Role of bacteria on the desorption of cesium from illite

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Introduction

As a result of the nuclear accident in Fukushima, various radioactive elements such as **cesium** were dispersed in the atmosphere before being deposited **on the soil** within a distance of 80 km around the nuclear power plant (Fig. 1a and b).

Cesium with half-life of 30 years and **properties similar to potassium accumulates in the clays**, especially illite, of the **upper soil horizons**.

Among soil remediation methods, phytoextraction is potentially relevant as it can be achieved *in situ* with no adverse effect on the biophysicochemical properties of the soil and more generally on the environment.

Cesium uptake by plants depends on sorption/desorption reactions to/from the soil particles and on biogeochemical processes in the rhizosphere.

Coupling bioaugmentation (use of microorganisms) with phytoextraction is expected to increase the bioaccessibility of Cs with consequently its higher accumulation in plants.

The aim of this work consists in increasing the release of Cs from illite .

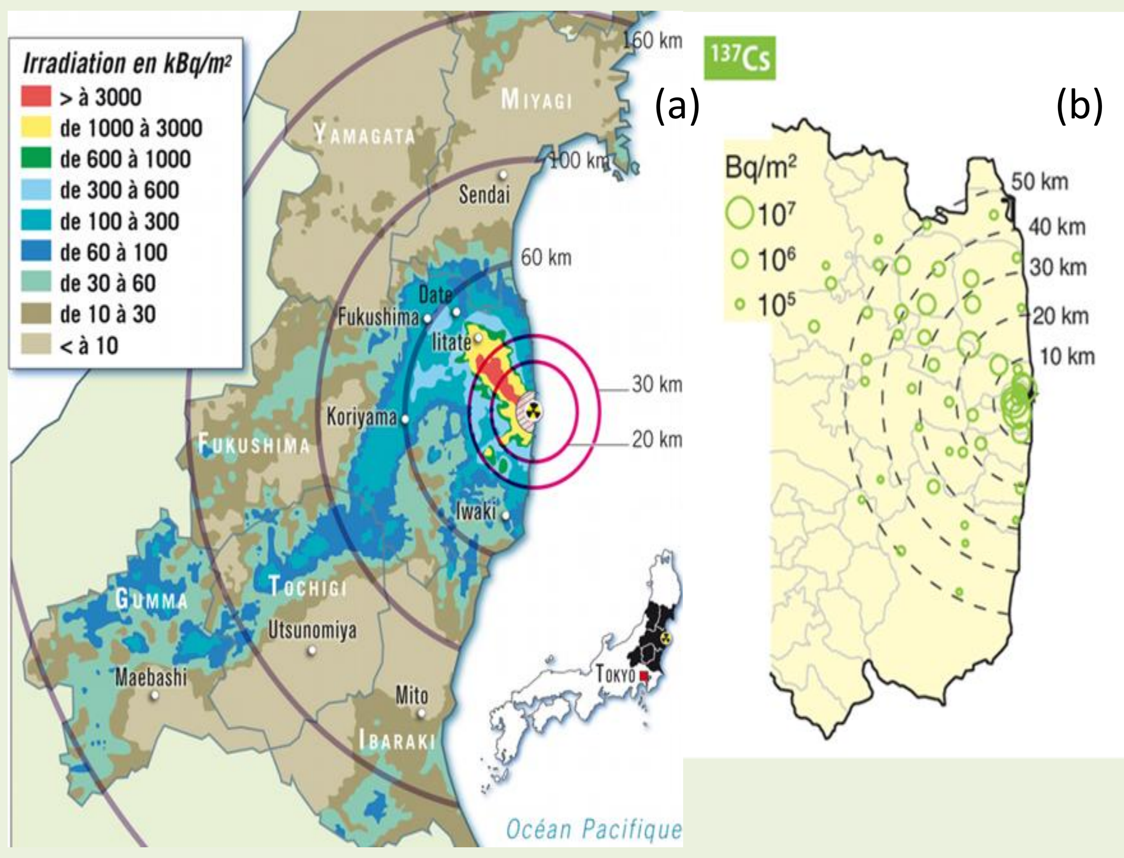

Fig 1 : Maps of the radioactivity distribution in the east of Fukushima prefecture; a: total irradiation; b: ^{137}Cs (Bq/m^2) [1]

