| Technology Information | |
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| Area | 2 |
| Title | Treatment of contaminated water (Tritium, etc.) |
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1. Overview of Technologies (features, specification, functions, owners, etc.)

**Introduction**

We are a French company specializing in the treatment of liquid nuclear waste, oil, grease, effluents, sludge and oily sludge etc. We are pleased to propose our technology as a solution to help purify water contaminated with radioactive elements and/or radionuclides by completely decontaminating the waste simply using a biological process in which we have lots of experience.

We hold patents of two processes, the first issued in 1995, Patent No. 15-01581 entitled: "*Method and device for processing oils and solvents contaminated by radioactive substances*." This patent was designed to capture 10 radionuclides of low and very low activity by ion exchange: (10 000 Bq / liter) (LLW and VLLW) such as: $^{60}$Co, $^{58}$Co, $^{64}$Mn, $^{110}$Ag, $^{65}$Zn, $^{54}$Sb4, $^{134}$Cs, $^{137}$Cs, Cs, Niobium and Tritium.

Over several years we simplified and improved the process using specific strains of microbes identified to provide complete transformation of the waste to constituents that can be dealt with efficiently using conventional means. The select microorganisms allow us to extract all metals from the matrix and all liquids microbiologically.

By attempting to accelerate the process known as bioleaching, and to develop an alternative, more efficient method of treatment and not involving the same types of microorganisms, we have found heterotrophic bacteria that are much more rapid than the biochemical reactions of autotrophic bacteria. These microorganisms synthesize several molecules capable of engaging in specific relations with metals by ionic exchange. We can use them to remove radioactive isotopes such as Tritium, $^{14}$Carbon, $^{35}$Sulphur and $^{32}$Phosphorus.

This new process was patented in 2012 by the INPI (National Intellectual Property Institute) under Patent No. 10 56596 entitled "*Method and Apparatus for Treating Oils, Greases, Solvents, Water or Oily Sludge Contaminated by Radionuclides*." Indeed, the bacteria used are able to extract all the radioactive or non-radioactive heavy metals from their matrix or liquid in which they are located and thus purify liquids and, in this specific case, the salt (or non-salt) water.

During the process of extraction and separation of liquid or sludge, we can separate and release metals and radionuclides or extracts in an extremely reduced volume into the appropriate containers, in compliance with the DER, as defined by the client's engineers. The process is commonly used in France in steel mills to extract the heavy metals found in the dregs before they are write-offs.

Our new process (second patent) has allowed us to treat cutting oils contaminated with radionuclides such as Ag, Al, As, Cd, Co, Cr, Cu, Cs, Fe, Fe, Hg, Ni, Pb, Sb, Si, Mg , Ti, U, Zn, Zr, Mn, Sr. We know that we can extract and capture all the metal elements on the Mendeleev table, including those that are non-radioactive.

With the two patented processes, we can treat oil and other contaminated products with an activity of 6700 $Bq.g^{-1}$ or 6.7 million Bq per kg in equivalent $^{60}Co$.

**Treatment of contaminated water (Current situation)**

We have noted that the cesium is first removed with other radionuclides using the ALPS process. We took note that the equipment has been repaired and ALPS is now operational but cannot eliminate the Tritium, and following treatment with ALPS the plan is to store partially decontaminated water in tanks of $1000m^3$.

Following treatment by ALPS, the water is marked by tritium whose activity is of a very high level of $5 \times 10^6$ Bq / l. This level should be lowered to $6 \times 10^4$ Bq / l or 5 000 000 Bq / l to 60 000 Bq / l. This means that it is necessary to extract and/or eliminate 4,940,000 Bq per liter at a rate of 400,000 liters per day.

We utilize microorganisms capable of degrading effluents that are purely organic and/or minerals marked with radioactive isotopes. By appropriately adjusting the operating conditions of the process (residence time, dilution, air, pH, temperature), and taking full advantage of the effects of biosorption and metabolism, we shall direct pollution from radioactive isotopes in its totality into the biomass. They will be subsequently disposed of via residual waste.

