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Accumulation of ^{210}Po in coastal waters (Gulf of Trieste, northern Adriatic Sea)

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ABSTRACT

The total activity of ^{210}Po was determined by alpha-spectrometry in various samples (matrices) collected in the Gulf of Trieste (northern Adriatic Sea) where fresh water inflows, especially from the Isonzo River in the northern part, affect water quality. Observed ^{210}Po levels were: 1) 0.56–3.75 mBq/L in the dissolved phase (<0.45 μm) in the seawater column and local rivers, 2) 0.35–3.11 mBq/L (400–2300 Bq/kg, dry weight, dw) in suspended particulate matter (SPM, 0.45–20 μm) in the seawater column and local rivers, 3) 40 (Isonzo River) – 158 Bq/kg (in a surface sediment cores collected in a N–S transect in the gulf and sectioned to the depth of 20 cm) and 4) 239 (autumn) – 415 to 1800 (spring) Bq/kg (dw) in meso(zoo)plankton (>200 μm). In seawater and tributaries, up to 80% (mean 49%) of total ^{210}Po was found in particulate form. In sediments, slightly higher levels were encountered in the Isonzo prodelta and in the central (depocenter) part of the gulf. K_D (L/kg) calculated between seawater and SPM, and seawater and sediment amounted to about 5×10^6 and 6×10^4, respectively. Lower autumn ^{210}Po levels can be a consequence of biological dilution by higher mesozooplankton biomass in the autumn compared to spring. Plankton fractionation revealed in general the highest levels in the >200 μm mesoplankton fraction (239–1800 Bq/kg) followed by 50–200 μm (388–996 Bq/kg) and 20–50 μm (318–810 Bq/kg) microplankton fractions. Obtained data show higher ^{210}Po levels in all matrices analyzed in the Gulf of Trieste compared to other Adriatic (central Adriatic) and western Mediterranean areas. The ^{210}Po/^{210}Pb ratios in water, plankton and sediments were mostly below or around 1, while this ratio was much higher at higher trophic levels (up to about 50), reflecting a preferential bioaccumulation of ^{210}Po over ^{210}Pb. ^{210}Po accumulation between seawater and SPM and seawater and mesozooplankton amounted to 3.7×10^4 and 1.1×10^4, respectively, similar to other Adriatic areas. Comparison of the relative importance of pelagic and benthic bioaccumulation pathways, excluding the filter feeder bivalves, suggests greater accumulation in pelagic-feeding species.

1. Introduction

Polonium-210 (^{210}Po, $t_{1/2} = 138.4$ days) is a naturally occurring radionuclide originating from the uranium-238 decay chain as the daughter of lead-210 (^{210}Pb, $t_{1/2} = 22$ years) (Siegel and Bryan, 2005). The alpha decay of ^{210}Po accounts for most of the radioactive dose to marine organisms (Aarkrog et al., 1997; Fowler, 2011). Moreover, ^{210}Po may become enhanced through atmospheric and run-off inputs due to anthropogenic activities, including coal combustion, mining, industrial, shipping and agriculture activities leading to increased public and occupational radiation exposure (Briand, 2002; Kim et al., 2005; Vreček and Benedik, 2003; Othman and Al-Masri, 2007). ^{210}Po is strongly associated with particulate organic matter in comparison to ^{210}Pb, which tends to adsorb onto mineral particles (Fowler, 2011). Consequently, ^{210}Po should have a longer residence time in surface waters than ^{210}Pb since it is more rapidly recycled between the dissolved phase and organisms (Stewart et al., 2008). The high radiotoxicity of ^{210}Po is a consequence of the combination of its high specific activity and its relatively efficient uptake into soft tissues. In some cases it can represent a serious risk to human health, i.e. contributor to radioactive dose to the population, particularly due to its biomagnification along marine (benthic and pelagic) food webs

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(Pentreath et al., 1989; Fowler, 2011; Delfanti and Papucci, 2013) to a greater degree than its parent ^{210}Pb. In the marine environment, plankton has been shown to play a crucial role in the accumulation, transfer and biogeochemical cycling of number of trace elements and radionuclides, including ^{210}Po (Fowler, 2011; Mason, 2013). This seems to be dependent on several factors including organism type and size, physiology, food type and ingestion rate, life cycle and environmental conditions.

The scope of this work was a radioecological study of ^{210}Po in water, particulate matter, plankton and sediments of the Gulf of Trieste (northern Adriatic Sea) to better understand the biogeochemical processes governing ^{210}Po concentration levels, distribution, seasonal dynamics and bioaccumulation in pelagic and benthic organisms. In order to comprehensively answer questions about the radiation doses previously reported for the Gulf of Trieste by Štrok and Smodiš (2011), an in-depth knowledge of the behavior of this radionuclide in a coastal marine environment is necessary (Fowler, 2011).