Material and methods

After analysis of Cs-background in illite (by HR-MS-ICP) and tyndallization (3 cycles at 75 °C every 24h), illite powder was spiked with sterile solution of CsCl (100 mM) to give the following concentrations: 0.1 mM and 1 mM (i.e. range of concentrations found in contaminated soils of Fukushima). 5 mg of Cs-spiked illite were suspended in 50 ml of NaCl (0.1 mM) or in Dworkin and Foster (DF) minimum medium [2]. Cs-desorption was monitored by MS-ICP.

0.04 mM of either **citric acid** or **oxalic acid**, and ***Pseudomonas fluorescens*** **(ATCC 17400)** which potentially produce siderophores and organic acids, were tested as desorbing agents. Bacterial cultures without any contact with illite (trapped in a dialysis membrane) ("free cells") or able to form biofilms by contact with illite ("biofilms") were compared.

Results

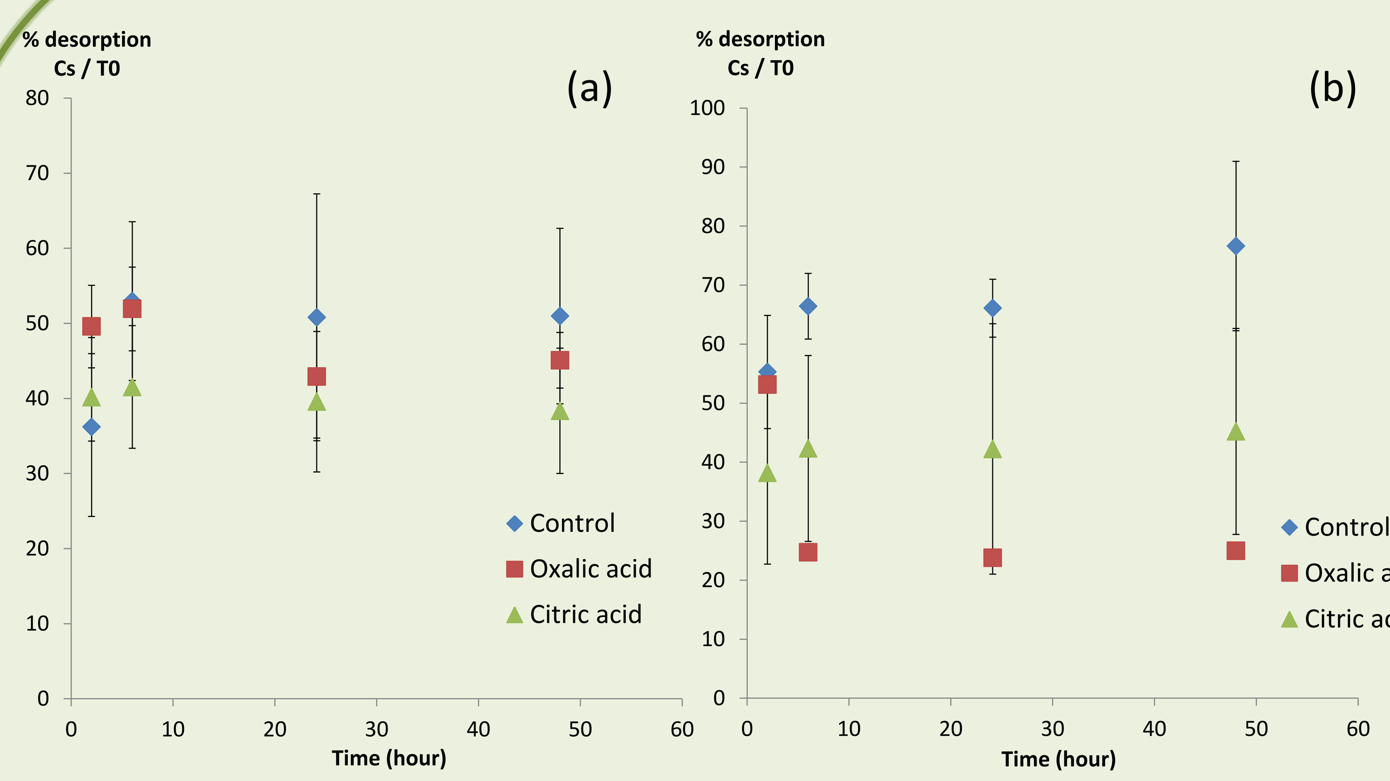

Fig 2 : Cesium (from illite) recovered in the solution (NaCl medium) after treatment with oxalic or citric acid. Initial Cs concentration in illite was 0.1 mM (a) and 1 mM (b).

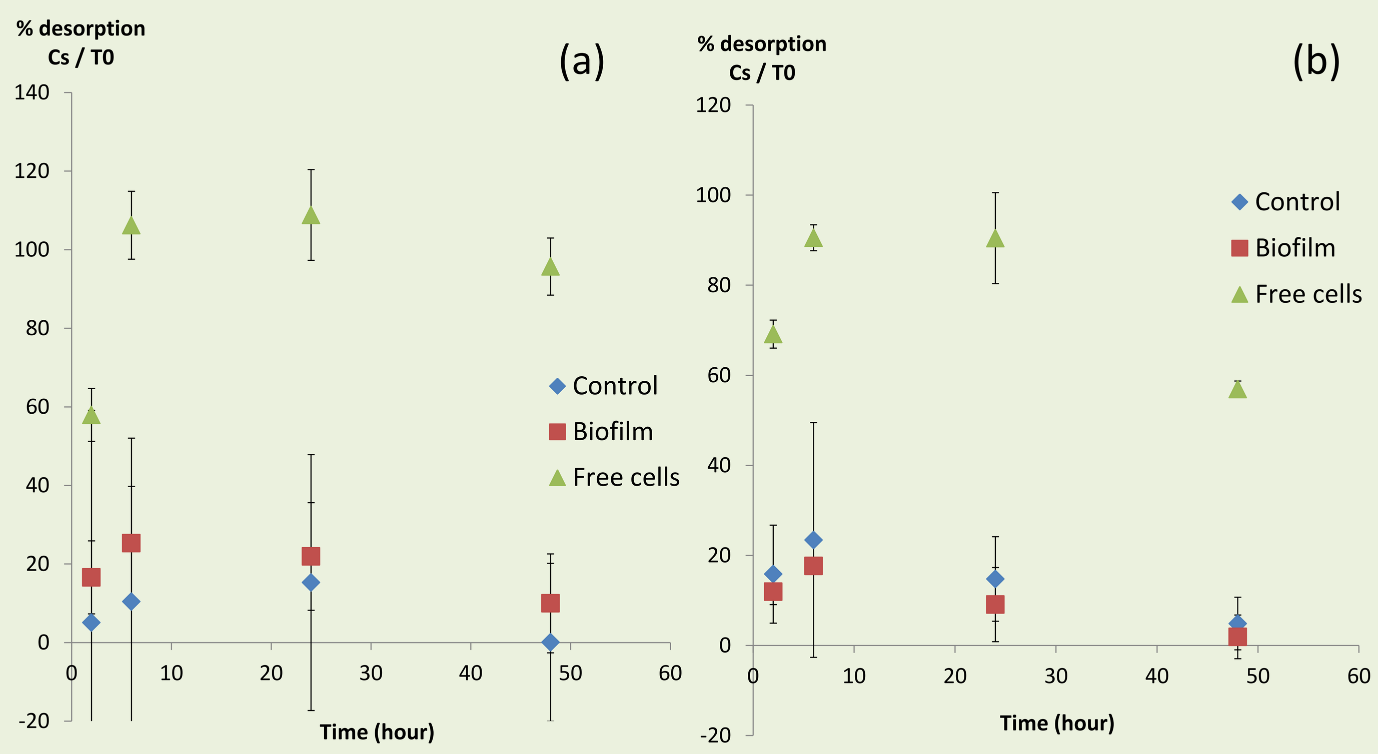

Fig 3 : Cesium (from illite) recovered in the solution (NaCl medium) after inoculation with *P. fluorescens*. Initial Cs concentration in illite was 0.1 mM (a) and 1 mM (b).