**The treatment method proposed**

It is anticipated that the effluent consists of sea water contaminated with tritium treated by ALPS and it will be stored in tanks of 1,000 tonnes (± 1,000 $m^3$). We propose that one of these tanks be converted and used as a reactor for our process in which the content of other tanks continuously circulates to remove the tritium and other radionuclides that may be present in the effluent ($^{90}$Strontium and $^{137}$Cesium ... and other).

The residence time is three days, maybe less, following a biodegradability test on a pilot (1 $m^3$) machine, which signifies that we can treat 1,000/3 = 333 $m^3$ per day. For this purpose it is necessary to make some adjustments in the tank that comprises installing 4 or 5 agitators to homogenize the mixture (effluent and microorganisms).

In addition to the agitators, a baffle section is required to evacuate an overflow of 333 $m^3$/day of treated effluent, which can then be transferred to an independent decanter. A stream coming directly from another tank via a pump in a second baffle opposite to the first one will allow for supplying 333 $m^3$/day of effluent from the bottom of the reactor tank, possibly up to 400 $m^3$ / d after the pilot test of 1 $m^3$ which will define more precisely the time required to remove the radioactive products.

An air distributor with flow meter, pH meter, temperature gauge, several Geiger-Müller types of sensors, and a stack to regulate the gas and air flow at the bottom of the tank and an automatic pre-programmable distributor of bacteria will complete the fixtures necessary to be built inside the tank.

A cylindrical decanter terminating at its lower part of the cone, whose dimensions are to be determined, would help treat 15 $m^3$ per hour (24/7) of the effluent treated in the reactor tank.

At the tip of this decanter, sludge composed of dead microorganisms, mineralized tritium and/or other metals that may be present will be set in micro-organisms or on their outer shells, thereby forming an extremely low volume of sludge that will then be transferred into lead containers for final storage.

The over-flow of clean water coming from the same decanter that is by now rid of tritium and metals can be collected in a third tank. We have noted that there is no mention of the sodium present in sea water.

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2. Notes

**Technology Readiness Level**

When the first patent (No. 15 01581) was issued in 1995, the process was researched and developed at a nuclear plant in France treating LLW of cutting oil with contamination rate of 10 000 Bq/liter, contaminated by ten radionuclides that were a side-product from the periodic mechanical maintenance of the primary circuit reactor. We were prepared to build a processing machine.

Since 1996 we have had numerous contracts using our biological process to treat oils and effluents in France. Some select samples:

- Processing 25,000 liters of oil transformed into water with a residual waste of 3 per 1000. The machine had a processing capacity of 200 liters/day;
- Biological treatment of 4 $m^3$ of oil contaminated with plutonium from swing bridge mechanisms and fission regulator mechanisms;
- Treatment of effluent polluted by hydrocarbon with our biological process;
- Biological treatment of sludge from spent fuel withholding tanks;
- Degradation of 25,000 liters of cutting oil contaminated with natural uranium;
- Depollution, by means of biological process, of effluents that are composed of waste water and various soluble oils, side-products from washing the tanks that manufacture these oils.

**Timeline For Application**

The technology has gone through numerous tests and prototypes and is ready for industrial use.

**Cost**

Our process costs significantly lower than any of the other existing technologies. However, to be in a position to provide an accurate cost associated with using this process to treat the contaminated waste, more information is required regarding, among other factors, the concentration of Tritium (and possibly $^{137}$Cesium and $^{90}$Strontium) in grams/liter in the waste water stored in the big reservoirs.

**Challenges**

This unique and environmentally friendly technology using micro-organisms to treat radioactive liquid waste is a viable choice that brings the client substantial cost savings and yields a significantly lower volume of final waste while using a clean tech solution.

In the nuclear industry, all treatment of waste by biological means is trying by any account.
The key challenge for us is convincing waste management decision makers and users to accept and adapt to the idea of a new and innovative technology as being a safe and feasible alternative.

We feel very confident that our technology addresses extremely important problems related to radioactive liquid waste treatment in general and frequently difficult-to-treat waste in particular. This process is not only a good solution from a technological standpoint and its versatility for multiple applications but it is also a considerable capital investment for the user. We would be very happy to provide further information upon request.