Bioshale is a project co-funded by the European Commission (FP6 programme) that started in October 2004.

The main objective of Bioshale is to define innovative biotechnological processes for “eco-efficient” exploitation of black shale ores.

Such ores contain base, precious and “high-tech” metals (Cu, Ni, Zn, Ag, Au, Pt, Pd, etc.) but also high contents of organic matter that handicap metal recovery by conventional techniques.

Three world-class black shale deposits have been chosen as targets of Bioshale R&D actions. These include one deposit that exists under natural conditions (Talvivaara, Finland), one currently being processed (Lubin, Poland) and one post-mining deposit (Mansfeld, Germany).

The social & economic benefits of the project include the continuation of mining activities in Europe (Lubin/Polkowice) and to help exploit new resources with considerable reserves (Talvivaara). The Mansfeld site is illustrative of and supports the evaluation of the Environmental Impact of black shale ore exploitation.
The main tasks of Bioshale project can be summarised as follows:

1. evaluation of the geological resources (geological modelling);
2. selection of metal-bearing components & biological consortia to be tested;
3. assessment of bioprocessing methods and determination of complementary hydrometallurgical processing routes for metals recovery;
4. use of new analytical tools based on molecular biology for the characterisation & monitoring of bacterial communities;
5. risk assessment relative to management of waste material from of the new processing routes;
6. techno-economic evaluation of new processes from mining to metal recovery including social and environmental impacts.

**GENERAL INFORMATION**

Duration:
3 years (start date 1st October 2004)

Total budget:
3.4 M€ (EC 2.3 M€)

Partnership:
13 Partners/8 European countries

Project efforts:
553 Man Months (+226 MM Universities Own Resources)

Reporting:
22 Deliverables
Major achievements (Process options & Academic R&D):
From a general point of view, and in the case of copper extraction technologies, the choice of the best technology is usually driven by both metal grade in the ore and total amount of resource. Nevertheless, it was demonstrated that the feasibility of a process on a given resource is also dependent on many site/resource-specific factors.
Pyrometallurgy remains the main technology for metal recovery in general and especially for copper extraction. Nevertheless, there are more and more potential niches for application of biohydrometallurgy. Nowadays, biohydrometallurgy is taking an important place in the mining industry of non-ferrous metals either in competition or in complement of classical technologies. Biohydrometallurgy definitely offers to the mining operators an alternative development option with attractive economics.

In term of process development, the work carried out in the frame of Bioshale is focused on two case studies, two types of "black shales" materials situated in Poland (Lubin/Polkowice Mine) and in Finland (Talvivaara deposit).
The most reasonable process options operations were described in the first 6 months of the project. These preliminary “process options” have been studied by Bioshale consortium with the objective to develop new bio-hydrometallurgical routes for the recovery of valuable metals from black shale ores and/or concentrates.
From the first results obtained in the different laboratories, some new "options" were also proposed by Bioshale consortium.

In both cases, the work on process options assessment took into account the current situation on the target sites in Poland and in Finland.
• In the case of Lubin, there is an existing concentrator plant combined with a smelter that extracts mainly copper and silver. A copper concentrate is produced there, along with an “enriched shale fraction”, so-called middlings.
• The situation with Polkowice is comparable to that of Lubin, but it is also suspected that significant amounts of precious and noble metals (the platinum group elements) could be recovered by biotechnology, thus adding value to the total operation.
• The most valuable metal in the Talvivaara deposit is Ni, while Co, Zn and Cu are also present in significant quantities. The deposit is not under exploitation yet, but an industrial project aiming to use bioheap technology to recover metals from the Talvivaara ore is under evaluation.

Combining all participant contributions, a detailed analysis of all process options including their strengths and weaknesses was carried out and presented in Bioshale mid-term report. The main conclusion concerning the process alternatives can be summarised for the principle “samples” of Bioshale project (Lubin, Talvivaara & Polkowice).
**For Lubin Mine samples**

Bioleaching tests have shown that Lubin black shales are amenable to bioleaching, with regard to solubilisation of metals present in sulfide minerals. Biodegradation of the organic matrix of black shales (Lubin ores and concentrates) has been more difficult to achieve.

No evidence of biodegradation was found with acidophilic heterotrophic bacteria. Experiments with neutrophilic microorganisms have been more successful; their positive impact on metal recovery efficiency remains to be quantified at larger scale. Continuous bioleaching tests using “stirred tank” technology are planned for the 3rd year of bioshale project.

**For Polkowice samples**

Some samples from the Polkowice mine became available for testing in the frame of the Bioshale project. If the grade of rare and noble metals is sufficiently high, these samples will be tested for bioleaching amenability. A special emphasis will be put on the relationship between the metals and organic matter.

**For Talvivaara samples**

The grade of the Zn-Ni concentrate obtained from Talvivaara ore remains too low to make continuous stirred bioreactor technology viable. Heap bioleaching pilot testwork carried out by TVK (owner of the deposit) on site, and in the frame of the industrial Talvivaara project, showed this biotechnological option to be very promising.

In the Bioshale project, several R&D actions are undertaken both on the GTK tower (simulation of heap leaching technology) and on TVK bioheap leaching demonstration operation (on site). These actions include microbial monitoring by molecular biology; complementary bioleaching tests at lab-scale (designed consortia; high temperature column leaching...); and modelling of heat transfer in the bioheap.

The work is coordinated in collaboration with TVK.
In addition to the development of bioprocess options, some of the R&D actions carried out during the first two years of the Bioshale project were dedicated to more academic work.

1. Providing new scientific data on noble metals occurrence (PGE,...) in black shales. Research into the identification of noble metal carriers in metal rich shales. This is important for the explanation of the mechanism of the origin of noble metals in various black shales worldwide.

2. Participation in the development of bioleaching technologies for copper recovery that can be applied to multi-element (metals) concentrates and black shale ores. Optimisation of silver recovery from residues after bioleaching. Demonstration of the ability to bioleach metals from black shale ores that contain organic matter.

3. Study of the microbial ecology of the TVK heap using molecular biology tools. Modelling and simulation of heat transfer using data from both pilot operations (GTK and TVK). This work is of crucial importance for designing industrial heaps.

4. Extension of the known habitats of mineral oxidising acidophiles, as well as general characterisation of microbial populations associated with black shale ores. These microorganisms have also formed the nucleus of the “Bioshale Culture Collection” that has been established within the frame of the project.

**Deliverable list:**
The following reports have been produced by the Bioshale consortium since the beginning of the project. All of these reports are confidential, but abstracts are available on the Bioshale web site & the main results will be disseminated to the public during the final year of the project.

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