Mycoremediation

Fungi, bacteria and plants break down the surrounding material; they absorb what is edible and neutralize what is harmful. Bioremediation is planned decontamination of a natural environment by the action of these organisms: the purpose is to transform contaminants into water and carbon dioxide with ideally no side effects and a cheaper cost than other methods. In this respect, fungi secrete enzymes around them, acids that modulate the environment at their convenience. They are more tolerant than bacteria to very high levels of toxicity. Mycoremediation is the use of these skills to dispose of substances that are harmful to us. Here are a few inroads.

Hydrocarbons

Worldwide, the search is on for means to mitigate pollution from oil, pulp, textile industries and other such processes. Fungi are unique in that they can break down lignin, the component that gives trees their rigidity and, at the same time, also degrade hydrocarbons, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and pesticides into innocuous molecules (Adenipekun & Lawal, 2012).

Inoculation

The inoculation of targeted soil with mycelium is the most widely publicized method. For years, Paul Stamets has been preaching mycoremediation in books like «Mycelium Running» or conferences such as «The Future is Fungi». He has demonstrated how swiftly oyster mushrooms (*Pleurotus ostreatus*) on a cellulosic substrate can clean an oil patch on which it rests, while dissipating innocuous gases. This popular edible has thus become the emblematic oil buster.

Many species, armed with lignin peroxidase enzymes, display the same capacity: among them, ubiquitous shiitakes, button mushrooms, turkey tails, and others less heralded but more efficient fungi.

In general, the mushroom should be made to grow on lignocellulosic material, the natural source of energy for these species, before tackling related substances. On the other hand, fungi need to breathe as we do, which usually restricts the range of their

action to the first oxygenated centimeters. Furthermore, the longer their cyclic chain, the more recalcitrant the PAH and the longer the process. Moreover, the "heavy metals" remain intact even if they are removed by fungi: they are simply concentrated in its flesh. Hence the usual recommendation to foraqers: avoid picking mushrooms near old mines, paved roads, dumps, all sites where lead, arsenic, nickel, mercury may be concealed. Finally, efficiency varies with species, sites and contaminants themselves: the proper one should be chosen for a given task.

Bio-stimulation

Bio-stimulation is based on the natural action of native microorganisms. It is one of the methods implemented at Lac-Mégantic, where a terrible disaster happened July 6, 2013.

A railroad train derailed, killing 47 people, destroying 30 downtown buildings and dumping 6,000 tons of oil.

Before reconstruction, decontamination had to be carried out.

The project consist in activating bacteria, actinomycetes and fungi already present in the soil by improving growth conditions (oxygen, nutrients, moisture, acidity, ...). As emphasized by the project manager, Marie-Claude Drouin, the microorganisms involved have not been specifically identified locally and their respective role in the collective effort has not been determined. The combination will differ from one site to another depending on the organic matter and soil pH on site.

Alternate solutions, ex-situ thermal separation and physico-chemical treatment do not require fungi but consume much more energy: both were abandoned in 2014 because of unsatisfactory results. Bio-stimulation has the advantage of being less expensive,

without significant emissions of gas. However, it operates slowly and requires disposal grounds. Reclaimed land, though clean enough for most uses, will not be completely free of long chain PAHs and "heavy metals". Preliminary conclusions will be drawn in 2016.

Assisted phytoremediation

Plants rather than fungi have been known for a longer time to decontaminate soils. The results obtained by phytoremediation can be improved when the symbiosis that binds fungi to plants is tapped. Dimitri Dagher, wih the IRBV in Montréal, is experimenting with a willow, *Salix purpurea*, tied to such mycorrhizal species. Fungi are relegated to a supporting role: speed up the growth of vegetation with willows having the lead role. The advantage of phytoremediation lies in the respective biomass: it takes a considerable number of mushrooms to match the weight of a single willow.

The accumulation of "heavy metals" in fungi can be useful sometime. It allows collecting undesirable substances and eventually disposing of them elsewhere. Several species accumulate heavy metals and other harmful substances. One species in particular, *Gomphibius glutinosus*, seems to benefit from the fallout around Chernobyl: it becomes radioactive while helping to clean the floor.

Radioactivity

In the same vein, in 1991 in Chernobyl, the discovery of black mold covering the walls of the nuclear plant has sparked quite a stir: the prevalent explanation is that the melanin contained in some fungi plays a role similar to that of chlorophyll in plants by transforming gamma rays into chemical energy. It is not for foragers to pick, though.

Cyanobacteria

In the process of recycling organic material, fungi often succeed bacteria whose actions have rendered nutrients readily available to them. They also typically secrete antibacterial metabolites around them. As is well known, they are the source of the discovery of antibiotics. Mycofiltration involves filtering bacteria and other undesirable

substances from a low flow stream. The simplest technique involves filling jute bags with mycelium inoculated straw and sawdust. Deposited across a low-flow stream, the bags form a barrier that filters water. The mycelium grows to fruition and captures E. coli, phosphate, nitrite and other substances which would have stimulated the growth of cyanobacteria (blue green algae) downstream. Stamets, who implemented such technique to comply with local effluent standards, concluded wine-caps (Stropharia rugoso-annulata) are efficient mushrooms for the task.

Conclusion

In many instances, the demonstration that mushrooms can clean up the environment is convincing. Up until now, results have only been obtained in the framework of pilot projects and laboratory experiments. Thus, to our knowledge, no large-scale decontamination has been performed yet. The mobilization of many complementary organisms, including fungi themselves, probably offers the best prospects. Species and strains are millions, most of them still anonymous; little is known about their specific capabilities. The power of fungi in restoring our environment is for us to discover and harness.