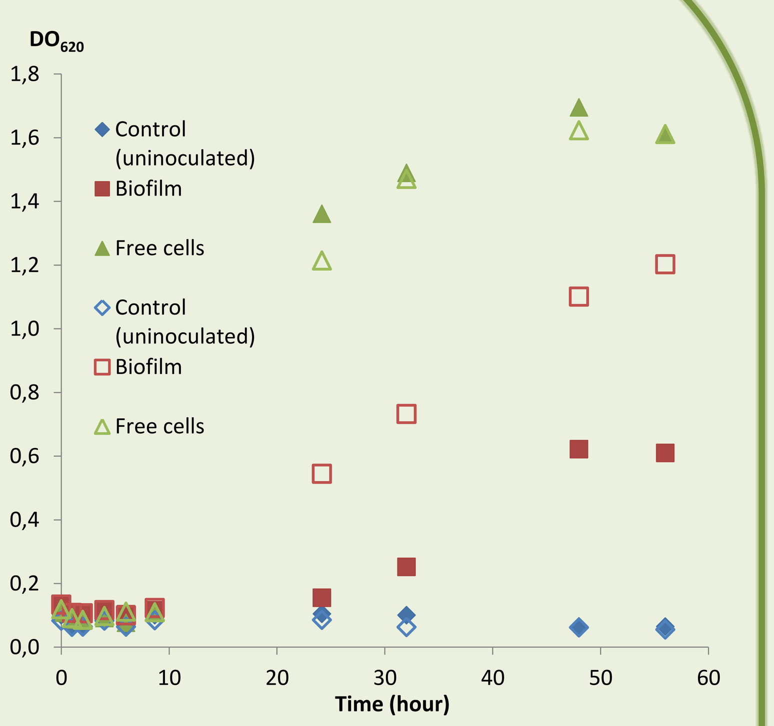

Fig 4 : Bacterial cell growth in DF medium with 0,1 mM (close symbols) or 1 mM of Cs (open symbols). Only free cells were taken into account, not those forming biofilms.

- For NaCl medium with illite spiked with 0.1 mM CsCl or 1 mM, citric and oxalic acids (Fig. 2a and b) are not able to desorb Cs from illite. Conversely, free cells (Fig. 3a and b) increased Cs desorption. Here, there is no differences depending on the Cs concentration used, contrary to what was observed by Wendling et al. [3], but concentrations were much higher.
- Bacterial cells grew with DF medium (Fig 4), but were not able to desorb Cs from illite in DF medium. A too balanced medium can explain this result by avoiding bacteria to mobilize illite minerals.
- An increase in the concentration of Al of illite was observed after 56h of desorption (data not shown). This is probably due to siderophores (produced by bacteria) via complexation of Al of illite.

Perspectives

- Analyzing interlayer sizes of illite to understand the mechanisms involved in Cs desorption: MET and MEB.
- Using growth medium free of minerals that bacteria are able to recover from illite (*e.g.* Fe, K, Mg).
- Testing other bacteria and other radionuclides (Am, Sr), especially siderophore-producing bacteria for Am.
- Associating bacteria with plant known for their (hyper)accumulation of Cs.

References:
[1] Fujiwara T. et al., 2012, Isotopic ratio and vertical distribution of radionuclides in soil affected by the accident of Fukushima Dai-ichi nuclear power plants, Journal of Environmental Radioactivity 113:37-44.
[2] Dworkin M. and Foster JW., 1958, Experiments with microorganisms which utilize ethane and hydrogen, Journal of bacteriology, 75:592-603.
[3] Wendling LA et al., 2005, Cesium Desorption from Illite as Affected by Exudates from Rhizosphere Bacteria, Environ. Sci. Technol., 39, 4505-4512.