2. Materials and methods

2.1. Study area

The Gulf of Trieste is a shallow marine basin in the northernmost part of the Adriatic Sea (Fig. 1). The Gulf is approximately 500 km^2 in area with a maximum depth of 25 m and is partially isolated from the rest of the northern Adriatic Sea by a shoal extending SE-NW, from the Istrian peninsula to the Grado-Marano lagoon. The salinity of the surface waters in the gulf ranges roughly between 30 (in late spring) and 38 and the surface water temperature varies normally between 8 (February) and 27 °C (July–August). Vertical temperature and salinity gradients in late summer result in bottom water oxygen depletion and occasionally hypoxia and even anoxia. The main freshwater inflow is from the Isonzo (Soča) River in the north with an average flow of about 150 m^3 s^{-1} exhibiting spring and autumn floods governing by snowmelt and rain, respectively. The second tributary is Timavo River, entering the gulf in the northeastern side with an average flow of about 30 m^3 s^{-1}. Smaller coastal rivers entering the gulf on its eastern side are Rosandra and Ospo (discharging into the Bay of Muggia), Rižana (discharging into the Bay of Koper) and Dragonja (discharging into the Bay of Piran) with average flows ranging between 4 and 1 m^3 s^{-1}.

Sediments in the northern part of the gulf primarily originate from the Isonzo River and are mostly composed of carbonates. In the eastern part of the gulf, sediment is derived from flysch deposits in the hinterland. Coarse sediments prevail along the northwestern littoral zone and grain-size decreases (clayey silt) towards the central part as Isonzo River influence diminishes (Brambati, 1970). Conversely, sediments in the central part of the Gulf of Trieste are mostly composed of clay and silt sized material along the southeastern shore, but quickly transition to silty sands in

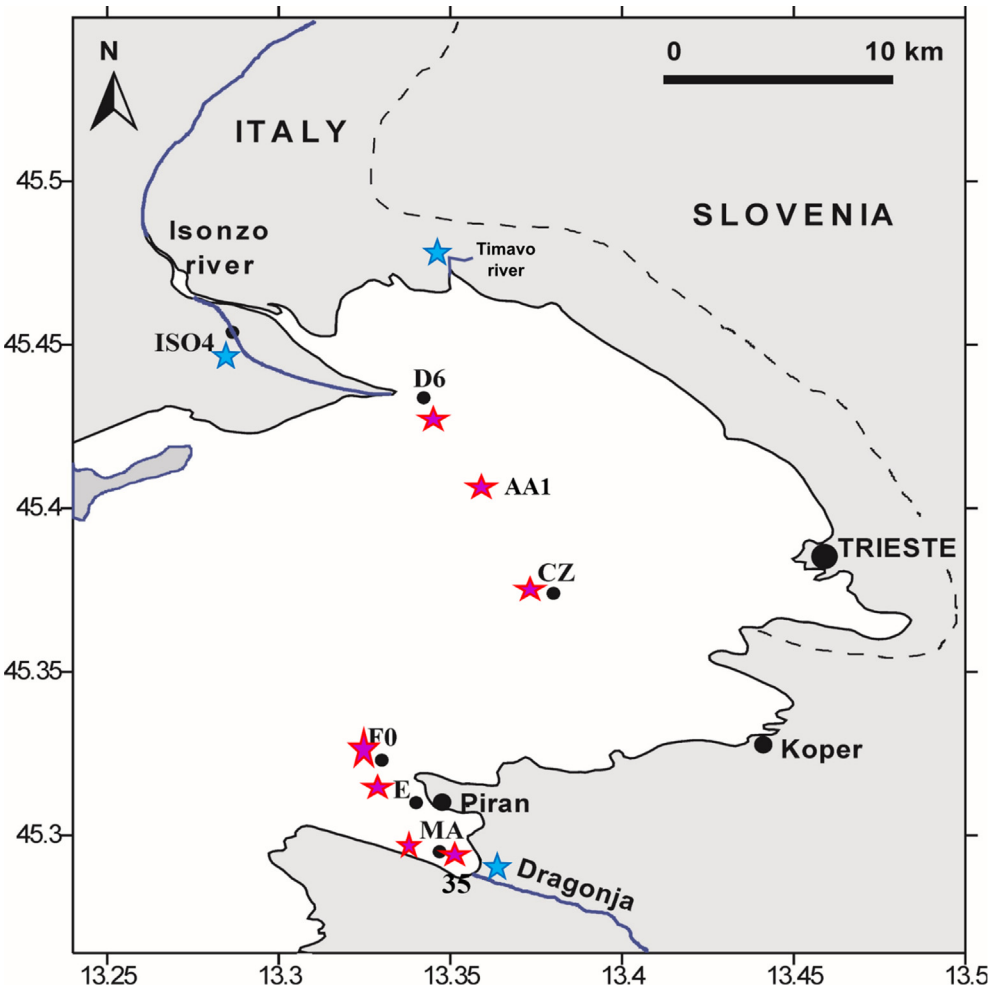

Fig. 1. Location of sampling sites in the Gulf of Trieste (northern Adriatic Sea).

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