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Fukushima urges international scientific cooperation in marine radioecology

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Fukushima drives a challenge for marine radioecology

Over the last decade, a number of tsunamis have been observed across the world's oceans, particularly in the Indian Ocean in 2004 off the coast of Sumatra and in the Pacific Ocean off the coast of Peru in 2007, off Samoa in 2009 and off Chile in 2010. Their characteristics and the impact they had on the coastal environments have been extensively studied [e.g.1,2,3,4,5].

The M_w 9.0 earthquake that hit northeast Japan on March 11, 2011 and the tsunami that followed, caused major disasters in the country: a natural disaster that has led to unprecedented industrial disaster[6]. The destruction of industrial and port facilities and especially the damage caused to the cooling systems at Fukushima Dai-Ichi nuclear reactor complex will have long-term consequences on the environment and the economy of the coastal fringe.

In this specific context of a natural disaster, studying the impact of radioactive releases on ecosystems is a challenge for radioecologists in general and for marine radioecologists in particular since this accident is in fact the first nuclear accident that has ever had such a direct impact on the marine environment. The fate of radionuclides in the marine environment will be particularly difficult to assess since other types of pollutants have also been released and some key parameters that affect their behavior in the environment have been changed by the impact of the tsunami.

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Combination of radioactive releases and tsunami impact: a multi-pollution problem

The radioactive contamination of the marine environment occurred by aerial deposition and by continuing discharges and outflow of water with various levels of radioactivity from the damaged reactors at Fukushima Dai-ichi nuclear reactor complex[6].

Reconstructing the radioactive releases will involve an enormous amount of work. The marine environment was first affected by the atmospheric releases that followed the reactor explosions. Around 10,000 m3 of controlled releases were also discharged from barges into the sea. Uncontrolled high level discharges were also released at various periods and other discharges are still occurring. Washout of the land contaminated by the various releases and subsequent transfer via coastal rivers is also a major contributor to this source term and will be long-lasting. Scientists will have to compare the information given by the Japanese authorities with measurements in the environment in order to thoroughly assess this source term. To this end, modeling will be a key tool.

However, releases from the damaged reactors are not the only source of pollution. The tsunami destroyed many industrial facilities along the coast, including port areas, and the soils appear to be strewn with all sorts of debris, implying that we should expect to find a wide range of hazardous products that have been discharged into the environment[7,8]. Studies on the impact of radioactive releases from Fukushima Dai-Ichi on the environment must take account of these multi-pollution aspects.

Environmental disturbances expected in the sediment compartments and biota

Sediment and suspended matter

The tsunami has mobilized huge amounts of sediment. Several videos showed tsunami waves that were already black before breaking inland. Generally, during tsunami, sediment is moved onto the land (run-up) and the ensuing backwash carries sediment and debris from the land to the ocean.

Geomorphological studies demonstrate that large tsunamis induce extensive erosion on shorelines and at river mouths. It is well known that such highly dynamic events lead to severe sediment disturbances, resulting in complex deposits due the combination of both erosion and deposition processes linked to landward and seaward flows. However, while onshore tsunami sediment imprints have been extensively studied, this is not the case for sediment deposited in marine coastal areas, mainly due to the low preservation of such deposits in high-energy areas with strong reworking processes by waves.

Land subsidence is also suspected to have occurred and is an additional factor in the disturbance of sediment distribution in this area.

All these geomorphological and sedimentary disturbances in the coastal zone would lead to an increase in suspended matter in the area impacted by the tsunami which in turn would impact on the behavior of radionuclides released both on land and in the marine environment. Such increases in suspended matter were observed at various locations in the Indian Ocean following the “Sumatra” tsunami in 2004[9]and increases in suspended matter have even been observed on a large scale for several years across the entire North-East Indian Ocean[10,11].

