SIXTH FRAMEWORK PROGRAMME

INTEGRATED PROJECT

Description of Work - Excerpt

Project acronym:	BioMinE
Project full title:	Biotechnology for Metal bearing materials in Europe
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NOTE: This document contains an excerpt of the Description of Work of the Integrated Project proposition BioMinE as prepared and presented to the European Commission during the contract negotiation in 2004. The general content, participant list, and outline of work are subject to change.

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1. Project Summary

This IP is aimed at ”the production of tomorrow” and involves biotechnological research to provide ”radical changes in the Basic Materials industry for cleaner, safer and more eco-efficient production”. The objective is to develop sustainable solutions covering the whole life cycle of products and equipment. Technological breakthroughs will allow the integration of innovative biotechnology based processes for recovery/removal of metals from primary materials such as ores and concentrates, secondary materials such as mining wastes, metallurgical slags, metal bearing scrap and combustion/power plant ashes. Processes will be developed which give consideration for eco-design, eco- and renewable materials and zero waste, with the aim of protecting people and the environment. The biotechnologies to be investigated will include bioleaching, biooxidation, biosorption, bioreduction, bioaccumulation, bioprecipitation, bioflotation, bioflocculation and biosensors, as well as microbiological research. The ultimate objective will be the establishment of environmentally friendly biotechnologies which are economic particularly at a small scale and will provide an alternative to current technologies such as roasting and smelting. The anticipated breakthroughs under the RTD programme will be commercially evaluated through integrated piloting of the new processes together with preliminary economic assessments. This will provide a sound basis for decisions by industrial companies on whether to then proceed to commercial demonstration. The work will be enhanced by Training and Educational activities. The Project will adopt a multi-discipline approach involving mining companies, waste treatment facilitators and equipment/instrument suppliers. The Consortium has achieved a critical mass being comprised of 35 partners from industry (12 including 5 SMEs) research organisations (7) universities (14) and government (2). The participants are from 12 EU member states, from 1 candidate country, and from South Africa (INCO Country). A strong management structure will be put in place with a General Coordinator and Secretariat, and 6 Work Package Coordinators, that compose the Management Committee of the project, mandated by the Governing Council to execute research and administration activities. The Governing Council is composed of a representative of each consortium partner and a representative of the European Commission.

2. Project Objectives

This Integrated Project is aimed at "the production of tomorrow" by carrying out biotechnological research for the basic materials industries. The objective will be to develop sustainable processes that will not harm "the people and the planet" and will cover the whole life cycle of products, equipment and infrastructures.

It is anticipated that technological breakthroughs will be made which will allow the integration of various innovative biotechnological processes for the recovery/removal of metallic elements from primary materials such as ores and concentrates, secondary materials such as mining wastes, metallurgical slags and metal bearing scrap, and ashes from combustion/power plants. The thrust of the proposal is the RTD programme supported by integrated piloting activities, which will allow the anticipated breakthroughs and radical innovations to be scaled-up and optimised for assessing their commercial potential. This work will be enhanced by Training activities where access to academics and post-graduates will provide a stimulus for the generation of innovative ideas. As it is essential to exploit the results of the work under this IP, Work Package No.5 has been established under the RTD programme to enhance the step towards commercial industrial implementation.

The work will develop processes that give consideration for eco-design, eco- and renewable materials and waste minimisation, with the aim of protecting people and the environment. Innovative biotechnological processes in the RTD programme are focused on metal recovery by bioleaching of mineral resources, biotreatment and resource biorecovery, bioreduction, and biomodification of mineral surfaces. Testwork will also be undertaken on the development of biosensors as a part of the molecular biological aspects of the research tasks and approaches to select or develop the most appropriate microorganisms are an integral part of the programme. A sustainability assessment will be carried out to enable an efficient analysis of the environmental impacts and resource intensity along the whole life cycle of products, processes and services. The ultimate objective will be the establishment of environmentally benign processes that will provide an alternative for current technologies such as smelting and roasting. While the industry has made significant advances in addressing the environmental issues resulting from 'conventional' technologies, such processes are usually only applicable for large-scale operations and generate large quantities of sulphuric acid that does not have a ready market for its use. The improvements resulting from the introduction and commercial-scale use of biotechnology could mean significant benefits with regard to quality and health of humans, animal and plant life, and the environment.

The potential impact of the development of innovative biotechnology for metals recovery/removal will be considerable, particularly with regard to its eco-toxicological and socio-economic effects, the development of sustainable technology and the development of environmentally friendly processes. The Project will adopt a multidisciplinary approach involving mining companies, waste treatment facilitators and equipment/instrument suppliers. The Consortium will comprise a total of 35 major industrial companies, SMEs, research and governmental organisations and universities. Critical mass will be achieved through the participation of organisations that have been chosen for their complementarity. The participants will come from several EU member states as well as from candidate and associated countries and those countries with which there are special arrangements. The Project will have a group of Scientific Advisory Experts, appointed and staffed by the EC and a strong management structure, with a General Coordinator and Secretariat and 6 Work Package Coordinators (WP1 - Resources and Sustainability Assessment; WP2 - Bioleaching; WP3 - Biotreatment and Resource Recovery; WP4 Process Integration and Applications; WP5 - Exploitation; and WP6 – Training). Issues relating to IPR will be covered by an IPR Committee as part of the overall Project Coordination

3. Participant List

Participant Number	Participant Name	Participant Short Name	Country
1	BRGM	BRGM	France
2	Hellenic Copper Mines	HCM	Cyprus
3	Tampere University of Technology	TUT	Finland
4	Technische Universitaet Berlin	TU Berlin	Germany
5	Universitaet Duisburg	UDE	Germany
6	IGME	IGME	Greece
7	National Technical University of Athens	NTUA	Greece
8	Bioclear B.V.	Bioclear	Netherlands
9	Paques B.V.	Paques	Netherlands
10	Wageningen University	WU	Netherlands
11	Instytut Metali Niezelaznych	IMN	Poland
12	Instituto National De Engeharia	INETI	Portugal
14	De Beers Consolidated Mines Ltd	DBCM	South Africa
15	MINTEK	MINTEK	South Africa
16	University of Cape Town	UCT	South Africa
17	University of Stellenbosch	Stellenbosch	South Africa
18	Universidad Autonoma de Madrid	UAM	Spain
19	Luleå University of Technology	Ltu	Sweden
20	MEAB Metallextraktion AB	MEAB	Sweden
21	Umeå University	Umu	Sweden
22	CellFacts Instruments Ltd	CIL	UK
23	Greenwich Resources plc	Greenwich	UK
24	Imperial College of Science & Technology	Imperial	UK
25	Rio Tinto Technical Services Ltd	Rio Tinto	UK
26	University of Wales, Bangor	UWB	UK
27	University of Warwick	Warwick	UK
28	Tecnicas Reunidas S.A.	TR	Spain
29	Outokumpu Research Oy	ORC	Finland
30	Umicore	Umicore	Belgium
31	Skeria-skelleftea	Skeria	Sweden
32	CNRS	CNRS	France
33	Universitaet Stuttgart	USTUTT	Germany
34	PE Europe GmbH	PE Europe	Germany
35	The Institute for Nonferrous and Rare Metals	IMNR	Romania
36	MiltonRoy Mixing	MRM	France

4. Relevance to the objectives of Priority 3 NMP – Research Area 3.4.3.2-1

This Integrated Project is targeted specifically at the FP6 NMP Priority Area 3.4.3.2-1 that covers "Radical changes in the "basic materials" industry (excluding steel) for cleaner, safer and more eco-efficient production".

It aims to carry out biotechnological research which will develop processes for the recovery/removal of metallic elements from metal bearing materials such as primary ores and concentrates, and secondary wastes from mines and smelters, metal bearing scrap, and ashes from coal and combustion plants. The biotechnological techniques will be innovative combinations of various chemical and instrumental methods and molecular biological developments, leading to novel advances in the bioleaching processes and associated microorganisms (e.g., mesophilic/thermophilic bacteria and propagated biomass). The test work will also address the environmental issues resulting from the metals processing industries using biotechnology such as biosorption, bioremediation, bioaccumulation, biodegradation, bioprecipitation, bioflotation and bioflocculation. Development work will also be undertaken on biosensors and the project will address such issues as materials of construction, equipment design and process control. Sustainability assessments using specialists in this field will feature as a discrete task to enable an efficient analysis of the environmental impacts and resource intensity along the whole life cycle ("cradle-to-grave") of products, processes and services.

The focus of the Project will be the RTD activities, which will encompass resource evaluation, biotechnological research, integrated piloting and preliminary economic evaluations of the new or improved processes. The integrated piloting activities, using existing in-house partner facilities, will be used for preliminary economic evaluation of promising projects as a means of securing interest from industrial companies to commercially demonstrate subsequently the new biohydrometallurgical processes. The ultimate objective will be to provide cost-effective biohydrometallurgical alternatives to current technologies such as roasting and smelting which are usually only suitable for large operations. The improvements resulting from the wide scale use of biometallurgy will mean a significant improvement in quality of life, health, safety, working conditions and the environment.

