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Need for research on the role of micro-organisms on the behaviour of radionuclides in aquatic and terrestrial systems and their transfer to Man *

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Summary

The authors underline the need for a co-ordinate multidisciplinar research on the role of micro-organisms on the behaviour of radionuclides in the environment. Aquatic as well as terrestrial micro-organisms appear to affect the biological availability of radionuclides. Besides, other species of micro-organisms, which are symbionts or inhabitants of the rhizosphere (plant-bacteria relationship) or of the digestive system (animal-bacteria relationship), seem important for the uptake, retention and release of radioactivity. Finally, together with new experimental approaches on the fate of radionuclides in aquatic and terrestrial ecosystems, models should also be developed for simulating, predicting and fitting the results and assessing the risk of potential transfer of radioactivity to man through the food chain.
Key-words : micro-organisms, symbionts, ciliates, radionuclides, food chain.

Résumé

Les auteurs soulignent la nécessité d'une recherche multidisciplinaire coordonnée sur le rôle des micro-organismes dans le comportement des radionucléides dans l'environnement. En effet, les micro-organismes aquatiques et terrestres semblent avoir une influence sur la disponibilité biologique des radionucléides. En outre, d'autres espèces de microbes, qui sont symbiotiques ou présents dans la rhizosphère (relation plante-bactéries) ou dans le système digestif (relation animal-bactéries), semblent également importantes pour la fixation, la retention et le relargage de la radioactivité. Des nouvelles approches expérimentales devraient être utilisées pour étudier le comportement des radionucléides dans les écosystèmes aquatiques et terrestres. Enfin, des modèles devraient être développés pour simuler, prédire et analyser les résultats et évaluer le risque d'un transfer potentiel de la radioactivité à l'homme, à travers la chaîne alimentaire.
Mots-clefs : micro-organismes, symbionts, ciliés, radionucléides, chaîne alimentaire.

1. Introduction

The contamination of the environment by man-made radioactivity has received considerable attention because of its potential harmful effects on living organisms and on man (see INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA), 1975, 1979, 1981, 1982). However, in spite of this effort, the behaviour of the radionuclides is not yet completely understood, especially in the biological portion of the biogeochemical cycle.

The potential importance of microbial action as a mechanism controlling or altering the biological availability of radionuclides in the aquatic and terrestrial ecosystems has been recognized (MASSON *et al.*, 1981; FISHER, 1982; MYTTENAERE and GIRARDI, 1982; and others). Together with the microbes are also acting pluricellular organisms, mainly on the resolubilization process of radioactivity. For instance, bioturbation, provoked by several benthic invertebrates, has been found to have a strong influence on the vertical distribution of transuranics. Bioturbation may thus in turn indirectly favour the resolubilization process by bacteria and other micro-organisms. Bacteria, together with heterotrophic flagellates and microzooplankters are now thought to play a major role in remineralization in the marine environment (AZAM *et al.*, 1983). In terestrial plants, grown in culture solution under gnotobiotic conditions, bacteria influence ion uptake, provoking either stimulatory or inhibitory effects (see literature in LYNCH, 1982). The relationship between plants and bacteria is a two-sided one : as symbionts and as inhabitants of the rhizosphere (which includes all microbes using root-derived substances as sources of carbon, nitrogen and energy), bacteria can either promote or inhibit plant growth (see GILES and ATHERLY, 1981; RHODES-ROBERTS and SKINNER, 1982).

In the human body and in animals, a similar two-sided relationship exists : the microbial population of the digestive system may either be beneficial (symbiotic micro-organisms) or harmful (pathogenic micro-organisms). It is known for instance that the gastro-intestinal flora constitues a defense system of the host against exogenous (eventually harmful) bacteria. Since techniques have been developed for controlling the microflora of the digestive tract in monogastric animals (see literature in DUCLUZEAU and RAIBAUD, 1979), it would be possible to study experimen-

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tally its effects on the absorption and distribution of ingested radionuclides.
In this paper we call attention to the need for research on the often disregarded but important role of bacteria and other micro-organisms on the behaviour of radionuclides in the aquatic and terrestrial ecosystems as well as in humans and animals.

