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The impact of the 1999 Mw 7.4 event in the İzmit Bay (Turkey) on anthropogenic contaminant (PCBs, PAHs and PBDEs) concentrations recorded in a deep sediment core

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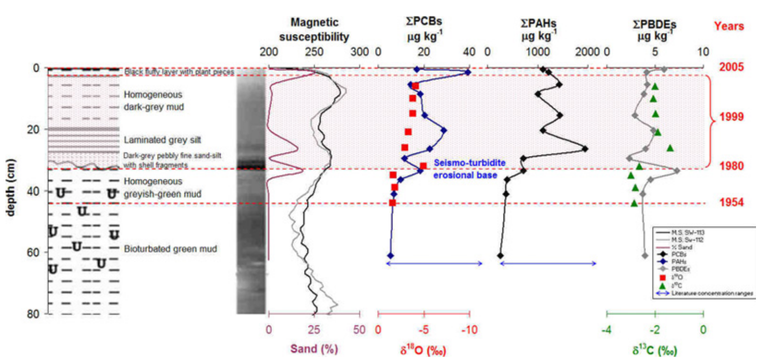
HIGHLIGHTS

- On August 17th 1999 an earthquake of Mw = 7.4 hit the İzmit Bay in the Marmara Sea.
- PCBs, PAHs, and PBDEs were measured in a sediment core from the Marmara Sea in 2005.
- Contaminant profiles well overlap the timing of industrialization in the area.
- The massive transport of contaminated sediments is evidenced in the seismo-turbidite.
- A scenario of unvaried inputs of pollutants is defined for the period 1980–2005.

GRAPHICAL ABSTRACT



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ABSTRACT

The 1999 Mw 7.4 earthquake triggered a tremendous human tragedy and had a great social impact over the population of the İzmit Bay, one of the most industrialized area of Turkey. Although the successive environmental disasters were well documented, information on its sedimentary record is lacking. The present research aims at filling this gap, through the analysis of organic contaminants (PCBs, PAHs, and PBDEs) in a dated sediment core collected in the depocenter of the Karamürsel Basin in 2005. Profiles of total PCBs and total PAHs overlap the timing of industrialization in the area (starting in the 1960s) with values increasing as the population and the number of industrial plants grew larger. Profiles for PBDEs are in accordance with increasing urban inputs but are probably affected by processes of natural formation and post-depositional mixing. The continuous sedimentary record is interrupted at a level dating back to 1980 due to the erosion caused by the 1999 earthquake, having removed a 5–7 cm thick sediment layer. Contaminant concentrations in the deepest 10–15 cm of a 30 cm thick seismo-turbidite unit, triggered by the 1999 event, increase with the progressive fining up and evidence massive transport of sediments from coastal, more polluted sites of the north-eastern Karamürsel shelves and shores. Additional inputs of PAHs are also evident, originating from a fire at the oil refinery that followed the shaking. The effects of the earthquake generated tsunami, its backwash fluxes and the following seiches are not

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uniquely displayed by each class of contaminants, and they could probably reflect successive inputs deriving from different parts of the basin that are subject to anthropogenic impacts of different nature. Concentrations measured at the top of the core are consistent with an unvaried input of pollutants in the period 1980–2005.

1. Introduction

On August 17th, 1999, in the vicinity of the city of İzmit (Turkey), an earthquake of Mw = 7.4 and focal depth of 18 km ruptured the entire North-Anatolian Fault (NAF) strand below İzmit Bay (Gasperini et al., 2011), the so called "İzmit Segment". The maximum damage was suffered around the epicenter (the small town of Gölcük), located on the south-eastern coast of the İzmit Bay (Balkıs, 2003), and the earthquake generated a tsunami, which inundated both sides of the Bay with a run up of more than 2.5 m and a maximum water rise above 10 m in Değirmendere near Gölcük (Yalçıner et al., 1999; Altınok and Ersoy, 2000; Altınok et al., 2001). Approximately 17,000 people died (but some estimates go up to 45,000 casualties; Marza, 2004) and most urban settlements around the Bay were completely destroyed (USGS, 2000). Associated to this huge human tragedy, a great environmental disaster struck İzmit Bay in the aftermaths of the event, since this is one of the most industrialized areas of the country and many petrochemical/production plants were located within 10 km of the epicenter (Tolun et al., 2006). The shaking caused the destruction of urban and industrial wastewater discharge systems and the surface waters of the bay were partly covered by thick petroleum layers and films. This was caused by an oil spill that occurred during routine transfer operations at the port of İzmit and the burning of the tank farm at the massive refinery facility operated by the state-owned oil company, TÜPRAŞ, near the town of Körfez. The oil spill and fire lasted for several days (Scawthron and Johnson, 2000; Tolun et al., 2006) and the petroleum layer covering the surface water reduced the transfer of oxygen across the air/sea interface, causing the onset of anoxic conditions at the sea floor and the consequent mass mortality of fish and other organisms. In addition, increasing effluent discharges into the bay produced an exceptional plankton bloom (Okay et al., 2001). These conditions lasted for at least a couple of months after the earthquake (Balkıs, 2003; Morkoç et al., 2007).

