Effects of Acute Gamma-irradiation on the Aquatic Microbial Microcosm in Comparison with Chemicals

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INTRODUCTION

Recently, there are a number of initiatives that are developing frameworks to provide criteria and a methodological approach for the protection of the environment from ionising radiation on a national and international scale. Discussion in such initiatives has raised some subjects to be studied. One of these subjects is comparison of environmental effects between ionising radiation and other toxic agents (Bréchignac *et al*., 2003; Polikarpov *et al*., 2004).

Ecosystems are exposed to ionising radiation as well as various toxic agents derived from human activities. Ecological effects of ionising radiation should be therefore assessed compared with those of other toxic agents for a better understanding of radiation risks, especially for the public and decision makers. However, effects of ionising radiation and other toxic agents on ecosystems (practically, individuals or populations of non-human biota in most cases) have been evaluated by different methods each other. Therefore, there have been few comparative effects data obtained by the same methods. In addition, indirect effects through interspecies interactions have not been taken into consideration, though their importance has been pointed out.

Against this background, we have started to compare community-level effects between ionising radiation and other toxic agents using experimental model ecosystems, i.e., microcosm, mimicking aquatic microbial communities, which play an important role in material cycles.

MATERIALS AND METHODS

The microcosm used in this study was developed by Kurihara *et al*. (1978). It consists of populations of the green algae *Chlorella* sp., *Scenedesmus* sp. and blue-green alga *Tolypothrix* sp. as producers; the ciliate protozoan *Cyclidium glaucoma*, rotifers *Lecane* sp. and *Philodina* sp. and oligochaete *Aeolosoma hemprichi* as consumers; and the bacteria *Pseudomonas putida*, *Bacillus cereus*, *Acinetobacter* sp., Coryneform bacteria and so on as decomposers. Interspecies interactions among these organisms mimic the essential processes in aquatic microbial communities.

The steady-state microcosm was acutely irradiated with ^{60}Co γ-rays at 100, 500, 1000 and 5000 Gy, and population changes were observed for 25 days. Cell densities of viable bacteria were measured by the colony counting method using the PY medium. Length of filamentous alga *Tolypothrix* sp. was measured in some microscopic images of the microcosm. The other organisms were counted under a microscope.

Holistic effects of γ-rays on the microcosm were compared with those of some chemicals using the following "effect index for microcosm (EIM)", which we had proposed previously (Fuma *et al*., 2005):

$$\mathrm{EIM} = \frac{100}{T}\int_0^T \sqrt{\sum_{i=1}^{n} W_i \left\{\frac{N_{i,\mathrm{Con}}(t) - N_{i,\mathrm{Exp}}(t)}{N_{i,\mathrm{Con}}(t)}\right\}^2}\, dt \quad [\%]$$

where

T = Experimental periods.

n = The number of species concerned.

Wi = Ecological weighting factors for species *i*.

<Producers> *Chlorella* sp., *Scenedesmus* sp. and *Tolypothrix* sp.: 1/3*1/3=1/9

<Consumers> *C. glaucoma*, *Lecane* sp., *Philodina* sp. and *A. hemprichi*: 1/3*1/4=1/12

<Decomposers> Bacteria: 1/3

$N_{i,Con}(t)$ = The log-transformed population of species *i* in the control microcosm on day *t*.

$N_{i,Exp}(t)$ = The log-transformed population of species *i* in the exposed microcosm on day *t*.

RESULTS AND CONCLUSIONS

In the control microcosm, population densities of the constituent organisms were almost constant during the experiment (Fig. 1). At 100 Gy, significant effects were not observed for any organisms. At 500 Gy, *A. hemprichi* died out. *C. glaucoma* was temporarily decreased just after irradiation. Green algae were decreased on day 25. *Tolypothrix* sp. was increased after day 15. The other organisms were not affected. At 1000 Gy, *A. hemprichi* died out. *C. glaucoma* was temporarily decreased just after irradiation. *Scenedesmus* sp. and bacteria were decreased after day 15. *Chlorella* sp. was decreased on day 25. *Tolypothrix* sp. was increased after day 15. Rotifers were not affected. At 5000 Gy, *C. glaucoma*, *Lecane* sp. and *A. hemprichi* died out. Bacteria were decreased just after irradiation, and the cell densities remained significantly lower than controls during the experiment. Green algae were decreased after day 15. *Tolypothrix* sp. was increased after day 15. *Philodina* sp. was not affected.

As a whole, degrees of the effects on the populations of the microcosm depended on radiation doses. However, some unexpected effects were observed. For example, *Tolypothrix* sp. was increased at 500 Gy or higher doses. It is likely that this unexpected result arose from indirect effects. In the irradiated microcosm, decrease in green algae would have provided *Tolypothrix* sp. with an advantage in the competition for light and inorganic nutrients. Breakdown products such as CO_2 and inorganic nutrients originated from dead organisms may also have contributed to this increase in *Tolypothrix* sp. This suggests that this microcosm test evaluated not only direct effects of radiation but also indirect effects through interspecies interactions.