Industrial sustainability will not be possible without creative innovations based on advanced science and technology and in this regard biotechnology plays an increasing role also in the minerals and mining industries. It is clear that any move towards industrial sustainability (i.e. lower consumption of energy and raw materials, and reduction or elimination of waste) affects all stages of process technology. There are at least four main drivers for clean technology based on the use of biotechnology:

- economic competitiveness, with companies considering the benefits of clean processes in terms of cost advantages or expansion to using new resource materials;
- depletion of conventional, non-sustainable resources provides additional incentive to the industry to seek innovative bioprocesses;
- government regulatory policies, which enforce or encourage changes in practice; and
- public pressure, which takes on strategic importance as companies seek to establish environmental legitimacy.

In a 1998 OECD publication[1] a number of key points were made which were relevant to biotechnology relating to the recovery/removal of metals:

- Biotechnology is a powerful enabling technology for achieving clean industrial processes that can provide a basis for industrial sustainability.
- The main drivers for industrial biotechnology processes are economic, government policy, and science and technology.

[1] Biotechnology for clean industrial processes – Towards industrial sustainability, Organisation for Economic Co-operation and Development, ISBN 92-64-16102-3, 1998

- For biotechnology to reach its potential as a basis for clean industrial processes, additional R&D efforts will be needed.
- Biotechnology and its applications have become increasingly important and there is a strong need for harmonised and responsive regulations and guidelines.
- Government policies to enhance cleanliness of industrial processes can be the single most decisive factor in the development and industrial use of clean biotechnological processes.

Four approaches have been taken in the commercial exploitation of biological leaching processes. These are heap, dump, *in-situ*, and stirred tank reactor leaching. The process of heap bioleaching has gone through various improvements over the years and changes in the design of heaps to prevent slumping, and optimisation of permeability and aeration have been major factors in this improvement.

As an indication of the importance of this technology a new collaborative initiative "Improved Heap Bioleaching" has commenced in Australia (lead by the CSIRO). This project is targeting the recovery of base metals and it is predicted that the technology could result in substantial savings for small operations, e.g. producing 10,000 tonnes Cu per annum. To demonstrate the potential of biometallurgy, results from a number of case studies have been reported. BHP-Billiton reports[2] "Generally speaking, the capital costs are significantly lower for a bioleaching (by as much as 50%) than those of the traditional smelting and refining processes (*for Greenfield projects*). The direct operating costs are also lower, up to medium scale operations (for copper around 150,000 tons per annum), but smelters achieve slightly better economies of scale thereafter. An additional advantage, which applies only to copper, is that bioleaching is a "compatible" technology – that is it produces dilute copper sulphate solutions suitable for feeding to existing solvent extraction-electrowinning (SX/EW) plants (i.e. in conjunction with heap leaching operation)." It is therefore essential that the EC responds to the challenges of this technology if the EU (particularly after its expansion) is not to become dependent on external expertise. Much effort has been expended to design a commercially viable process for bioleaching in stirred tank reactors. The main stumbling block has been slow leaching rates but breakthroughs have now been achieved, making bioleaching commercially feasible in certain instances. Advances in reactor design as well as the use of moderate thermophilic acidophiles have played a part in this breakthrough. Leaching in reactors with extreme thermophiles has been evaluated although some studies suggest that these archaea have a more limited tolerance to high pulp density than moderate thermophilic and mesophilic bacteria. Further scientific advances could allow the successful and patented results of a previous EC project[3] to be built on and to promote commercialisation. It is clear that scientifically based biometallurgy has made significant strides in its development as a commercially viable technology for the processing of sulphide ores. The technology for biometallurgical processing of metal oxides, carbonates, and silicates on an industrial scale awaits the underlying RTD.

In view of its potential as an environmentally benign process biometallurgy is a promising alternative to pyrometallurgical extraction methods particularly for small-scale operations and for low-value mineral resources. Breakthroughs and radical innovation will be achieved under the RTD activity, which can be brought closer to commercialisation by the integration of the activities in the frame of WP5 "Exploitation". This work will be enhanced by Training activities, which will provide additional stimulus for innovative ideas.

Critical mass and interdisciplinary interaction will be achieved through the participation of 35 partners including major industrial companies and SMEs, leading research organisations and universities working in this field, and governmental organizations.

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[2] B. Gilbertson, Billiton "Creating Value through Innovation" Special lecture, The Institution of Mining and Metallurgy, May 9, 2000

[3] High Temperature Bacterial Leaching: Continuous Large Scale Testwork - HIOX®. CEC Contract No. BRPR-CT96-0250 (Contractors: MIRO, La Source Compagnie Miniere S.A.S., Boliden AB, Cognis KGaA, BRGM, Greenwich Resources plc, University of Warwick)

State-of-the-art

Current bioleaching applications in the mining industry exploit iron and sulphur oxidizing micro-organisms. Many of the mesophilic organisms can be assigned to genera *Acidithiobacillus* and *Leptospirillum*. Several acidophilic thermophiles have been detected in warm and hot zones in waste and heap piles, such as the gram-positive *Sulfobacillus* spp. and extremely thermophilic archaea *Sulfolobus*, and *Acidianus*, and *Metallosphaera* spp. As in other areas of microbial ecology, only a small fraction of organisms in acid bioleaching operations may be recoverable by conventional culture techniques.

Molecular ecological tools such as 16S rRNA gene amplification and sequencing, characterisation of interspacer gene sequences, denaturing gradient gel electrophoresis of restriction fragments, terminal restriction fragment polymorphism, and fluorescent *in-situ* hybridisation have revealed a great deal of phylogenetic diversity in microbial populations in bioleaching- and acid mine drainage-impacted environments. A good understanding of the genetic, biochemical, and ecological characteristics of these organisms is of paramount interest in developing industrial and field applications of biotechnology. Extreme thermophiles such as *Sulfolobus* and *Metallosphaera* spp. hold promise because of their faster oxidation rates of sulphide minerals and ferrous iron as compared to mesophilic acidophiles. Acidophilic pyrite and iron oxidizers have been found with molecular tools from mine water samples with pH values on the negative scale.

Mechanisms of bioleaching, the cornerstones of mineral biotechnology, have been explained with various model systems that emphasise such processes as surface interactions, thermodynamics and gap energies of sulphide minerals, and electrochemical reactions – all these being relatively poorly and superficially analysed in biological leaching systems. Kinetic models have been put forward to explain and predict mineral dissolution in well-defined solid-liquid systems, especially in bioreactor-based mineral biotechnology. However, bioleaching processes in dump and heap leaching systems have been based on empirical, sometimes even phenomenological data, which give little operational control and reliability.

An example of the disadvantage that follows from superficial knowledge is that the bioleaching of chalcopyrite, the most abundant natural source of Cu, continues to be hampered by low recoveries and unresolved passivation effects, effectively preventing commercialisation in this area. Efforts to increase rates and yield in chalcopyrite bioleaching have shown great promise of extreme thermophiles (>80°C). Although pilot-scale tests are underway, this may not be a mature biotechnology in the near future and other avenues should also be pursued in search of innovative bioprocesses.

Tailings from mining and metallurgical processes pose a potential environmental problem because of their metal content. Documented physical failures of tailings impoundments, spilling millions of tons of toxic tailings into receiving waterways, have raised questions about safe disposal, the biological stability of residual sulphide minerals, and bioavailability of metals as they dissolve from the mineral matrix. Tailings used to be considered as mine waste to be stored in perpetuity, but this view is now obsolete in the light of research efforts to recover or remove residual metals and define end points for tailings management.

Biotreatment systems for sequestering metals from dilute solutions have tested numerous biological components from plant and microbial cells. The lack of detailed molecular-level information on surface interactions during biosorption has slowed down the progress toward commercialisation of biosorption technology. There is a dearth of information regarding fundamental, molecular-level knowledge and pilot-scale test systems of biosorption. Metal sequestration is also of major importance in passive treatment systems for acid mine drainage that rely on wetland biological processes. Biological processes in such constructed wetland systems are not well understood as the monitoring efforts have focused on wetland water chemistry rather than efficiency of microorganisms and plants to transform and accumulate metal ions. Processes affecting the translocation of metals in passive treatment systems are poorly understood.

Sulphate reducing bacteria have been used to precipitate metals in acid mine drainage, and a number of plants have been installed for groundwater treatment systems to remove heavy metals and sulphate. These systems produce solid phases often of unknown stability as sulphide precipitates metal ions from solutions. Precipitation as biogenic metal sulphides may have application in selective recovery of metals from metallurgical solutions. As with other applications, the concepts of these bioprocesses have not advanced to a stage where economic evaluation would be possible from the reduction to practice. The enclosed table, presented below, summarises some of the matters concerning the state-of-art.

