172 million tonnes with four European groups ranking among the top five world cement producers. As in the lime industry, these very large companies have quarries and plants with a long tradition in their region [105]. They employ many people who live in surrounding communities—at one of its sites, a UK cement company has calculated that 76% of its workers live less than 16 km away, with only 12 workers living more than 40 km away! [13]. These groups also have activities in other construction materials sectors such as aggregates, concrete, gypsum products, etc. [38]. Over 60% of cement is used for buildings and dwellings. Users have long understood the benefits of cement, which explains why world wide cement consumption is growing steadily by around 3% a year!

Major environmental benefits are derived from the use of concrete. Its environmental performance can be assessed in relation to that of competing or substitute materials. If the embodied energy content (in GigaJoules/tonnes) of various construction materials are measured, values of 5 GJ/t for cement and 0.25 GJ/t for aggregates are obtained [23]. Combining these in concrete containing 15% Portland Cement with no energy reducing slag or ash additions, and allowing 0.4 GJ/t for transport and site works, will give a total energy content of around 1.4 GJ/t. This compares well with timber (from 1 GJ/t for rough sawn wood to 5.3 GJ/t for kiln dried and treated timber), glass (20 GJ/t), structural steel (about 30 GJ/t) and aluminium (270 GJ/t).

The Lime Industry

The largest users are the steel industry (45%), the construction materials industry (25%) and other industries such as the chemical industry (10%) [19]. In 1995, the output of the European lime industry was 22.4 million tonnes, a fifth of world production [18] [56]. Quicklime and hydrated lime are the lime industry's most important products. More than 20 million tonnes are produced annually in Western Europe. The major lime producing countries are Germany, Italy, France, Belgium and Great Britain; other main producers are located in Finland, Sweden and Denmark [24]. We have seen that lime is also one of the most effective products for reducing industrial pollution and for treating water and polluted soil.

The Gypsum and Plaster Industry

Known world reserves of gypsum ($CaSO_4.2H_2O$) are estimated at 2.26 billion tonnes, with Europe accounting for 35% of these reserves. European output of extracted gypsum was 21 million tonnes in 1996 [58]. The European industry has 220 factories producing gypsum products and provides direct and indirect employment for more than 400,000 people.

The Egyptians discovered the versatile properties of gypsum some 5,000 years ago. They discovered that gypsum rock could be broken down to a fine powder, and after exposure to fire, this powder could, with the addition of water, be used as a quick drying plaster to give a smooth finish to rough stone and brick surfaces. However, it was not until 1755, in France, that the chemistry behind gypsum became clear and by 1870, that a method of delaying the setting rate of plaster was developed. In addition to extracted gypsum, flue gas desulphurisation (FGD) gypsum is also widely used as a raw material [47]. The construction market uses approximately 95% of total gypsum production (crude gypsum is also widely used in cement production - at between 3-6% of overall content) but gypsum is also used in other industries. It is used in the production of container glass, as a conditioner for soil, as a filler for glass, as a soil conditioner, as filler for products such as animal food or ice cream or as an agent in beer processing, and as extenders in pharmaceuticals, rubber, artificial wood, plastics, paper and pigments.

It has been estimated that each year in Europe, 1.5 billion m² of interior surfaces are built or covered with gypsum products; the equivalent of the total surface of Greater London. It is estimated that approximately 80-90% of all interior surfaces and partitioning of European housing are made with gypsum products, such as plasterboard and plaster. With their thermal and acoustic qualities, these products contribute significantly to people's everyday comfort. In non-housing (shops, offices, etc.), gypsum accounts for 50-60% of all interior surfaces. With outstanding fire protection characteristics, gypsum products contribute to safety in all buildings particularly in such public places as cinemas [60] [135].

The Industrial Minerals Industry

Due to their diversity, industrial minerals are found in a large variety of deposits located in specific geological settings: talc (in certain conditions of hydrothermal circulation) occurs in metamorphic rocks of ultrabasic or dolomitic origin; perlite occurs in recent volcanic massifs of rhyolitic type; kaolin is found in weathered feldspathic rocks (granite, gneiss or feldspathic sandstone); pure feldspars are generally found in coarse pegmatites of clear granite or in certain feldspathic sand deposits, etc.

The market for industrial minerals is certainly the most diversified in the extractive industry. They are used as basic raw materials, additives or processing aids in a wide range of products including paper & board, paint & varnishes, plastics, rubber, glass, fibreglass, foundry moulds, ceramics, china, detergents, fertilisers, pesticides, feedstuffs, drugs, cosmetics, etc. The spectrum of markets covered is specific to each individual mineral. Generally, 3-4 key applications account for 60-70% of each mineral's market. Glass, ceramics, foundry, paper & board and plastics account for a very significant part of these markets. Overall, the EU production amounts to about 90 million tons per year. Europe counts several of the worldwide top producers, operating EU deposits and having acquired control over deposits throughout the world.

