Transport of anthropogenic radionuclides between the Pacific and Indian Oceans

Daniela Pittauer and Helmut W. Fischer

Man-made radioisotopes are forms of radioactive elements present in the environment as a result of human activities. They originate from nuclear research and industry, including nuclear weaponry. This is also the case for plutonium isotopes. A nuclear material is created by nuclear fission or activation in a reactor core or a nuclear bomb explosion. Sometimes it is further processed industrially, for example in a weapons complex or spent fuel reprocessing plant. Even after being released into the environment, accidentally or deliberately, the substances keep a characteristic isotopic composition - a fingerprint of their origin.

Studying trace amounts of plutonium isotopes in ocean sediment cores in combination with natural radionuclides makes it possible to reconstruct sedimentation histories in individual study sites and quantify sedimentation and/or deposition rates. Additionally, plutonium isotopes provide information about transport of water masses and particles with the ocean currents between the identified source (e.g. nuclear test site or a damaged nuclear reactor) and the sampling location.

The sediment cores for this study were taken at deep sea stations in the West Pacific Ocean margin and the Indonesian Throughflow (ITF), which is a complex array of passages that provide a low latitude connection between Pacific and Indian Ocean (Figure 64). They were sampled during sea-

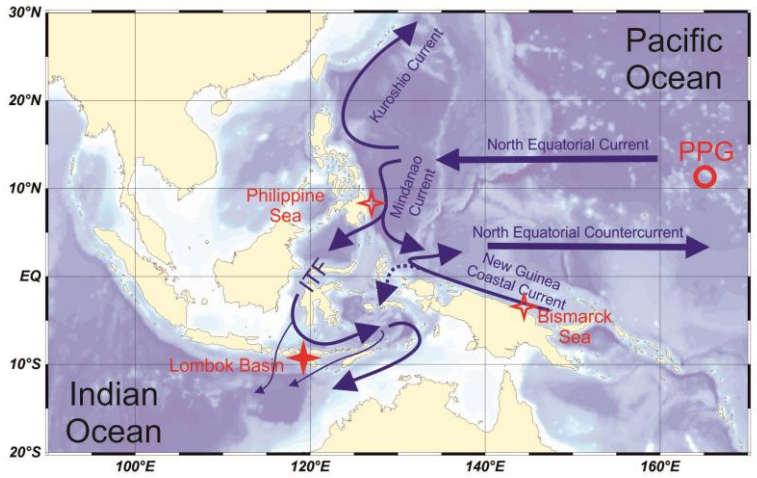

Figure 64: Locations of study sites in the Indonesian Throughflow (ITF) and west Pacific margin. Pacific Proving Grounds (PPG), where the U.S. performed 109 atmospheric tests during 1940's and 1950's, is marked with a circle.

going expeditions on the German research vessel "Sonne", organized by MARUM – Centre for Marine Environmental Sciences, University of Bremen, in 2005 and 2013. Samples taken from the upper sediment layers, covering approximately the last century of sedimentation, were studied by a combination of radiometric and mass spectrometry techniques, including gamma and alpha spectrometry at IUP and Alfred Wegener Institute in Bremerhaven, as well as accelerator mass spectrometry (AMS) at Department of Nuclear Physics, Australian National University in Canberra, and inductively coupled plasma mass spectrometry (ICP-MS) at Centre for Nuclear Technologies, Technical University of Denmark in Roskilde. Studying activities and ratios of plutonium isotopes revealed the deposition history and sources of plutonium in the region.

The United States conducted an extensive nuclear test programme at the Bikini and Enewetak Atolls in the Marshall Islands, known as the Pacific Proving Grounds (PPG), during 1940's and 1950's. The total estimated fission yield was 57.7 Mt, which is over 30% of 189 Mt globally. Moreover, PPG is an important local and regional source of anthropogenic radionuclides. Plutonium isotopes deposited from the local fallout are known to be distributed from the PPG by the North Equatorial Current and Kuroshio Current towards the Northwest Pacific Ocean marginal seas.

In the Lombok Basin, located more than 5000 km southwest of PPG, we could demonstrate that the transport of the transuranic radioisotopes is also significant in the southern direction, along the Mindanao Current and further through the ITF (Pittauer et al., submitted). Based on the end-member analysis of plutonium atom ratios, we inferred that the portion of PPG derived plutonium at this site was close to 100% during 1950's and 1960's. Starting in the 1970's, a portion of plutonium originating from the global stratospheric fallout is also present, yet PPG plutonium remains a significant source due to continuous remobilization until these days (Figure 65). Another transuranic isotope related to nuclear weapons testing, Americium-241, is also present in the sediments. This is not the case for a common fission product, Caesium-137, which is not well preserved in ocean sediments due to its higher solubility.

In our on-going research we focus in deep sea sediments at another two stations, in Philippines Sea east of Mindanao and Bismarck Sea east of Papua New Guinea. Here the plutonium deposition conditions at the entrance of North Pacific waters to the ITF are investigated, as well as possible exchange of anthropogenic radioisotopes between the North and South Pacific.

References

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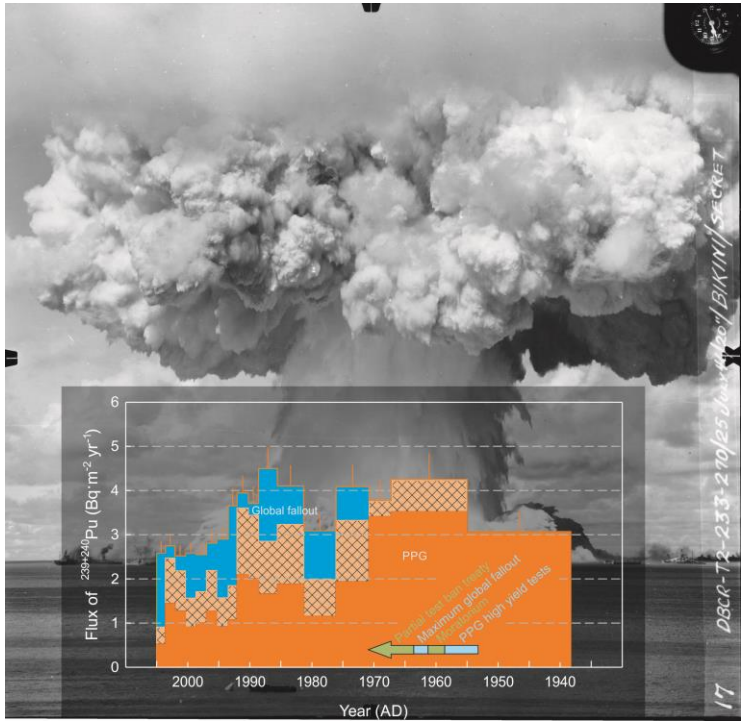

Figure 65: Mean yearly Plutonium isotopes fluxes to the sediment estimated based on the Lombok Basin core analysis, illustrating a continuous transport of the anthropogenic isotopes through the ITF. Different sources are distinguished by different colours: orange (and cross-hatched orange) stands for lower and upper estimate of PPG origin; the portion of global stratospheric fallout is marked in blue. Background photo: Bikini Nuclear Test 25 July 1946 (credit: Naval History and Heritage Command).