Parameter	**State-of-the Art**	**Anticipated Advance**
Recovery of Cu from Chalcopyrite	Treated using pyrometallurgical processes Cu recovery not feasible at present using biometallurgy	RTD activities, including integrated piloting, will evaluate the commercial potential of biometallurgy by a better understanding of the process mechanisms
Zn bearing sulphide minerals	Treated using roasting and hydrometallurgical processes Research work has indicated the possibility of using biometallurgy but not commercially viable at present	Process mechanisms are understood but the results could present commercial opportunities for biometallurgical processing
Complex sulphides	Treatable using “conventional” technology but economics are unfavourable Not feasible at present using biometallurgy	Better understanding of process mechanisms could lead to commercial advances for biometallurgical processing
Au bearing base metals	Treatable pyrometallurgically but low return on Au values Not feasible at present using biometallurgy	Process mechanisms are understood but the results could present commercial opportunities for biometallurgical processing
Metaliferrous wastes	Not universally treated and present an environmental problem Not feasible at present using biometallurgy	Better understanding of process mechanisms could lead to commercial advances for biometallurgical processing
Metals recovery from aqueous waste solutions	Present an environmental problem and treatment is not feasible at present using biometallurgy	Better understanding of process mechanisms could lead to commercial advances for biometallurgical processing
Combustion-Incineration ash	Majority is dumped to landfill Not used metallurgically	Neutralisation during bioprocessing using ashes could present environmental and economic advantages
Environmental (S removal and CO_2 generation)	Pyrometallurgical processing produces SO_2 and H_2SO_4 Limestone for neutralisation generates CO_2	Bioprocessing will bind the SO_2 within a tailings discharge Use of ash (see above) will reduce limestone consumption and CO_2 generation
Investment decisions for the metals industry	Not possible to assess the investment criteria of biometallurgical processing	Preliminary economic analyses, facilitated by integrated piloting, will facilitate development of improved cost models

5. Potential Impact

The introduction of biometallurgical processes will lead to substantial improvements for metal production by increased recovery, reduced costs, reduced energy demands, increased revenue, and new resources. Biometallurgy has the potential for a major technology breakthrough for the metals and minerals industry. This is underlined by the great interest shown by major international companies for this new technology. At present research and development is in progress for a number of metals such as copper, nickel, cobalt and zinc.

There already are more than ten bioleaching plants in the world to process auriferous refractory sulphide ores for subsequent gold recovery. These plants signal the advent of controlled bioprocesses in the mining industry, and the willingness of the industry to seek input from biotechnology experts. In contrast, copper recovery in heap and dump leaching processes is an established, but mostly empirical technique for secondary Cu sulphides. However, it is not yet economically feasible with chalcopyrite. There has been little fundamental research published that would be helpful in modelling and optimisation of Cu dump and heap leaching processes. The IP proposed here would close these current gaps in our understanding on how to best apply biological processes for ore materials that are traditionally considered to be recalcitrant or economically not feasible to process. The IP will bring together the leading European (and South African) experts in microbiological research relating to metals and the integration of this expertise will have a major impact on research in the EU in this field.

To demonstrate the potential of biometallurgy, a number of case studies (e.g., high and low grade Ni and Zn concentrates and Au bearing low grade Cu concentrates) have been made. These studies refer to comparisons between today's well-established 'conventional' techniques and the new biometallurgical process technique. The economic comparison is between selling concentrates to existing smelters, at present terms, and investment in a new biometallurgical plant to produce the metal at the mine site. Economic comparisons clearly show that biometallurgy improves the economics for production of metals in the cases studied. In none of the cases can 'conventional' process techniques compete with the new biometallurgy. This is the case even though the comparison includes investment in new facilities for the biometallurgical alternative. If the comparison relates to greenfield plants both for the conventional pyrometallurgical and biometallurgical processes, the biometallurgical alternative will be even more significant.

Today, many sulphidic mineral deposits in Europe and worldwide are not exploited due to their antimony, bismuth, arsenic and mercury content. These elements are deleterious for conventional pyrometallurgical processes and will therefore not generate values, which would motivate exploitation. Furthermore, a number of existing mines can be identified, which are threatened due to increasing operating cost and decreasing product values. Many of these deposits and concentrates have already been evaluated with regard to exploitation with different hydrometallurgical methods. In most cases, the test work has been conducted in laboratory scale. In some cases, the basic test work has been conducted on a limited pilot scale. The preliminary economical evaluation often indicates a positive net present value. In spite of that, no project has been commercialised.

Biotechnology also has great potential for use in the reclamation of metals from waste products. In biometallurgical processes the use of limestone could be replaced with other alkaline products, thus minimising the emission of CO_2. Possible alkaline products might be flue dusts and ashes from smelters and incineration plants that are classified as hazardous due to their metal content. As a result, metals will be recovered with a minimised emission of CO_2, reducing the overall contribution to the greenhouse effect. The results of the work on this IP will therefore have both direct and indirect benefits.

In general, the main reason for not commercialising is that the introduction of new processes means a huge economical risk both for the operator and the investor. To minimise the risk, as a first step, a new process has to be piloted where all individual process circuits are integrated and operated for a sufficient period of time. The inclusion of integrated piloting activities under Work Package 4 will enable the generation of preliminary process design and economics to be established, providing a firm basis for decisions by potential industrial end-users to proceed to commercial demontration. It is anticipated that the IP will make it feasible for small and medium size mining, metal and energy companies to economically evaluate environmentally friendly hydrometallurgical processes for non-exploited deposits, dirty concentrates, industrial wastes and by-products.

The metallurgical technologies that will be demonstrated within this project are believed to be far more eco-efficient and flexible than conventional pyrometallurgical routes. Biometallurgy almost totally eliminates any risk of air pollution as the metals are extracted into aqueous solutions.

Environmentally hazardous compounds such as SO_2 or mercury are not emitted into the air. Treatment of discharged effluent from a bioleaching plant in a water purification plant is easier. For example, in a bioleach solution there is normally an excess of ferric ions, which make it possible to precipitate the arsenic content in the form of ferric arsenate, which is considered to be a very stable compound.

In comparison with conventional smelters it is anticipated that the internal environment (working conditions) is favourable for a bioplant. The integrated processes are in general wet and operating at lower temperatures, consequently dust and gas emissions are minimal. Today, municipalities within Europe are producing considerable amounts of fly ashes, which are classified as hazardous and require a sophisticated disposal solution. By using fly ashes in a biometallurgical process for extraction of metal from primary sulphidic sources, the need of land for deposits will decrease. It is expected that the final ash residues can be classified as harmless and can be combined with the ordinary flotation tailings from a concentrator.

To develop and operate a biometallurgical process a wide range of competences and skills are needed. This will prepare ground for a stimulating and innovative climate and necessitates a training programme for employees and community outreach activities to inform those not directly associated with the bioplant. Training and education must be in the forefront at the community level because mineral biotechnology is not an old industry and hence ignorance of details is not uncommon. The activities under the training work package will provide a cross-disciplinary and cross-cultural understanding of the project issues, will produce flexible, case-based distance teaching materials for use in and outside the project, will enable the training of staff for subsequent commercial demonstration projects by interested industrial companies.

The integrated project will give a possibility to conduct advanced research within a number of areas andwill be a link between the society and the academic world. This IP is designed to give stimulus to the European mining industry and improve its competitiveness in the world market. Some mining companies with the EU are already facing the depletion of domestic mineral deposits and must seek other avenues to respond to market demands. Development of expertise and know-how in this IP project will help companies to shift away from traditional mining toward new biotechnological directions. The proposed multi-partner programme will help ensure that the best available expertise is available to tackle new problems. This IP will also help EU retain leadership in the mining industry that has long traditions but old infrastructure and waning conventional resources.

The overall objectives are to create biological processes for exploitation of new and unconventional types of mineral resources. These bioprocesses will maximise the yield from primary raw material resources and minimise energy consumption, environmental effects from waste products and gas emissions and the overall contribution to the greenhouse effect.

Novel processes will be developed for base metal recovery, which will integrate primary metal extraction with waste minimisation and treatment. However, uncontained waste such as tailings or ash from primary sources remains, toxic to the environment. The integrated piloting activities offer the opportunity to examine process parameters that affect both the product and waste quality and process reliability. RTD in this IP will enable the partners to standardise and exchange information on analytical methods and to calibrate test work results with analysis of the integrated piloting results.

6. Outline implementation plan for the full duration of the project

The overall objectives are to create biological processes for the exploitation of existing, as well as new and unconventional types of mineral resources. These bioprocesses will maximise the yield from primary raw material resources and minimise energy consumption, environmental effects from waste products and gas emissions and the overall contribution to the greenhouse effect.

