Project “Cobalt Buster” : Safety

Team Lyon INSA-ENS

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1 Introduction

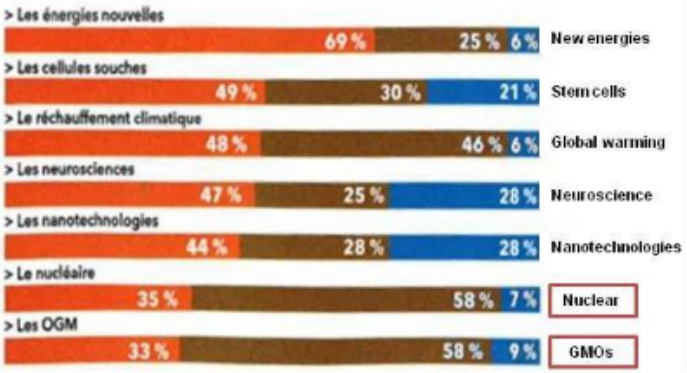
We present here our reflexion about safety issues of the Cobalt Buster project based on a modified Esherichia coli strain able to capture and concentrate cobalt from its environment. **This reflexion based on the questions provided by iGEM safety judges**, is presented in a form that we believe more convenient.

Radioactive cobalt is released in water systems of nuclear power plants, thats why we aim at using **this strain as bio-filter** for nuclear wastewater treatment to **improve efficiency** and **reduce both nuclear waste volume and the costs of the treatment.**

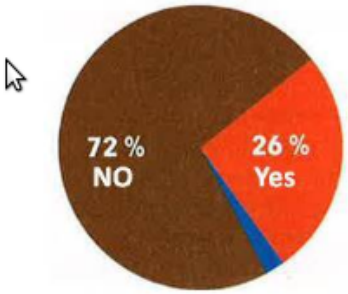
In this context we considered Researcher safety and, as we are aware that this project combines two technologies that scare a significant proportion of the population (GMO and nuclear power plant, as shown by a recent french survey resumed below), we paid particular attention in defining the potential risks for the Public and the Environnemt.

French survey published in « La Recherche » n°455 in september 2011

Would you say that you tend to trust scientists to tell the truth about the results and consequences of their work in the following areas ?



The safety of french nuclear power plants will be evaluated. You think... Scientists will conduct studies independantly and their results will be reliable ?



For each of the following players please indicate if you trust him to explain the issues of scientific research and debates that they can generate ?

To prepare safety issues we organised a public debate called " Nuclear technology and Genetically Modified Organisms : Can scientists keep control? ".

2 Researcher Safety

First of all, **no radioactive elements** will be manipulated during this project. To ensure safety of students during lab handling, only non radioactive cobalt will be used.

All *E. coli* strains we used have a **biosafety level of 1**, which means they are not known to cause diseases and have minimal environmental hazards. Although the final Cobalt Buster strain is designed to work in radioactive environments, it can be produced in normal conditions, like any other strain.

Cobalt is toxic by inhalation and contact and must be **manipulated with gloves and masks** and disposed in appropriate waste containers.

DNA manipulation will require the use of solvents and carcinogenic molecules which require the use of **gloves and chemical hoods**.

Thus, as for every bio-synthetic project, usual **lab safety measures** are enough to protect researchers efficiently during the Cobalt Buster project : wear a labcoat, gloves and dispose biological material in biohazard containers and metal in specific container. This strain is not more dangerous for people in the lab than any other E.coli strain, and thus doesn't require any additional care in handling them.

3 Public and Environmental Safety

We considered Public and Environmental safety from both hazard and probability point of view. To measure how **nuclear power plants related procedures** and

nuclear waste treatments are strictly regulated we organised **two visits**. First we visited **the nuclear power plant of Tricastin** to have an idea of **how radioactive compounds are confined** and how **human workers are protected**. Then we chose to visit **the Centraco** site which attend to a part of radioactive waste management.

3.1 Hazard

In usual working conditions, **our strain will accumulate radioactive cobalt**. Cobalt is **toxic** by inhalation and contact. It has been proven to *cause cancer, respiratory system damage, skin damage* among others on humans and various effects on other species including plants. It is important to notice that cobalt in our bacteria could be more concentrated than in usual resins. Radioactivity of the compound adds to the danger, with various damages that cant be neglected : *nausea, cerebral edema, sterility, foetal damage...* Only low-dose effects can be effectively treated. A previous study showed that **cobalt accumulation capacity of the bacteria** is **not infinite** and that bacteria death will conduce to **the liberation of cobalt** in the medium with the potential health or environmental issues that have been described if it ends up in the environment. For these reasons it is very important to ensure that the Cobalt Buster bio-filter will not release bacteria in environment after the processing.

In case of an unexpected release of the bacteria in the environment before it has fixated cobalt, we consider that **hazard is low**. Indeed, adding to the *difficulties for the bacteria to survive* in the Environment, none of the parts we will construct present a direct danger for Public as they will not modify the biosafety level of the *E. coli* strain and the bacteria does not produce any human or environmental toxic element by itself. However, *antibiotic resistances* carried by the different parts we will add to the *E. coli* strain may provide a selective advantage in environments where antibiotic selective pressure is high. Antibiotic resistances could be transferred to other bacteria strains, potentially human pathogens which would be favored by natural selection in such environments.