More details of facts and figures are available on the IMA-Europe website: http://www.ima-eu.org.

The Dimension Stone Industry

The end-use markets for dimension stone vary enormously and each investment in extraction has to be analysed accordingly. As with aggregates, dimension stone can be found in some form or other in virtually all European regions, e.g. the famous marble of Italy and Greece, limestone in Belgium and Ireland, slate in Wales, Brittany and Portugal, granite in West and Southern France and Spain, sandstone and limestone in Germany, etc. In 1995, total European Union output of dimension stone was 20 million tonnes or 45% of total world production [18]. European slate production represents 27% of total world production with a volume of 947,000 tonnes [56]. Italy remains the world's main producer of dimension stone blocks (with 8 million tonnes/year) followed by Spain, Portugal, Greece and France. The world market has been radically transformed over the last few years with the arrival of products from outside Europe, mainly in the form of rough blocks. Imports come from India (+ 827% since 1981!), China and Brazil. The dimension stone sector is characterised by a large number of companies smaller in size than in the other sectors of the extractive industry and the number of local jobs is certainly more important, as for example in the Massa-Carrara district in Italy where, there are some 1.247 companies! [18]. One important aspect of this sector for the European Union is its thriving export business mainly to North America and the Far East. This success is not only for the material, but also for associated industries: in the mid-nineties, South East Asia was the most important market for the Italian dimension stone quarrying and processing technology sector. Traditional uses of dimension stone in construction (new building, renovation and maintenance), furnishings, funereal art and interior design are well known. The continuous evolution of quarrying technology has made raw material readily available whilst the development of processing technology has widened the variety of potential end-uses. New techniques exist, for example, to make very thin natural stone (ranging from 4 to 28mm in thickness) that can be combined in sandwich panels with composite products or that are translucent [63]. In Europe, traditionally high levels of consumption, extensive production, a high level of process technology and a building market centred on maintenance and renovation, all favour the use of natural stone. It is often looked upon as a material that increases the prestige of a building whether it is housing, offices or public buildings. Furthermore, there is a wide use of dimension stone in old houses and this use helps to promote the market and the image of quality products [63].

Annex 2
European sectoral organisations

The initiative of this guide arose from co-operation between the Enterprise Directorate General of the European Commission and seven of the European trade associations in the non-energy, non-metals extractive industry: Cembureau, Cérame-Unie, EuLA, Eurogypsum, Euro-Roc, IMA-Europe and UEPG.

Cembureau (The European Cement Association)

Cembureau, founded in 1947, is the representative organisation for the cement industry in Europe. Its full members are the national cement industry associations and cement companies of the European Union and the European Economic Area countries plus Switzerland and Turkey, together with five associate members from Eastern Europe. Cembureau thus represents a total cement production of 241 million tonnes (16% of total world cement production) and a total direct employment of 95,000 people [87]! Cembureau fulfils its primary objective of advancing its member's interests through active representation at European and international levels. In maintaining a permanent dialogue, Cembureau acts as spokesman for the cement sector towards the EU institutions and other public authorities and communicates the industry's views on all issues and policy developments with regard to technical, environmental, energy and promotional issues. Cembureau provides its members with a platform for international co-operation and a forum for the exchange of ideas and experience. It helps to ensure that the cement industry develops in a sustainable manner within an appropriate regulatory and legislative framework and through advances in efficiency and technology that respect the environment [51].

For further information, please contact:
Cembureau (The European Cement Association)
Rue d'Arlon 55, B- 1040 Brussels
Phone: + 32 2 234 10 11 - Fax: + 32 2 230 47 20
E-mail: secretariat@cembureau.be
URL: http://www.cembureau.be

Cérame-Unie (The Liaison Office of the European Ceramic Industry)

Cérame-Unie represents the interests of the European ceramic industry at the EU level since 1962.

The industry records total sales of around € 25 billion, and employs 250,000 people across Europe. The European industry is estimated to provide a third of total world production, and has been able to maintain a positive trade balance with third countries over the years. Its products range from bricks and rooftiles through refractories, technical ceramics, wall and floor tiles, sanitary ware and clay pipes to table and ornamental ware.

The raw materials used by the industry are mainly clays, in various degrees of refinement. In many cases, raw materials for the refractories and bricks industry are extracted by the producers of the final products; the raw materials used for the production of fine ceramics are mainly extracted and refined by specialist producers, represented in Cérame-Unie.