Novel processes will be developed for base metal recovery, which will integrate primary metal extraction with waste minimisation and treatment. However, uncontained waste such as tailings or ash from primary sources remains, toxic to the environment. The integrated piloting activities offer the opportunity to examine process parameters that affect both the product and waste quality and process reliability. RTD in this IP will enable the partners to standardise and exchange information on analytical methods and to calibrate test work results with analysis of the integrated piloting activities results.

The work to be carried out has been broken down into 6 Work Packages with Tasks and Sub-Tasks within each. Table 1 indicates which partners are involved in each Work Package.

WP0	**WP1**	**WP2**	**WP3**	**WP4**	**WP5**	**WP6**
BRGM	**BRGM**	BRGM	BRGM	BRGM	BRGM	TUT
Paques	HCM	HCM	TUT	Paques	Paques	IGME
Mintek	UDE	TUT	TU Berlin	Mintek	Mintek	NTUA
TR	IGME	UDE	UDE	MEAB	TR	Paques
Skeria	Paques	IGME	NTUA	Rio Tinto	Skeria	Ltu
LTU	IMN	Bioclear	**Paques**	**TR**		Umu
	MINTEK	Paques	WU	IMNR		TR
	Greenwich	IMN	INETI			**Skeria**
	Imperial	INETI	Ltu			
	RioTinto	DBCM	UmU			
	TR	**Mintek**	CIL			
	ORC	UCT	Imperial			
	Umicore	Stellenbosch	Rio Tinto			
	USTUTT	UAM	UWB			
	PE Europe	Ltu	Umicore			
		UmU				
		Greenwich				
		Imperial				
		UWB				
		Warwick				
		ORC				
		CNRS				
		IMNR				
		MRM				

Table 1 - Association of project partners with proposal work packages

6.1 Research, technological development and innovation activities

The work packages which are included under this activity are:
WP1 - RESOURCES AND SUSTAINABILITY ASSESSMENT
WP2 - BIOLEACHING
WP3 - BIOTREATMENT AND RESOURCE RECOVERY
WP4 - PROCESS INTEGRATION AND APPLICATIONS
WP5 - EXPLOITATION OF RESULTS

WORK PACKAGE No. 1 RESOURCES AND SUSTAINABILITY ASSESSMENT

Task 1 - RESOURCES
Primary and secondary sources in Europe for metal extraction will be identified in relation to market and societal needs. The identification of the resources will consider the mineralogical, chemical, economic, and infrastructure characterisation. Based on the needs for our economy and the obligation to minimise negative environmental and social impacts, an initial series of European metal bearing resources will be listed. Sub-activities in task 1 are:
Sub-task 1.1 Resource identification - Assessment of the Europe's primary and secondary metal sources (solids and liquids) and prioritisation of the materials for WP2 and WP3
Sub-task 1.2 Resource characterisation - Volume/quantity estimations of beneficial elements and harmful by-products for each metal source
Sub-task 1.3 Infrastructure characterisation - Assess availability of water, transport routes, tailings, co processing substances for each metal source site
Sub-task 1.4 Benchmark resources proposition - Cost/benefit (socio-economic and environmental) evaluation of resource recovery, by inclusion of the above sub-tasks and task 2

Task 2 - SUSTAINABILITY ASSESSMENT
Further assessment, in relation to task 1 and to the RTD development in other work packages, of the potential impacts on human welfare and on the environment of the identified biotechnological processes versus 'conventional' metal recovery processes. The interaction of the technologies will be monitored and directed by a continuous process of simultaneous decision support to the project partners at all stages of the project. This will integrate process-chain and life cycle environmental information, costs, and work environment (i.e. accidents, labour, health etc.) within one consistent model. The efficiency of the assessment will benefit from an optimal two-way data communication between WP1 and WP2, WP3 and WP4 assuring a close link between advanced RTD results and the integrated evaluation to benchmark the results in their respective social, economic and environmental periphery. Sub-activities in task 2 are:
Sub-task 2.1 Compilation of sustainability assessment input data - Continuous compilation and review of environmental and societal Life Cycle Information (LCI)-data for all biotechnological processes in the areas of extraction, leaching, waste water treatment, metal concentration/purification, for all relevant primary and secondary resources. For the equivalent conventional processes benchmark data will be compiled and reviewed
Sub-task 2.2 Modelling and assessment of the Environmental Impacts for the technologies under development – This will include LCA of the investigated biotechnological processes and process-chains in comparison to their conventional benchmarks and examination of the potential contribution to Kyoto protocol commitment. State-of-the art and best practice proposals will be prepared for waste water treatment and tailings management, by incorporation of the new European Waste Directive BATs. Evaluation of net risks imposed on humans and the environment caused by technology failure (Risk Assessment) will also be carried out.
Sub-task 2.3 Modelling and assessment of net effects on jobs, working environment and resource availability - Modelling and assessment of the processes' and products' working environment and special evaluation of energy efficiency as well as land use effects.
Sub-task 2.4 Continuous Sustainability Assessment decision support - Integration of the results of Tasks 2.2 and 2.3 as well as other HSE relevant information provided by other partners and provision of a continuous decision support to the project consortium.
Sub-task 2.5 Know-how databases - Compilation of technological data, risk data and toxicity data, all characteristic data of primary and secondary metal resources and sustainability assessment data into a coherent know-how database.

WORK PACKAGE No. 2 BIOLEACHING

Task 1 - BIOLEACHING OF ORES AND CONCENTRATES

Sub-task 1.1 Low-Grade and Complex Concentrates - Up to six feed concentrates will be subject to studies in bench-scale piloting facilities capable of simulating near industrial-scale bioleaching conditions for extraction and leach kinetics optimisation. Important targets will be complex and polymetallic concentrates and low-grade zinc concentrates, and laboratory testwork will assess their amenability to bioleaching using existing mesophilic and thermophilic microbial cultures. This work will also allow the production of leach solutions and solids residues for metals extraction studies under WP3 and WP4, and the characterisation of waste solids related to environmental impact (sub-task 1.6).

Sub-task 1.2 Precious Metals-Containing Concentrates - Work will be carried out on copper-precious-metals concentrates using a novel two-stage thermophilic bioleaching process. Further, the potential of the process to realise reduced thiocyanate pollutant formation during downstream cyanide leaching for gold recovery will be assessed under WP4.

Sub-task 1.3 Novel Bioleach Process Configurations - Studies will be carried out on process configurations in which the bio-oxidation of ferrous to ferric iron and the chemical oxidation of sulphides by the acid-ferric lixiviant are separated. A high-rate fluidised bed bioprocess for ferric generation will be studied at bench-scale to assess the optimum microbial consortium and optimum microbial carrier particle.

Sub-task 1.4 Alternative Bioleach Reactors - The potential advantages for employing lower-cost air-stirred & aerated reactors will be assessed. Bench-scale reactors will be studied to assess novel methods for mixing, oxygen gas-liquid mass transfer and heat transfer, for bioleaching applications.

Sub-task 1.5 Heap Bioleaching - These studies will be aimed at low-grade and complex base metal ores, and at waste materials (Task 2) where pre-concentration is not possible or is uneconomic. The types of target ores are likely to contain a significant component of refractory sulphide components, such as chalcopyrite, so that high-temperature (thermophilic) heap bioleaching will be necessary to achieve economic levels of metals extraction.

Sub-task 1.6 Novel uses of waste solids - This will include the sustainable commercial utilisation of solid waste (non-metal containing) products generated from tank and heap bioleaching processes (data supplied from sub-tasks 1.1 and 1.5 and Task 2).

Task 2 - BIOLEACHING OF METALLURGICAL AND INDUSTRIAL WASTES

Sub-task 2.1 Metallurgical Tailings - The recoverability of metals values from flotation tailings and mine waste resources by bioleaching will be assessed, especially with naturally occurring microbes, potentially more resistant to inhibitors. The results will be integrated with more detailed research into microbial consortia in tailings dumps (Task 3) and also the work on anaerobic microbial activities in tailings dumps to be completed under WP3.

Sub-task 2.2 Smelter Waste Products - Bioleaching for upgrading or metals recovery from waste products produced by Cu and Zn smelting operations will include the ability to remove important contaminants such as alkali metals and chlorides, to recover valuable base metals components, and to produce a higher-grade solid-products acceptable as smelter feeds. The potential for applying new and metals-resistant microbial strains and consortia (Tasks 3 and 4) will be assessed. An added challenge may be the presence of a significant hydrocarbon component in the wastes. Waste solids will also be assessed for co-processing in sulphide bioleaching processes and simultaneous use as lower cost neutralisation agents.

Sub-task 2.3 Other Industrial Waste Products - Metallurgical industry waste, sludges, dusts and ash will be assessed for co-processing in sulphide bioleaching processes and simultaneous use as lower cost neutralisation agents.