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Biota and halieutic resources

Regarding the biota, it is expected that the initial surge of the tsunami badly damaged the coastal area and it is likely that species living on hard substrates were scraped off and in some cases it may have even removed the substrates. Soft-bottom communities have also certainly been affected by disturbances produced by the tsunami, such as changes in sediment granulometry and community destruction due to wave forces.

It is likely that the coastal ecosystems that have been affected will undergo a re-colonization of the environment first by opportunistic species, as classically observed in disturbed systems, this process of re-colonization should take several months.

Although there are numerous studies on tsunami impacts on seagrass beds and coral reefs and on the possible roles played by them in buffering (or not) the physical impacts of a tsunami, little is known about the large-scale response and resilience of benthic communities to tsunamis. Indeed, the effects of physical disturbances on soft-bottom communities have long been studied from coastal areas to deep sea and there is extensive literature related to this topic but high-energy tsunami event disturbances have seldom been considered.

It is quite obvious that the effects of tsunamis on benthic communities are dependent on many factors, such as community structure, habitat, the extent of the physical disturbance (magnitude and scale) and the possibility of immigration and colonization by organisms from undisturbed areas. Kendall[12] and his collaborators have shown that although massive disturbance has removed much of the shallow-burrowing infauna from sandy beaches, deeper burrowing species appeared to have survived well following the 2004 Indian Ocean tsunami on the coast of Thailand.

Changes may also be caused by indirect effects, such as changes in the organic enrichment of the sediment and in suspended matter contents, which in turn lead to changes in light levels. The deep geomorphological- and sedimentological- related tsunami modifications should lead to an increase in filter feeders and grazers. Indeed, Lomovasky[13] and his collaborators demonstrated clear differences in the structure and composition of the soft-bottom macrofauna assemblages before and after the 2007 tsunami in Peru, with an increase in both number and biomass of deposit-feeders, suspension-feeders and grazers.

If it proves to be the case that substantial changes have occurred to benthic community structures, disturbances to pelagic communities will also be expected, together with the possible consequences for halieutic resources.

The tsunami has also destroyed all the aquaculture facilities, of which there were many in Sendai Bay, changing the landscape of the coastal environment. Reconstruction will be difficult in zones affected by releases from the Fukushima Dai-Ichi nuclear reactor complex and this may remain the case for a

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relatively long time, mainly subject to assessment of contamination in these zones and how this changes over time.

The impact on activities related to the sea, especially farming and fishing, will be considerable and coastal zone management specialists will need to assess social and economic consequences of these events. To this end, the lessons learned from this disaster and from the numerous studies that have been made in the last ten years regarding the impact of tsunamis, especially following the very powerful tsunami of 2004 in the Indian Ocean, which affected many countries, should serve to improve the ways in which coastal hazards such as the tsunami hazard are factored into integrated coastal area management[14].

Triggering wide collaboration of the international scientific community

A variety of challenges must be met to carry out a full assessment of the impact of radioactive releases within the context of a natural disaster which has caused a great change to the environment and has led (and continues to lead) to many different pollutants being released into the environment.

Although the tsunami has affected the terrestrial environment just as extensively as the marine environment, the specific nature of the marine environment means that its analysis is a more delicate matter. Furthermore, the accident at Fukushima is the first nuclear accident that has directly impacted on the marine environment. Pre-tsunami and post-tsunami data will be required, including at least coastal geomorphology, bathymetry, sediment characteristics, and the functional groups of benthic communities. A huge amount of work is involved, which cannot be achieved without the Japanese scientists and local stakeholders; however, they should certainly not work in isolation but be able to draw on the input of scientists from all over the world.

It is essential for the wide international community to learn all it can from the consequences of the disaster at Fukushima, in the area of facility safety, naturally, as well as in other areas, including ecology, radioecology, coastal area management and preparedness for managing serious accidents. The number of sites in the world where studies such as these can be performed is, fortunately, very limited, and, therefore, we must endeavour to ensure that they can serve as international research and observation laboratories.

September 2[d], 2011

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