2. Micro-organisms in aquatic ecosystems and in nuclear facilities

The aquatic ecosystems are inhabited by a broad population of micro-organisms : bacteria, fungi, microalgae, flagellates, microzooplankters. All these micro-organisms interact with the components (abiotic, as organic materials and sediments or biotic, as plants and animals) of the external medium, where they find nutrients necessary to sustain their life.
In the aquatic ecosystem, photosynthetic bacteria and microalgae (as well as macroalgae and higher plants) bioconvert solar energy into organic matter, being thus primary producers. These latter utilize the organic matter produced. However, a part of it is released into the external medium and used by micro-organisms (see literature in NIENHUIS, 1981) or by various animals (see literature in ELLIOTT, 1979). Another part is transferred to higher trophic levels by bacteriovores and various grazing animals. Bacteria, thanks to their large surface-to-volume ratio, may absorb nutrients at very low concentrations (AZAM *et al.*, 1983). It is thus possible that sedimentary bacteria are capable of incorporating very efficiently radionuclides diffused from contaminated sediments, even if the diffusion rate would be extremely low. Since bacteria are eaten by microflagellates, which are in turn preyed upon by microzooplankters, radionuclides taken up by them might be transferred to higher trophic levels and eventually to man. The utilization of experimental food chains (AMIARD and AMIARD-TRIQUET, 1975; KIRCHMANN *et al.*, 1978), in which micro-organisms are used as first links, would be useful to evaluate the potential hazards of radionuclide transfer to man.
The role of micro-organisms in nuclear facilities and in dumping areas deserves particular attention. Aerobic micro-organsims (several bacterial strains and a red yeast) have been harvested, during a shut-down of the BR2 reactor, from the water circulating in the primary loop of the pool and the storage canal (HORSTEN *et al.*, 1980). Moreover, aerobic and anaerobic micro-organisms have been found to influence the migration of organoradionuclide complexes and production of volatile products, which escape into the atmosphere (FRANCIS *et al.*, 1980 a, b; FRANCIS, 1982; COLOMBO, 1982).
Micro-organisms living on deep sediments of the dumping areas (GOMEZ *et al.*, 1981) might also influence the migration of radionuclides by similar processes. However, our knowledge of the deep sea microbial population is still limited and research on this topic should be encouraged.

3. Micro-organisms in terrestrial soils and in the rhizosphere

A large number of micro-organisms have been found in terrestrial ecosystems. Soil microflora has been extensively investigated for their relevance to agriculture. For the same reason, the microbial community of the rhizosphere has been studied by many research groups (see RHODES-ROBERTS and SKINNER, 1982). Published work has demonstrated unequivocally that bacteria influence ion uptake by plant roots (LYNCH, 1982). Bacteria may either stimulate ion uptake, possibly by providing chelating agents or plant growth regulators which promote active ion transport, or produce an inhibitory effect, by competing for the nutrients or by producing phytotoxic substances (LYNCH, 1982). It has been found that specific strains of the rhizobacteria *Pseudomonas* produce extracellular compounds, called siderophores, which promote plant growth by complexing environmental iron and thus making it less available to certain native microflora (KLOEPPER *et al.*, 1980). As chemical and biochemical similarities have been observed between Fe(III) and Pu(IV), the siderophores could play an important role in the Pu transfer in the food chain (MYTTENAERE and GIRARDI, 1982).
Despite the demonstration of the role of bacteria in ion uptake by roots from plant culture solutions, their effects in soils have been scarcely investigated. The use of radiation-sterilized soil has revealed that the presence of bacteria decreased the P content of plants (BENIANS and BARBER, 1974), probably by competing with them. However, phosphate-dissolving bacteria may provide plant with P, a function usually attributed to mycorrhizal fungi (LYNCH, 1982). Soil micro-organisms and especially rhizobacteria might thus influence the uptake and distribution of radionuclides in plants and play consequently a role in their transfer to man.

4. Micro-organisms in higher trophic levels

Invertebrates as well as vertebrates possess a large number of micro-organisms. It has been calculated that the human body contains about 10^{14} bacterial cells and is itself constituted by 10^{13} animals cells, which consequently represent only 10 % of the total cell population.
Like man, animals possess a large number of bacterial cells, mainly in their digestive systems (DUCLUZEAU and RAIBAUD, 1979). It has been speculated that human and animal life would be impossible without the intestinal microflora, if its role was not artificially replaced by added substances and by special devices. One may thus argue that the microbial population of the digestive system would play also a major role in the utilization by the host of ingested radionuclides. The effect of the microflora can be demonstrated by experiments on the metabolism of radionuclides in normal and in germ-free animals. Particular antibiotics which control the microflora may prove also to be useful (DUCLUZEAU and RAIBAUD, 1979). Another

approach would consist in studying *in vitro* the metabolic processes of the symbiotic micro-organisms, using radioactive materials. For instance, interesting studies have already been done on the bacteria and ciliates, which enable ruminants to utilize plant material (DELFOSSE-DEBUSSCHER *et al.*, 1979a, b; THINES-SEMPOUX *et al.*, 1980; HELLINGS *et al.*, 1981; SNYERS *et al.*, 1981; and others). Extension of such studies to other animal systems might be of value for a better understanding of the role micro-organisms play in uptake, distribution and retention of radionuclides.

5. Modelling

Several models have already been elaborated for the uptake and transfer of radioactivity in aquatic and terrestrial ecosystems (BELOT and DELFORGE, 1982; BONOTTO *et al.*, 1982; BOONE *et al.*, 1982; BUNNENBERG *et al.*, 1982; FRISSEL *et al.*, 1982; KOCHER, 1982; KOMATSU, 1982; LINSLEY and SIMMONDS, 1982; LINSLEY *et al.*, 1982; MEHTA and SHERMAN, 1982; STRACK, 1982). Advantage may thus be taken from existing models for elaborating new ones, which include the role of micro-organisms. Such models would be useful for simulating, predicting or for fitting the experimental results and assessing the risk of a potential transfer of radionuclides to man through the food chain.

6. Conclusion

The above considerations clearly show that an urgent need exists for a co-ordinate multidisciplinar research on the often disregarded but important role of micro-organisms on the behaviour of radionuclides in the environment. International co-operation would permit to realize this research more efficiently and in a shorter period of time.

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