Task 3 - BIOLEACHING MICROORGANISMS

Sub-task 3.1 Microbial Prospecting - Biodiversity profiles of metal converting ecosystems will be carried out and new micro-organisms with potential to improve the efficacy of bioleaching processes will be prospected in extreme environments, including high metal ion concentrations (mine sites), high temperatures and high salinity. Other key characteristics will involve tolerance/adaptability to common inhibitors found in commercial ore deposits or wastes resources, including chloride, fluoride, nitrate, phosphate, arsenate and arsenite, as well as new combinations of inhibitors encountered in specific waste product resources.

Sub-task 3.2 Microbial Genetics. Several aspects of the molecular biology of common mesophilic and moderately thermophilic bioleaching bacteria will be progressed, with special emphasis on arsenic resistance. These studies will be extended to developing DNA transformation systems for currently unstudied species, including important thermophilic species.

Sub-task 3.3 Microbial Detection, Identification and Monitoring - A common theme in Tasks 3 and 4 is the application, and in some cases specific development for bioleaching applications, of molecular biology tools for the identification and monitoring of bioleaching processes including use of gene libraries, phospholipid fatty acid compositions, terminal restriction fragment length polymorphism (T-RFLP), fluorescent in-situ hybridisation (FISH), denaturing gradient gel electrophoresis (DGGE) and DNA chip methods. A reporting of the technological transfer of these techniques to the bio-hydrometallurgy field will be updated based on the further developments and applications of these techniques as achieved in WP2 and in WP3.

Task 4 - BIOLEACHING MECHANISMS

Sub-task 4.1 Microbial Consortia - The bioleaching characteristics of "designed" microbial consortia assembled using pure cultures of acidophilic microbial species will be investigated. Specific applications will include improved performance (resistance to inhibitory components) for bioleaching of complex polymetallic concentrates, control of sulphide oxidation to affect the balance of elemental sulphur or sulphate final product, and enhanced microbial arsenite (to arsenate) oxidation to promote waste solids environmental stability.

Sub-task 4.2 Microbial Adaptation to Stress - Comparative proteomics of key bioleaching microorganisms will be investigated to determine proteins involved in iron and sulphur oxidation and subsequently the proteins produced in response to environmental stress, such as toxic metals concentrations (such as arsenic), primary substrate (Fe^{2+}, oxygen or carbon dioxide) deficiencies and others. Specific studies will be carried out to provide insight into how the cells adapt to the presence of increasingly elevated solution components, where this provides a platform for future strain and consortia development.

Sub-task 4.3 Biooxidation of Non-Sulphide Minerals. The role that acidophilic iron and sulphur oxidising microbes play in the dissolution of silica minerals that occur as auxiliary minerals in sulphide deposits, and the consequences of this for sulphide bioleaching processes, particularly in the performance of heap bioleaching processes (sub-task 1.5) through their effect on diffusion processes or the release of toxic trace elements will be investigated.

WORK PACKAGE No. 3 BIOTREATMENT AND RESOURCE RECOVERY

Task 1 - METAL RECOVERY AND SULPHATE REMOVAL

Subtask 1.1 Sulphate reduction by extremophiles - This work will consist in isolating novel strains of sulphate reducing bacteria (SRB) and archaea including acidophiles (pH 3-4) and psychrophiles (0-10°C) from cold and acidic environments (i.e. arctic and boreal environments). The presence of extremophiles in natural environments will be investigated and the diversity, physiology and ecology of sulphate-reducing communities in AMD impacted area's and submerged soils will be characterised. Strains will be isolated whenever possible.

Subtask 1.2 Improvement of electron donor requirement - Fundamental research will be conducted with bacterial consortia that enable the use of synthesis gas as electron donor. Continuous bench scale tests will be run during the first 18 months. For smaller scale application, the use of light to convert excess hydrogen sulphide produced by sulphate reducing bacteria into hydrogen and elemental sulphur by catalysis with green sulphur bacteria will be evaluated. The hydrogen can be recycled to sulphate reducing reactor in order to reduce the global energy consumption of the system and this concept will be tested on a continuous bench scale.

Subtask 1.3 Biological metal reduction and sorption - The focus in this task will lie on developing economically sound process flowsheets incorporating direct metal bio-reduction by SRB and biosorption. Essential will be the comparison between different types of traditional (i.e. fixed and fluidised bed) and new reactor types like the moving-bed sand filter or an in-situ bio filter.

Sub-task 1.4 Amenability testwork and process engineering - All concepts will be developed with emphasis on treatment of bleed streams and effluent of the bioleaching operation, for their application in WP4. The specifications of the influents will therefore be adjusted in accordance to the information that becomes available from WP2 and WP4. The reusability of the products of these recovery methods, i.e. metal sulphides and metal loaded organic material, will be evaluated within WP1, WP2 and WP4 as required. The ecotoxicity of the effluent of these treatment methods will be determined within sub-task 3.1. Optimisation of the process engineering of the processes will occur along with the amenability tests.

Task 2 - BIOLOGICAL SEPARATION PROCESSES

Two new concepts of separation process using biological material will be investigated: namely bio-flotation and bio-coagulation. The materials for practical evaluations will result from the selection of resources in WP1.

Sub-task 2.1 Bio-flotation - Bioflotation is based on the properties of the extracellular polymeric substances (EPS). EPS attachment to minerals appears specific for various metal sulphides and renders them selectively hydrophilic. It is proposed to determine whether the principle of a mechanical separation by flotation after bacterial attachment or introduction of cell-free EPS is technically feasible and economically viable.

Sub-task 2.2 Biocoagulation - The selective "Biocoagulation" of microorganisms and micro-dispersed solids is enabled by the electrostatic charge of the (living) cell surface of the microorganisms. Selective coagulation between microorganisms and PAH particles has already been proven on a laboratory scale. The efficiency and reliability of the process will be evaluated in scalable conditions.

Task 3 - MONITORING AND QUALITY ASSESSMENT

Subtask 3.1 Ecotoxicology of effluents in metal and mining - The work will be to assess the potential reduced risks associated with the discharge of non-ferrous aqueous effluents to the aquatic ecosystem resulting from biotreatment and physico-chemical treatment. Their impact on water quality will be studied using commonly agreed eco-toxicological testing (OECD) and risk assessment principles (TGD, 2003). In addition, a device developed for monitoring biomass and physiological state of cells will be tested for its application to determine influent and effluent toxicity on a continuous basis.

Subtask 3.2 Development of methods for control and monitoring of biological processes - Testwork of continuous flow monitoring of biomass will be carried out to develop the automation of sample preparation and for continuous operation, to modify the data analysis software for trend analysis, and to amend the existing instrument system with a green laser signal system for dual fluorescence analysis.

WORK PACKAGE No. 4 PROCESS INTEGRATION AND APPLICATIONS

Task 1 - DETERMINATION OF THE SCALE-UP CRITERIA FOR BIOPROCESSES

Based on lab results from WP2 and WP3, preliminary scaling criteria for the developed bioprocesses will be determined with regard to process design parameters and operating conditions. The investigation will be in different complementary areas, such as hydrodynamics, mass transfer balancing, process simulation, etc. Once the criteria are defined, the scaling will be carried out to enable the bioreactors and equipment to be designed and commissioned for the next development stage.

Task 2 - INTEGRATION OF BIOPROCESSES AT LAB SCALE
This task aims at the integration of all the bio and chemical processes stages leading to the recovery of the valuable metals. It will be closely dependent on WP2 and WP3 since both work packages will provide data and samples of solid, liquid and slurry for further testing in WP4. Research will be specifically focused to avoid or minimise waste generation, and to consider use of secondary materials as a cheap and reliable alternative to chemical reagents. Solid-liquid separation is also to be dealt with to set the optimum operating conditions after applying and comparing different techniques or equipment. The lab research work will be particularly focused on the following topics:
Sub-task 2.1 Leaching - This work is connected with indirect bioleaching. The leaching behaviour of the different primary and secondary feed materials will be tested aiming to define most efficient conditions. Comparative experiments will be carried out for those feed materials using synthetic leachants of similar composition to bio-regenerated chemical, specifically ferric sulphate. Relationships with interconnected bio step will be checked also.
Sub-task 2.2 Bioresidue treatment - Residues from direct or indirect bioleaching processes will be treated to obtain efficient extraction of valuable metals (e.g. Au, Ag, Pt group metals or Pb). Different leaching conditions and reagents will be tested, e.g. cyanide, brine, etc. Other techniques will be applied to separate or concentrate the valuable metals for further treatment e.g. flotation, gravity separation, etc.
Sub-task 2.3 Minerals characterisation - Mineralogical characterisation of the feed and residues is a key factor to properly set the leaching process, and therefore, partners involved in characterisation will supply the necessary information to those performing the tests.
Sub-task 2.4 Impurities removal step - Pregnant solution from bioleaching or the integrated bio and chemical leaching must be treated to eliminate impurities, such as dissolved iron, before recovery of the valuable metals. Different methods will be considered such as oxidation-precipitation, selective precipitation, cementation, resin absorption, etc. Minimum waste generation is the target and recovery of clean gypsum as a marketable by-product will be studied.
Sub-task 2.5 Valuable metals separation and concentration steps - Depending on the valuable metals to be recovered appropriate techniques will be assessed such as membrane technologies, solvent extraction, etc. As the spent solutions must be returned to bioleaching, special care will be paid to the possible effect of its composition on bioleaching performances.
Sub-task 2.6 Metals recovery - Concentrated solutions will be treated for pure metals recovery and techniques like chemical precipitation, electrowinning, etc., will be investigated.
Sub-task 2.7 Toxicity of generated solid products - Intermediate and final products as well as solid residues of the integrated processes will be assessed regarding toxicity and chemical stability. For that purpose, the most suitable control tests will be previously selected.