These producers have developed a classification of clays and are actively participating in the development of Cérame-Unie's positions on health and safety issues, environmental matters and trade policy issues relevant to the industry.

For further information, please contact:

Cérame-Unie (the liaison office of the European Ceramic Industry)

Rue des Colonies 18-24, B-1000 Brussels

Phone: +32 2 511 30 12 - Fax: +32 2 511 51 74

E-mail: sec@cerameunie.org

URL: http://www.cerameunie.org

EuLA (The European Lime Association)

The European members of the International Lime Association (ILA), which operates worldwide, created EuLA in 1990. As of 1 January 1999, the number of EuLA member countries rose to 20 (Eastern Europe included). The aim of the association is to co-ordinate questions of common interest, to find solutions to common problems, and to represent the European lime industry in Brussels and at international level in dealings with political bodies, governments, scientific institutions, other industrial associations, etc. For specific topics and problems, working groups and working parties are established within EuLA. Such workings groups are currently discussing problems relating to CO_2 emissions, environmental legislation, technology, BAT and European standardisation [19].

For further information, please contact:

EuLA (The European Lime Association) - Sekretariat

Annastrasse 67-71, D-50968 Köln

Phone: + 49 221 93 46 74 0 - Fax: + 49 221 93 46 74 10
E-mail: eula@kalk.de

Eurogypsum (The Association of European Gypsum Industries)

Eurogypsum, founded in 1961, is a non-profitmaking European federation of national associations of producers of gypsum products. These producers own and manage gypsum extraction operations. Eurogypsum's prime aim is to promote both the products and the interests of these producers. It does this through joint research projects on relevant scientific, technical-economic and legal matters and by initiating information and public relation programmes. Particular emphasis is placed on dialogue with European governmental institutions. Eurogypsum has three commissions, one for scientific and technical matters, one for environmental and raw materials issues and one for economic issues and public relations [42].

For further information, please contact:

EUROGYPSUM (The Association of European Gypsum Industries)
Gulledelle 98 box 7, B-1200 Brussels
Phone: + 32 2 775 84 90 - Fax: + 32 2 771 30 56
E-mail: eurogypsum@pophost.eunet.be
URL: http://www.eurogypsum.org

Euro-Roc (The European & International Federation of Natural Stone Industries)

In spite of the fact that trading in dimension stone has a very long history, the industry at the beginning of the century was only organised at a national level. The first steps of the European unification process in the 1950s led to the foundation of Euro-Roc. Today all European stone federations, accounting for 44% of the world market of 45 million tonnes, are represented within Euro-Roc.

The market for dimension stone can be divided into two main parts:

- the construction industry, where the use of marble predominates, but where the use of granite has been on the increase, particularly over the last decade
- the funeral monument sector, where granite and similar stones are predominantly used.

Due to the fact that dimension stone shows a wide range of applications, the stone industry looks set to develop strongly into the next century. The outlook is therefore a very positive one.

At a European level, Euro-Roc is the representative of the European stone industry vis-à-vis European institutions, working in the raw materials area and as member of the Non-Energy Extractive Industries Panel. The range of work includes environmental questions, health and safety issues and the promotion of dimension stone. Keeping members permanently informed on relevant developments and promoting members' interests are key elements of Euro-Roc's work.

For further information, please contact:

Euro-Roc, General secretary
Bremthaler Str. 43, D-65207 Wiesbaden, Germany.
Phone: + 49 6127 66388 - Fax: + 49 6127 61957
E-mail: merke@suk.fh-wiesbaden.de

IMA-Europe (The Industrial Minerals Association – Europe)

IMA-Europe was founded in 1993 in order to assure a specific sector-based representation for industrial minerals, and to promote the common interests of its members. The Association is particularly oriented towards representation at European level (in the European regulatory field or in standardisation) but also at local or world-wide levels to coordinate contacts or services for its members. IMA-Europe is involved in issues relating to the properties and safe use of minerals as well as in questions relating to their extraction, processing and distribution. When necessary, scientific and socio-economic data are also collected and exchanged. IMA-Europe also provides scientific support to its members and promotes or co-ordinates reviews or research on specific topics, namely, health, safety, and the environment [46].