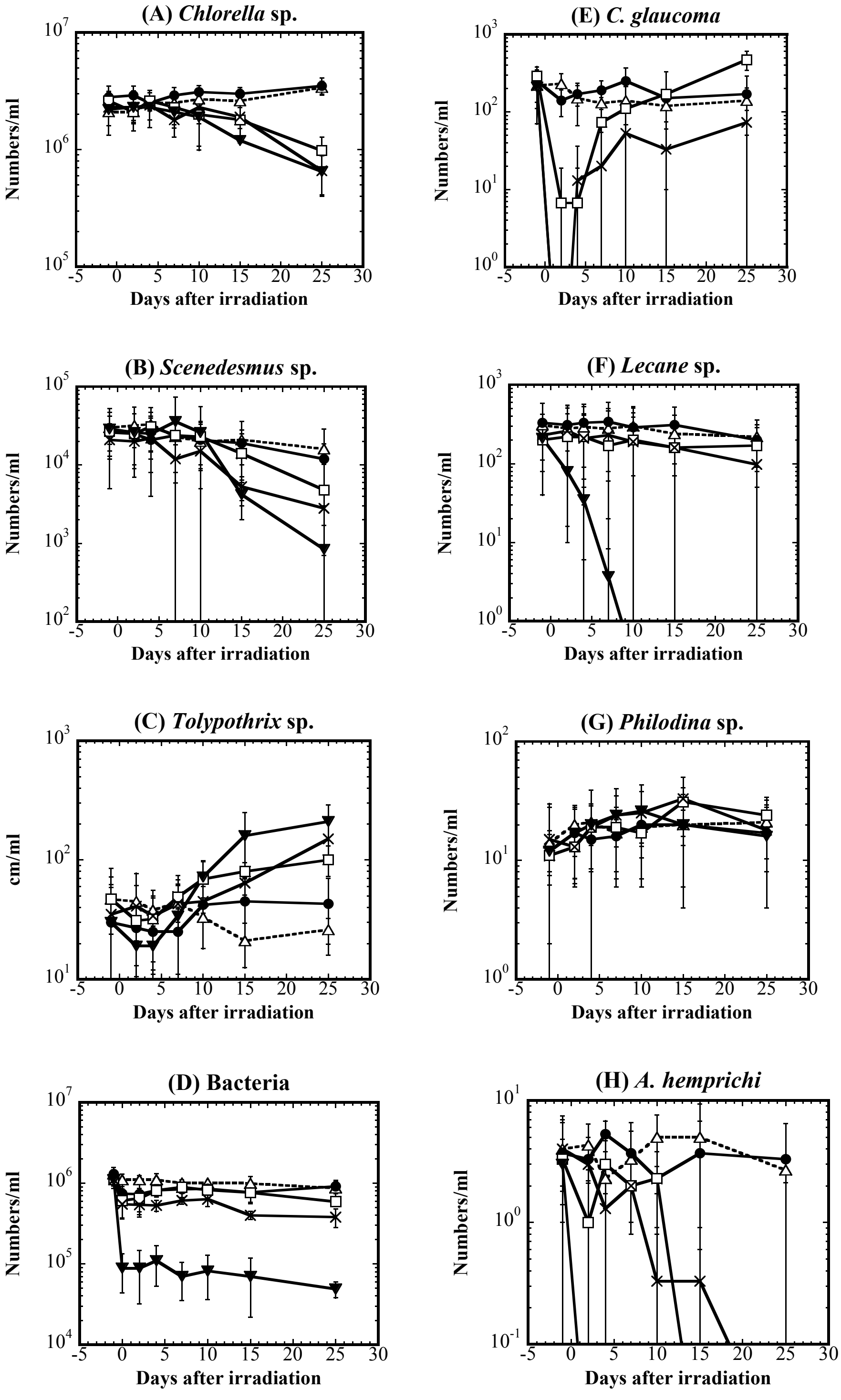

Figure 1. Population changes in the microcosm after γ-irradiation. Error bars are standard deviations (*n*=3).

Effects of γ-rays on the microcosm were quantitatively compared with those of some chemicals, which had been already evaluated in other studies (e.g., Takagi *et al*. 1994). For this comparison, the EIMs were calculated for γ-rays and benthiocarb (herbicide), and the resulting dose-EIM relationships are shown in Fig. 2. A 50 % effect dose for microcosm (ED_{M50}), i.e., dose at which the EIM was 50 %, was 5600 Gy for γ-rays, while it was 6.7 mg/l for benthiocarb. This comparative effects data, i.e., equi-dosimetric data, will contribute to an ecological risk assessment of ionising radiation compared with benthiocarb in aquatic microbial communities. However, this contribution will be limited in scenarios of severe nuclear accidents or inadequate disposals of highly radioactive wastes, because the microcosm was acutely irradiated by high doses of γ-rays. Comparative effects data on simazine (herbicide), LAS (linear alkylbenzenesulfonate; surfactant), soap and copper will be also presented in the conference.

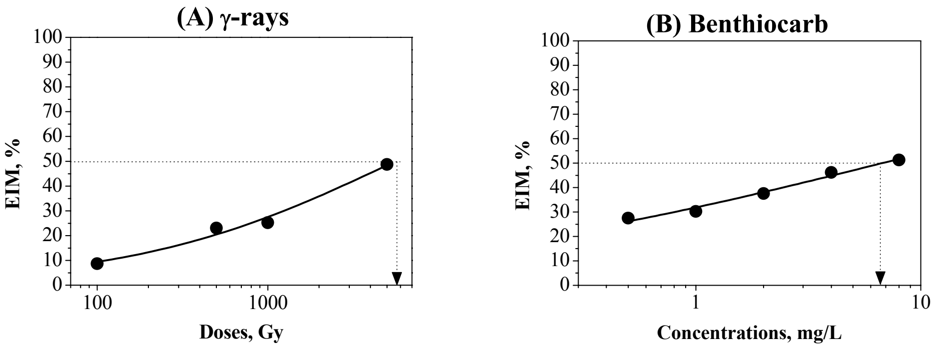

Figure 2. Dose-EIM relationships of γ-rays and benthiocarb.

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