Task 3 - BENCH SCALE TESTING OF THE INTEGRATED PROCESSES
Results of bio and chemical developments at lab scale would be assessed under preliminary evaluation of the various integrated processes. Then, the most promising alternatives will be selected to be testing at bench scale conditions. On the basis of the laboratory data, a scaling up will be performed to design, arrange and test the needed equipment for every stage of the set process. Scaling up will be carried out by means of engineering standards comprising process design, hydrodynamic studies, heat and material transfer, etc.
The performance of this task implies arrangement of existing equipment at bench scale. Once the pieces of equipment are ready, a series of tests will be accomplished, adapted to every specific valuable metals or application. That way, eventually, the following lines would be studied: Copper line, Zinc line, Nickel line, Precious metals line, Combination of the above for complex sulphides, etc. Besides, products provided by WP3 partners involved in

biotreatment or bioremediation, etc. will be also tested. Amounts of samples should be defined in accordance with involved partners and adapted to bench scale capacity.

Task 4 - PROCESS ENGINEERING AND EVALUATION
The engineering design and evaluation of the integrated processes will be performed at three levels, a conceptual evaluation after lab works accomplishment (month 18 of the project), a preliminary evaluation after bench scale testing (month 36 of the project), and a final evaluation of the project on month-48 based on pilot-scale testing results.
The laboratory data of the developed biotechnologies, combined with necessary chemical processes, will be integrated in new-concept biometallurgical processes. A conceptual engineering design and process evaluation will be undertaken based on high-quality engineering standards. Most promising research lines will be chosen to continue further developments. Main selection criteria for biometallurgical processes assessment will be economics, waste minimisation, and valorisation of low grade or complex ores and concentrates as well as other secondary materials. Finally, standard procedures for assessing the new biometallurgical processes will be established in a conceptual approach. These procedures will allow evaluating the technical and economical suitability of new metal bearing resources to the processes.

Task 5 – PILOT-SCALE OPERATIONS
A selection of the most promising processing ways will be established along with the evaluation studies through the WPs 2, 3 & 4 . In conclusion of these evaluations and in particular at the end of the 18 month period, pilot-scale operations will be proposed, designed and then launched after agreement of the Consortium.
As a matter of fact, economic assessment and rigorous technical evaluation at a pre-feasibility level will require data that can only be established at a pilot-size scale. It is clearly foreseen that such operations will be required in the themes of tank bioleaching of high-grade sulphide concentrates or metallurgical waste product; heap bioleaching of low-grade primary ores or metallurgical wastes; indirect bioleaching of industrial waste; metals recovery from metallurgical or industrial effluents.
The pilot-scale operations might be carried out with existing facilities of the partners, who have the most appropriate experience and technical means for the selected subjects. It might also take place on industrial sites in the form of large-scale demonstration operations.
Following the pilot-scale operations and the relevant techno-economic evaluations, assessment of opportunities for commercialisation will be undertaken under WP5.

WORK PACKAGE No.5 EXPLOITATION OF RESULTS

Although the IP is research driven, a major objective is to promote opportunities for the Exploitation of the research results in terms of industrial applications. This will be particularly done through the provision of market analyses and support. The guidance to the Consortium partners in terms of development of plans for use and dissemination of the Knowledge arising from the project will be supported by the provisions of the EC contract and Consortium Agreement. During the first 18 months, these Exploitation issues will be handled by the Management Committee, which subsequently will appoint an appropriate Coordinator to manage the activities of this Work Package.

Task 1 - MARKET ANALYSIS
Sub-Task 1.1 European Market - To maximise the number of commercial opportunities that will result from RTD results the prospective market needs will be analysed. The market analysis will give an overview of the European market and indicate its size and identify potential opportunities for the results.
Sub-Task 1.2 Country Markets – For each participating country a more thorough market analysis will be performed, as a base for each partner to plan the exploitation.

Task 2 - EXPLOITATION PLANS

Sub-Task 2.1 Preliminary Exploitation Plan – Based on the market analyses a preliminary exploitation plan will be collated early in the project. Each partner will contribute to this by indicating their potential intentions for exploiting the results of their work.

Sub-Task 2.2 Final Exploitation Plan – The preliminary exploitation plan will be updated at the end of the project and will form the "sales proposition" for the results. Each partner will provide a description, including appropriate quantitative information indicating how they propose to exploit their results and this will be collated into a final exploitation plan.

Task 3 – DISSEMINATION PLAN

The dissemination plan will describe the activities to be carried out both during and after the project. A part of this will be a plan for an international MSc education (according to the European Bologna process) in biohydrometallurgy using the Learning Objects developed in WP6. This masters education can be a joint degree exam where more than one university can participate.

Task 4 – TECHNOLOGICAL IMPLEMENTATION PLAN

A technology implementation plan (TIP) will be prepared for areas of breakthrough technology arising from the RTD programme. The TIP will encompass issues such as potential markets and return on investment for the specific breakthrough technologies identified. Where relevant, the TIP will also encompass specific intentions of Partners, subject to the IPR provisions of the EC Contract and Consortium Agreement, or as otherwise agreed between the Partners at the time.

6.2 Training activities

WORK PACKAGE No. 6 TRAINING

Task 1 - PLANNING AND DESIGN

The resources have to be mapped up as a training and education landscape among the partners, and networks between partners have to be established. The scope of the training content has to be decided on, analysed and organised in a curriculum of 10 learning objects with production divided among the partners. The use of learning object standards has to be agreed on and a working definition of "Learning Object" has to be made for use within the project. Specifications for the simulations must also be agreed on, and connections with WP4 where there is a need for a simulation model will be established. Planning on how training can be accessible to all partners is also a question that demands planning. The task also includes an establishment of a web site for communication purposes related to training, which will later host the distance education platform.

Task 2 - DEVELOPMENT OF CROSS-DISCIPLINARY PROJECT-FOCUSED TRAINING

Sub-task 2.1 Cross-disciplinary definition work - When developing interdisciplinary knowledge both for working together and for common training efforts, it is most essential to have a mutual understanding of the terminology of the field involved, which often differs between specialists of different disciplines. A foundation will be laid in form of a net-based BioMinE WIKI-glossary with customised multi-language and search functions. This will become the foundation for further development of learning objects (and a learning object as such), but also a working tool for good communication and collaboration in the project work.

Sub-task 2.2 Development of 10 case-based Learning Objects. - "Learning Objects" do not yet have a clear definition but in general they will be the basis of "object oriented programming" and "open source development" of e-learning. These objects can be used standalone or as a part of a distance or residential course or for 'just in time' learning. Ten Learning Objects, covering the essential learning content of the project, from geology and biology to issues such as environmental science, production economy and ethics, will be developed. This will be for in-house training needs of the industrial partners and for higher

education institutions. It can also work for integration of biometallurgical methods in existing courses and as components in construction of new courses.
Sub-task 2.4 Web-based distance course - A web-based distance course, consisting of the learning objects implemented in an e-learning platform, will be run by a partner specialising in this work with support of other relevant partners. Partner organisations in the project will be encouraged to use these objects within their own training and education structures (outside the project).
Sub-task 2.5 Assessment and revision of learning objects and distance course - When the course has been running for some time, the results will be assessed and revisions made. These revisions will be based on the results from other WPs which can be brought into the course by partners active in those WPs. Evaluation of the usability of the learning objects in the partners' own training infrastructures will also be made.

6.3 Consortium Management activities

WORK PACKAGE 0 – CONSORTIUM MANAGEMENT

Task 1 - MANAGEMENT STRATEGY AND STRUCTURE The BioMinE project will require particular attention by the Consortium to overall management and coordination. An appropriate management framework will link together all of the project components. Communications will be maintained with the Commission on behalf of all partners. All IPR issues will be handled and matters relating to Exploitation, covered under WP5, will be monitored. The General Coordinator will undertake responsibility for monitoring the overall scientific content of the work to ensure that the work is carried out to the highest standards and that relevant scientific information is disseminated between all of the researchers. Five Work Packages have been identified and each will have a Coordinator responsible for its technical performance and for ensuring that the work of the partners within their respective package is effectively coordinated as well as ensuring coordination between the work packages.