As far as **malicious use** is concerned, this strain could indeed be used to capture and concentrate cobalt from a medium in order to use it to pollute water for example. However, this method is more complicated and less efficient than using other

poisons in liquid solutions, which makes it **a very poor way of causing intentional environmental or health troubles**.

If a serious nuclear incident occurs (as INES scale level 7 nuclear disaster), the presence of our Cobalt Buster bio-filter will **not enhance adverse consequences on health and environment**. Indeed, in this case radioactivity level of the bio-filter can be neglected compared to releases generated by the incident and bacteria will probably be killed.

All this hazard is mainly caused by the capacities of accumulation of cobalt of the Cobalt Buster strain, added to the ease of retrieval thanks to the adherence. The parts that we are creating allow to make any E.coli strain adherent in presence of cobalt, so **no part we are going to enter to the registry can be considered hazardous in a regular E.coli strain**.

3.2 Probability

Once in working conditions, our strain will **form a biofilm** and be **bound to a confined filter**. As the biofilter is intended to work in nuclear power plants to capture radioactive cobalt, every steps of the industrial use of the Cobalt Buster strain will be done in **confined conditions with a very strict procedure**. Indeed, after the capture of radioactive cobalt in nuclear waste-water, our Cobalt Buster filter will be considered as **nuclear waste** and it will be supported following a very strict and highly regulated procedure.

Strict radioactive discharge protocols and storage conditions ensure that **the probability of unintentional release is close to zero**. Nuclear power plants are extremely confined and regulated areas. This implies that the probability of an unexpected event is extremely low. Moreover, water systems treated by the filter are isolated from each other and especially isolated from the environment which greatly reduces the risk of release.

All procedures in place in nuclear power plants are made **to respect the precautionary principle** and **reduce the exposure of humans and environment to the minimum**. The presence of our Cobalt Buster bio-filter will not increase the probability that a nuclear incident occurs in the power plant. We must notice that only two major nuclear incidents have occurred in the last fifteen years of nuclear

power plants exploitation : is it low or high incident probability ?

3.3 Conclusion

As a conclusion, despite the danger due to the accumulation of radioactive metal in a non pathogenic E. coli strain, the potential hazard is rather low compared to other damage that an accident in a nuclear power plant would produce. Moreover, our device would change very little to the processes already implemented in nuclear power plants, that work with minimum exposure. Confinement in nuclear areas ensures a very low probability : the discharge is thoroughly controlled. Malicious uses are extremely unlikely due to the presence of more efficient ways of achieving the same result. **The potential benefits** of the Cobalt Buster bio-filter, **reducing the volume of nuclear waste by 100** and **decreasing costs of waste disposal**, are **greater than the risk we run**, and according to us justifies the addition of such a device in nuclear power plants.

4 Biosafety Guidelines

Neither of our institutions (INSA Lyon and ENS Lyon) have a **biosafety group**. However, we have a general safety and health committee that deals, among others, with issue related to GMOs and that allowed their handling in the different institution, that has however not reviewed our project. All students follow a 4 hour **general health and safety lecture**, teaching how to handle chemical, biological and fire risks among others, completed by **additional biosafety and lab training all along the year** by the professors, in relation to their course. Our institutions do not have any specific biosafety rules and follow the general french laws on biosafety. As far as the legal aspect is concerned, **synthetic biology doesnt have specific rules** yet in France. As our bacteria are Genetically Modified Organisms, we are due to respect the **general laws** about the use of GMOs and **ethics**, which are relatively restrictive in France, based on the the precautionary principle.
In industrial conditions, additional safety rules about handling radioactive material will need to be applied because of the accumulated radioactive cobalt in the bacteria : confinement, limitation of human exposure, storage in adapted radioactive waste containers ensuring that no cobalt escapes to the environment during its lifetime,

control of the composition of the water liberated into the environment... These rules are already implemented.

5 For a Safer Genetic Engineering?

The debate **Nuclear technology and Genetically Modified Organisms : Can scientists keep control?** we organised aroused several safety issues and suggestions that have been proposed to tackle with them.

First, **the standardisation of parts** makes it simpler to **use and share for researchers**, but also **for malign or careless uses**. All the informations related to the iGEM projects are freely available on the net **without any access control**. It has been evoked that, with these informations, anyone with basic microbiology knowledge could try to build **his own bio-weapon** (like people nowadays can find the recipe to create their own bomb on the net) or, on a safety point of view, could **misuse a part and accidentally harm people or environment**.

Yet, would it be a better solution to restrict access to iGEM members ?

It would mean to give up on the valuable open source model, where everyones experience contributes to enhancing our knowledge, including the knowledge about the safety of the parts (what should and should not be done with a part, what precautions you must take, what unexpected behaviour has been observed...). Concealing the information would not prevent people from accessing it illegally, as shown by

the numerous web security breaches that are regularly reported. This means that synthetic biology should be careful about safety issues and discussions or reflections concerning the open source should not be overlooked.

General safety issues about GMOs have also been mentionned, and the reasons why the general public considers them unsafe. The quick development of plant GMOs was, in the eyes of the general public, a search for immediate profit with few concerns about safety and ethics and moreover very few efforts of communication have been made, which has created a fear about them. We noticed that generally, **GM bacteria** are widely used in **medicine and food industry**, but are less known by the public who is less scared about them. Synthetic biology should avoid such a mistake, by communicating to the public before releasing new devices, and ensuring that they will be accepted by a distrust public.