near-field studies include geochemistry, geohydrology, hydrothermal interaction and geomechanics.

This is a gargantuan undertaking in which almost every conceivable aspect of materials science is being studied. Apart from possible solutions for the disposal of nuclear wastes, this programme may contribute greatly to newer aspects of material science. Some of the results have already been published. The rest will not only be discussed in conferences but are also expected to appear in open literature.

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Bacteria precipitate arsenic

Mining sites are important sources of pollution. The oxidation of metallic sulphides, under the action of surface waters, produces sulphuric acid and the metals released are soluble in these acidic waters. A number of metals and metalloids, including arsenic, are poisonous and pose a threat to the environment.

Primitive forms of life can colonise these extreme conditions. Chemolithotrophic bacteria draw their metabolic energy from electrons released during oxido-reduction. Bacteria such as *Thiobacillus ferrooxidans* catalyse oxidation reactions of iron sulphide and are used industrially to retrieve metals in poor ores (bacterial leaching). Arsenic contained in sulphides can be released; according to its state of valency, it will be soluble (As^{3+}) or insoluble (As^{5+}). That is, it will either be a poison released in the medium or it will precipitate in a relatively stable form with ferric iron.

The mining site of Carnoulés, in Gard, in the South of France, abandoned for the past 30 years, includes quarries where lead sulphide ore was exploited. A sizeable stock of wastes resulting from the processing of ore, containing another 10% of iron sulphide, lead and arsenic were also found. Water from the Carnoulés stream is very acidic (pH 2.5–3.5) and rich in metals (Fe, Zn, Pb) and causes pollution over several kilometres downstream. This was already studied by Michard and Faucherre in 1970. Scientists noted high concentrations of arsenic (100 to 200 mg/l – about 2000 times greater than the limit approved for drinking water) in the upper portion of the stream. At 1.5 km downstream, acidic waters do not contain more than 0.2 to 4 mg/l of arsenic as this element gets deposited on the way. In fact, the sediments of this stream are essentially composed of iron and arsenic; in the upper part of the stream, there is about 9 to 20% of arsenic in the form of yellow deposits of ferric arsenate. These sediments show structures of bacterial construction which remind us of the most ancient forms of life that appeared on earth:stromatolites.

Research was then directed to the study of these deposits. Forms that could be identified with their morphology and their size such as bacteria were observed under a sweeping electronic microscope. Scientists discovered that bacterial stromatolites could thrive in continental acidic waters. In just a few days, the bacterial colonies formed extending bacterial carpets on sulphide sand deposits. Semi-quantitative analyses with the electron microscope could show that the bacteria had a covering of arsenic and iron.

In the second stage, bacterial species present in the acidic waters have been determined in the laboratory through culture on selective mediums. The most abundant forms are of the *Thiobacillus* type (*Th. acidophilus, Th. ferrooxidans*) and the *Leptothrix* type. The role of bacteria on the precipitation of iron arsenates was studied in the laboratory by measuring the quantity of arsenic precipitated by different strains of bacteria. The sample taken was the arsenic present in soluble form in the acidic water of Carnoulés. These results were compared with the precipitates in the absence of these bacteria. This experiment, followed for several weeks, showed that two bacterial strains enable the precipitation of 80% of the arsenic, whereas without bacteria, only 25% of the arsenic precipitated. The bacteria thus favour oxidation of arsenic and the precipitation of arsenate. Lead, which is also present in strong concentrations (1.1 to 2 mg/l) in the acidic waters of Carnoulés, precipitated with the arsenic (0.25% Pb in bacterial sediments). Now, it has to be determined if bacteria catalyse only chemical precipitation reactions (oxidation As^{3+}–As^{5+}), by lifting an electron on the way or if they use arsenic in their metabolism.

As for environment, the bacterial action is positive. There is on-the-spot storing of most of the arsenic (and lead); but, these deposits are fragile and can be quickly eroded and carried downstream by a heavy rain. This remarkable site with its chemical 'reactor' and acidic ecosystem forms a natural laboratory to study and quantify the flow of arsenic and metals as well as specify the role of bacteria.

The biological control of toxic arsenic levels in water assumes importance in view of the recent arsenic poisoning tragedy in West Bengal (*Curr. Sci.*, 1996, **70**, 976–986).

Source: Technical News, May 1996, Centre for Documentation on Universities, Science and Technology, Embassy of France, New Delhi.