Sub-activities in Task 1 are:

Sub-task 1.1 Management Strategy and Structure (month 0-3)
- Implementation of a secure web-based project management system for follow up, reporting, briefing, information, document handling and sharing as well as meeting planning and day-to-day communication
- Development of a project quality plan
- Design and launch for a project website and other information material for internal and external communications
- Introduction of new partners and up-dating of Consortium Agreement

Sub-task 1.2 Project Management (month 0-48)
- Planning, organising and leading the project meetings
- Coordination of the technical activities of the project
- Overall legal, contractual, ethical, financial and administrative management of the consortium
- Preparing, updating and managing the Consortium Agreement between participants
- Coordination of the knowledge management and other innovation related activities
- Preparation and distribution of periodic management, financial and technical reports including final reports
- Periodic updates of the implementation plan
- Search for new scientific and industrial partners
- Implementation and management of the gender action plan

Task 2 – INTELLECTUAL PROPERTY RIGHTS
- Implementation of the IPR Committee (month 0-18)
- Definition and periodic updates of the project's Intellectual Property portfolio
- Assessment of international IPR status and exploitation opportunities

6.4 Plan for using and disseminating knowledge

Data dissemination through presentations at scientific and technical meetings and publication in scientific journals and conference proceedings are highly encouraged. Publication is subject to review and approval by the IP Management Committee in consultation with the respective WP Coordinator. Detailed policy will be established.

Annual Conferences will be organised, along the lines of those held for the Framework V Projects and Thematic Networks, and non-confidential information will be published in Conference Proceedings. It is anticipated that the final meeting could be opened to non-project members.

The Management Committee establishes contacts with potential clients for the technical and scientific results coming from the IP. Subsequent projects that focus on further refinement and development may be started within the consortium, normally without financing from the EU.

The handling of intellectual property rights shall be entrusted to the Intellectual Property Rights Committee. Existing intellectual property has to be defined and the policy for ownership decided upon. Generally, the consortium member that created the intellectual property will also own rights to it. This Committee will also have responsibility for the Exploitation of the results of the IP.

A project information dissemination website will be a public part of the project work website, containing basic facts, contact persons, public news about the project, and one learning object covering a popular orientation of biohydrometallurgy. This learning object can function as a popular mini-course, besides being an introductory module in the web-based distance course within the project.

The training materials will be disseminated under the open source concept to European learning objects repositories (for example "The European Knowledge Pool"), for use in the construction of new training and education by any organisation interested in biohydrometallurgy. This will be a dissemination resource also after the project.

6.5 Gender Action Plan

The project involves several technical and scientific disciplines, microbiology, chemistry, metallurgy and process technology. Traditionally there is a significant female representation in microbiology and chemistry. During the last 25 years the number of female graduates in metallurgy and processing has increased, e.g. a typical figure for Mineral Processing and Extractive Metallurgy at Lulea University of Technology, Sweden would be about 30%. It has been experienced that female graduates in metallurgy and related subjects have a preference for spending their career in research and development rather than management and operations. There are of course several exceptions. There have always been a large percentage of women employed as laboratory assistants dealing with chemical assays.
The objective of the gender action plan is to increase the female participation and involvement at all levels as described above. The following specific actions are foreseen:

- Preferable recruitment of females as graduate students for the various tasks performed at participating universities.
- Co-operation with outside financial sources providing opportunities for recent female PhD's to spend time as post-doctoral researchers in other institutions to qualify for higher academic positions.
- Development of career plans and systematic training for a number of selected female scientists to be employed in the project.

- Invitations for female secondary school students to visit selected R&D centres within the project; e.g. Orléans (BRGM), Duisburg, Bangor, Warwick, Randburg (MINTEK), Madrid (Tecnicas Reunidas)
- Offering subjects for theses for MSc students in relevant disciplines and when possible financial support with preferential treatment of female candidates.
- Offering vocational training to female laboratory assistants.
- Retaining a recognised gender expert to continuously monitor and evaluate the gender dimension during and after the project.
- A special session to review and discuss gender issues will be organised in conjunction with the second collegiate conference.

One important aspect is to make it possible for and to encourage female engineering graduates to advance from the traditional starting positions in research and development into management and executive positions. A personal development and career plan will therefore be developed for female and male engineering graduates engaged in the project.

Mobility and spending time at other institutions is often a problem for female scientists and engineering graduates since they have to take responsibility for their children. It is the intention to develop means of solving this problem, which primarily is of a practical nature within the projects. Complementary funding will be sought for this issue.

Training materials and solutions will be planned and constructed for making it possible for people with education backgrounds other than the traditional, male-dominated, engineering education in mining and metallurgy. Interdisciplinary training can work well as a kind of shortcut for females educated in, for example, microbiology into work in traditional male-dominated workplaces. The study of a future international masters degree will also aim at being a cross-disciplinary solution, bringing together students with different but relevant education backgrounds.

A Gender Awareness Group will be established which will encourage networking and mentoring amongst females and which will collect gender statistics. This will be in addition to the sex-disaggregation required by the Commission. The Gender Awareness Group will be appointed by the Management Committee at project start-up and will report regularly to the Management Committee and anually to the Governing Council.

6.6 Raising public participation and awareness

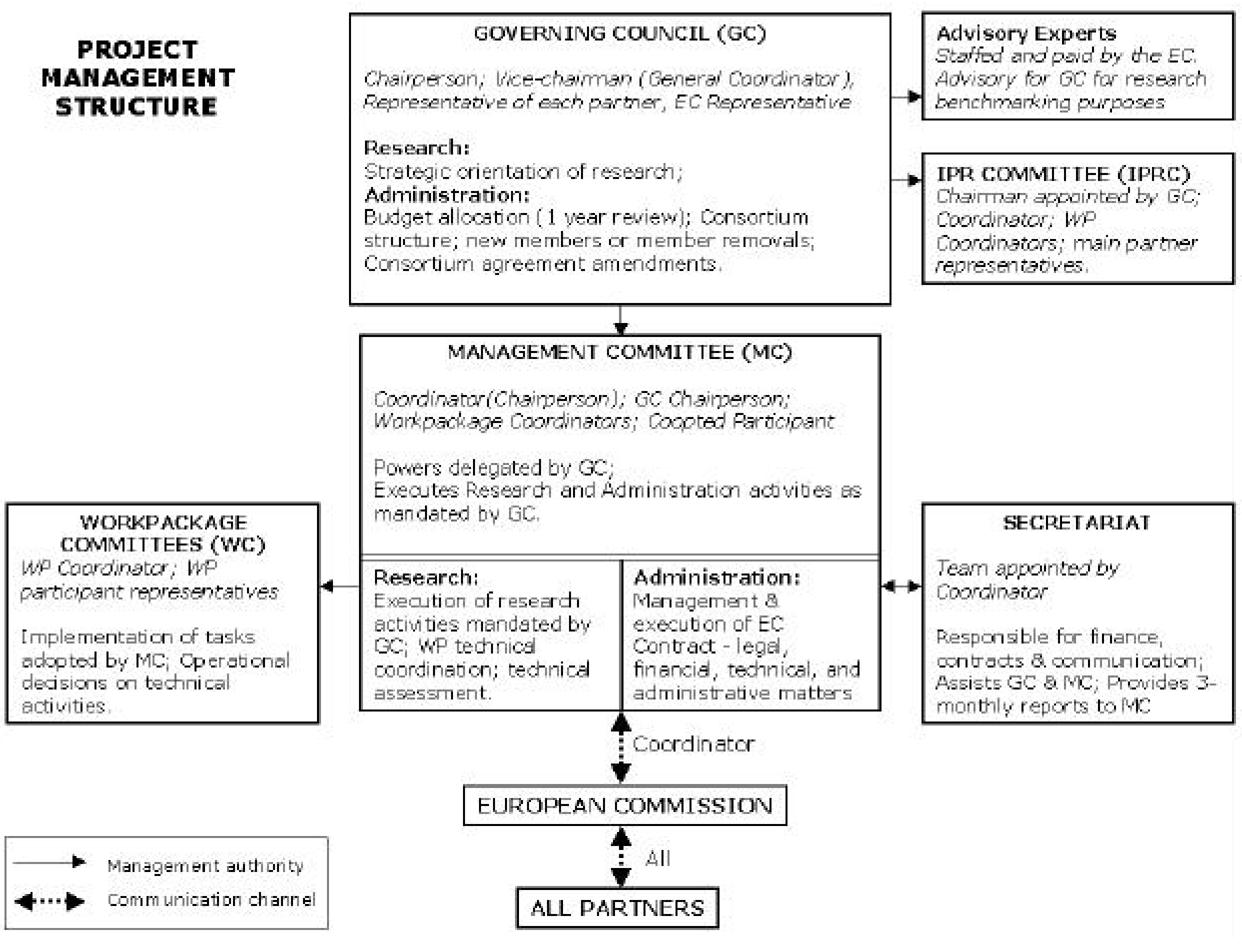
After the project has started the Management Committee will assign a member of the project with responsibility for raising public awareness. In particular this will involve a press entrance as well as news releases and explanations for 'laymen' on the public web-site. The publication of information leaflets and training material for schools will also be considered.
Articles will be published in popular scientific journals and quality newspapers.
For the time being, the General Coordinator will take up the responsibility for raising public awareness, via the distribution of newsletters to the Consortium and external interested parties, seminars and via the advertisement of the project website.