For further information, please contact:

IMA-Europe (The Industrial Minerals Association)
233, Bld Silvain Dupuis bte 124, B-1070 Brussels
Phone: + 32 2 524 55 00 - Fax: + 32 2 524 45 75
E-mail: ima.eu@skynet.be
URL: http://www.ima-eu.org

UEPG (The European Aggregates Association)

UEPG has a membership that covers more than sixteen European states (Eastern Europe included) with a total production in 1995 of over 2 billion tonnes [3]. For the producers of aggregates, this association founded in 1987, is the official voice to the European Commission, the European Parliament and other institutions such as CEN (the European Standards Organisation). UEPG operates primarily through three key policy committees: the Technical Committee which monitors the development of European standards, the Recycling Committee which plays an increasing role in the overall recycling of construction materials, and the Environmental Committee which works with European institutions in matters of legislation to improve environmental protection.

For further information, please contact:

UEPG (The European Aggregates Association) – Secretary General
Haus der Baustoffindustrie, Düsseldorfer Strasse 50, D-47051 Duisburg
Phone: + 49 203 9 92 39 0 - Fax: + 49 203 9 92 39-99
E-mail: braus @CompuServe.com

Annex 3
Centre Terre et Pierre

CTP (*Centre Technologique International de la Terre et de la Pierre*), recently created with EU funds (*Objective I*), is a multidisciplinary team with a single policy: to contribute to an optimal management of mineral resources and equipment, at the various stages of mining and treatment, from the mine or quarry to the enriched (or recycled) final products (industrial projects, new processes, environmental aspects, etc.). Operational since late 1996, the CTP has a team of around fifteen senior managers, young engineers and scientists. The CTP assists in scientific and technical training, by setting up technological databases, publishing papers and organising symposia and scientific or technical events.

An organisation based on solid foundations

Created in Tournai (Belgium) using European funds and with the assistance of IDETA, a local public partner, the CTP has the objective of increasing the added value of both non-metal bearing ores—the Walloon area being particularly rich in them (limestone for industrial or ornamental uses, dolomite, sandstone, porphyry, chalk, etc.)—and in metal bearing ores of various origins as well as secondary raw materials.

The CTP has started with a small team of experts coming from both industry and universities. Its success depend on two bases:

(1) An industrial base via the equipment manufacturer ALC (Ateliers Louis Carton) and thanks to support of the Belgian Employers' Federation of Extractive Industries (FEDIEX).

(2) An academic base: The Ore Treatment Laboratory (LTM) of the Catholic University of Louvain (UCL) is now established on its new site, together with its researchers and equipment. All its equipment as well as its technical library are to be found there.

Aims and Objectives based on the requirements of industry

The main objectives of the CTP in the sector of the extractive industry are threefold:

(1) Research and develop specific industrial projects that may lead to new processes, equipment or products to increase the added value of the minerals to be mined.

(2) Optimise the environmental management of natural resources and recycled products.

(3) Form a centre of excellence for training and for international scientific and technological debate, by setting up technological databases, publishing quality scientific papers, holding symposiums and other scientific and technical events.

(4) By way of its multidisciplinary team, its flexibility in structure, the quality of its equipment and sub-contractors, to become a centre of consultancy and expertise in the treatment of raw and secondary solid materials, in the engineering of equipment for mineral or recycled materials benefaction, in the field of raw material characterisation (geology, chemistry, etc.) and in environmental management.

Men, Techniques and Capabilities

The CTP is established as a centre of technological development. With a streamlined structure, CTP offers the following benefits to industry:

(1) The service of competent engineers and doctors of science with their origins in industry and academic institutions.

(2) Successful study and research techniques (modelling, simulation, etc.) supported by modern computer facilities.

(3) A workshop for testing equipment, of a capacity which permits both testing on a laboratory and semi-industrial scale, and the development of new processes and equipment. The equipment includes calcining ovens and kilns, crushers of various kinds, mills, cyclones, screens, magnetic and electrostatic separators, flotation machines, flocculation and leaching equipment, filters, jigs, shaking tables, Reichert cones, etc.

(4) Laboratories enabling extremely accurate physico-chemical and mineralogical analyses to be undertaken.

(5) Quality sub-contractors for specific research and tests (thin sections, drilling, special chemical analysis, etc.).

The confidentiality of the research and development for our customers is guaranteed.

For further information, please contact:

Centre Technologique International de la Terre et de la Pierre

Chaussée d'Antoing 55 - B-7500 Tournai (Belgium)

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URL: http://www.ctp.be

Annex 4
Bibliography and further reading.

All the documents are available for consultation at CTP. Most of them have been directly collected in CTP's library and others, preceded by ( ), have been provided by the participants in the project: (c) Cembureau, (u) UEPG, (l) EuLA, (g) Eurogypsum, (d) the European Commission (Enterprise DG), (i) IMA-Europe, (r) Euro-Roc.

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