7. Project management

The following diagram indicates the management structure which will be used. The General Coordinator has the executive and signing power to lead the project and the overall responsibility to represent the Consortium in matters involving the European Commission.

The General Coordinator is supported by the Governing Council, which will meet annually or more frequently if necessary. The Governing Council is composed of a representative of each consortium partner and a representative of the European Commission. The Governing Council Chairperson for the first Governing Board has been appointed by the Management Committee as being Professor Eric Forssberg. Decisions at the Governing Council will be taken by the majority of the votes present or represented .

The Advisory Experts will function as an advisory group for the Governing Council and will be appointed and staffed by the EC.



In accordance with the Consortium Agreement the functions of the Coordinators are defined as follows.

The General Coordinator shall have the following functions, in addition to the Coordinator's functions pursuant to the EC Contract:

- Overall leadership and management of the project according to directions given by the Governing Council and the Management Committee,
- Providing the primary communication link between the project and the EU Commission on all matters (financial, administrative and scientific) related to the project.

- Establishing and managing the Secretariat to facilitate all financial and administrative matters related to the project, and, where necessary the transmission of such related documents and information to the Parties.
- Providing the management of meetings held by these bodies, and the distribution of minutes of these meetings to all the Parties.
- Convening meetings of the Governing Council and the Management Committee
- Withholding payments for, constituting and administration of the Joint Fund, including, but not limited to, the Common Fund
- Leading the scientific matters related to the project according to the directions given by the Governing Council and the Management Committee,
- Ensuring (i) effective Project integration, (ii) achieving the Project scientific deliverables, and (iii) effective interactions with the EU Commission on project scientific matters.
- Preparation and approving reports, deliverables for transmission to the EU-Commission by the Coordinator,
- In collaboration with Work Package Coordinators, promote and maintain scientific links between Parties within and between Work Packages, in order to ensure project deliverables
- In collaboration with Work Package Coordinators, analyse scientific results from all Work Packages and make recommendations to the Management Committee for new scientific tasks and collaborations and for best exploitation of results inside and outside the Project.

The Work Package Coordinator shall have the following functions:

- Leading and coordinating the scientific matters related to the Work Package according to directions given by the Management Committee
- Preparation and approval of reports and documents related to the scientific matters of the Work Package for transmission to the Coordinator,
- Convening meetings of the Work Package Committee
- Collation, approval and transmission of Work Package deliverables to the Coordinator, and
- Facilitate and maintain communication on scientific matters and the transmission of documents, information and materials between the Parties of the Work Package, and, as necessary, with Parties in the other Work Packages.

The IP will be coordinated by **Dr. Dominique Morin**, who is Head of Biotechnological Unit of BRGM. Dr. Morin is a Process engineer and Doctor-Engineer of Ecole de Mines de Paris. He has expertise from the conception of new processes to commissioning of industrial operations and is in charge of a team of leaders of research projects covering activities in biogeochemistry, microbiology, molecular biology and biotechnological processing.

Dr. Eric Forssberg, Professor of Mineral Processing, Luleå University of Technology,has been put forward as Chairman of the Governing Council for the first year of the project. Dr. Forssberg has over 25 years of experience in cooperative projects between industry and academia including several EU-funded projects. Dr. Forssberg is Chairman of the Council of the International Mineral Processing Congress and Member of the U.S. National Academy of Engineering and the Chinese Academy of Engineering.

Dr. Andor Lips, who will assist Dominique Morin in his duties as General Coordinator and who will be the Coordinator of WP1 is Project Manager in the Mineral Resources Division of BRGM. He has an MSc and PhD in geology and geodynamics from Utrecht University. He has been involved in mineral exploration programmes in 4 different continents, in the development and assessment of comprehensive continental-scale metallogenic and environmental GIS, and in the ESF funded GEODE project resulting, amongst others, in the realisation of metallogenic and environmental GIS covering all Central and Eastern Europe (BRGM’s GIS Central Europe).

Dr. Tony Pinches, who will be the Coordinator of WP2, is Manager of the Biotechnology Division of Mintek where he is in charge of bioprocessing. Dr Pinches has had 30 years experience in biochemical engineering and biohydrometallurgical research and development in the UK and South Africa. He has been with Mintek since 1988 and has been instrumental in developing and promoting commercialisation of bioleaching processes applied to refractory gold and base metals, as well as other fields of biometallurgy, in collaboration with major international mining companies and research organisations.

Dr. Jacco Huisman, who will be the Coordinator of WP3 is technology manager of the metals department within Paques. He has studied chemical engineering and specialised in bioprocess technology. He has a PhD from the ETH in Zurich and has worked as a post doc at the university of Tokyo in Japan. He is currently workgroup coordinator within a 12 M€ project that has resulted in the first full scale hydrogen fed sulphate reduction reactor.

Carlos Frias-Gomez, who will be he Coordinator of WP4, has a Masters Degrees from University of Madrid in Chemical and Environmental Engineering and prior to joining Técnicas Reunidas he worked for eight years at Rio Tinto Minera S.A. performing activities to improve the plant process efficiency. For five years, he was responsible for the Research Department engaged on projects for the hydrometallurgical treatment of complex sulphides. He joined Técnicas Reunidas in 1991 where he is Director of R&D projects in the fields of hydrometallurgy and electrochemistry. He has expertise in chloride hydrometallurgy applied to primary and secondary materials.

Anders Norberg, who will be Coordinator of WP6, is Developer of Higher Education for the community of Skellefteå. He has experience as a teacher, director of studies and project manager for a number of education development projects since 1990, including adult education and training programmes to bachelors and masters programmes. He has a special interest in trends towards the future infrastructure of education and experience in several EU projects (structural funds project and transnational projects).

The Work Package Coordinators report to the Project Coordinator for measures in their respective areas. There will be seven categories of Work Package Coordinators as follows:

Project Work Packages	Coordinator
WP0 Management (including IPR)	BRGM (France)
WP1 Resources and sustainability assessment	BRGM (France)
WP2 Bioleaching	MINTEK (South Africa)
WP3 Biotreatment and Resource Recovery	Paques (Netherlands)
WP4 Process Integration and Applications	Tecnicas Reunidas (Spain)
WP5 Exploitation	Committee to appoint
WP6 Training	Skeria Utveckling (Sweden)

It is the intention to involve all the consortium members actively in several work packages and tasks. The Work Package Coordinators will form WP Management Committees that will meet at least twice a year. It is anticipated that the General Coordinator and the WP Coordinators will visit the partner institutions and corporations. The objective is to achieve active management and integration between the formal meetings.

The WP Coordinators will prepare a consolidation report every six months. The Project Coordinator shall establish an IP web site, which will provide open information as well as internal information protected under passwords. A periodic hard copy newsletter will accompany this web site.

Data dissemination through presentations at scientific and technical meetings and publication in scientific journals and conference proceedings are highly encouraged.

Publication is subject to review and approval by the IP Management Committee in consultation with the respective WP Coordinator. Detailed policy will be established.

Annual Conferences will be organised, along the lines of those held for the Framework V Projects and Thematic Networks, and non-confidential information will be published in Conference Proceedings. It is anticipated that the final meeting could be opened to non-project members.

The Management Committee will, where appropriate, provide support to Partners to establish contacts with potential industrial end users of the results arising from the IP. The intention here is to promote further commercially-related development or demonstration activities within the consortium, usually without financing from the EU.

The handling of intellectual property rights shall be entrusted to the Intellectual Property Rights Committee (IPRC) that comprises the chairman, appointed by the Governing Council, the representative of the Coordinator,the 6 Work Package Coordinators, one legal advisor for each main partner and, when handling disputes, one legal advisor for each of the disputing partnersExisting intellectual property has to be defined and the policy for ownership decided upon. This Committee will also have responsibility for advisory actions concerning the Exploitation of the results or any other IPR issues of the work in the IP.
The IPR Committee shall meet at the request of it´s chairman or at any other time when necessary at the request of the Management Committee.