Several studies investigated the effects of the 1999 earthquake on the environment of İzmit Bay related to both its chemical and oceanographic parameters (Balkıs, 2003; Morkoç et al., 2007) and levels of Persistent Organic Pollutants (POPs, mainly polycyclic aromatic hydrocarbons, PAHs) in mussels, seawater and surficial sediments (Okay et al., 2001, 2003; Tolun et al., 2006). The results showed that total PAH concentrations increased considerably in all analyzed matrices, especially near the refinery (Okay et al., 2001, 2003), being related mostly to the uncontrolled discharge from petroleum industries rather than from the refinery fire (Tolun et al., 2006).

None of the above cited researches studied the effects of mass-wasting events triggered by the earthquake in sediment cores, but limited their analyses to repeated surficial sediment samplings at fixed coastal stations. In addition, other important POPs such as polychlorinated biphenyls (PCBs) were not considered, although the production facilities along the coasts of İzmit Bay were proven to be important input sources (Gedik et al., 2010). Çağatay et al. (2012) documented the records of major earthquakes during the last 2400 years, including the 1999 İzmit event in the Central Karamürsel Basin of İzmit Bay. These records are represented by turbidite–homogenite mass-flow units (THUs) with a basal coarse layer, a middle laminated silt layer and an overlying homogeneous mud layer, showing a typical vertical size grading. Structures such as multiple coarse or laminated silt levels and occasional bi-directional cross-bedding structures in the THUs show evidence of water column oscillations.

Coastal and open-sea sedimentary successions are well suited for pollution studies, since they act as recorders of environmental conditions and can provide information on the chronology of pollutant inputs (e.g., Frignani et al., 2004; Mugnai et al., 2011; Bellucci et al., 2010, 2012) even in case of high perturbed deposition (Giuliani et al., 2015a). The principal aim of this paper is to study PCBs, PAHs, and polybrominated diphenyl ethers (PBDEs) concentrations and distributions in sediment core successions from the İzmit Gulf, including those within mass-flow units triggered by the 1999 earthquake, using source identification via congener composition and statistical data treatment. In addition, five surface sediments collected in 1991 were analyzed for comparison. The attention was focused on PCBs, PAHs, and PBDEs, because of their high persistency in the environment, which makes them a serious threat to human health and aquatic organisms. The methods and scientific approach presented in this paper can be transferred to other locations in the world, where natural seismic risks sum up with those due to increasing anthropogenic pressures.

2. Study area

İzmit Bay is a tectonically-controlled semi-enclosed, E-W elongated water body, located in the NE sector of the Marmara Sea (Fig. 1). It is 50 km long, and 2 to 10 km wide, for an area of 310 km^2. It consists of three distinct basins (eastern, central and western) connected through narrow sills and with varying water depths: the eastern basin (Gölcük Basin) is relatively shallow (about 30 m), the central basin (Karamürsel Basin) has two small depressions with depths of 160 and 200 m, while the western basin deepens westward from 150 to 300 m and connects the bay to the Marmara Sea (Fig. 1). The northern branch of the NAF enters the Gulf of İzmit from the East, where it ruptured during the 1999 earthquake (Gasperini et al., 2011). The Gulf of İzmit is at the transition between the linear, strike-slip regime of the NAF system to the East and the transtensional (pull-apart) basins of the Marmara Sea to the West.

The bay presents a constant stratification of water masses throughout the year, with waters coming from the Black Sea forming a 25 m thick, well oxygenated but nutrient-poor and brackish (20–22 ppt) surface layer. Saltier (37.5–38.5 ppt) oxygen-depleted and nutrient-rich waters originating from the Mediterranean Sea underlie the permanent pycnocline (Tellı-Karacoç et al., 2002; Morkoç et al., 2007, 2008). Circulation changes seasonally, with surface brackish waters entering into the Bay and the lower saltier layer flowing to the Marmara Sea during spring and summer, vice-versa in autumn and winter (Balkıs, 2003). Due to the strong thermohaline stratification of both İzmit Bay and Marmara Sea throughout the year and the relatively low current activity in the bay (Oğuz and Sur, 1986), the renewal of the water masses within the İzmit Bay is slow, especially in its eastern part (Morkoç et al., 2007); therefore eutrophication and deterioration of water quality can become a serious problem (Tellı-Karacoç et al., 2002).

The fragile oceanographic setting described above is further threatened by İzmit Bay and its surroundings being one of the most industrialized and densely populated areas of Turkey, receiving more than 300 industrial and domestic effluents since 1965 (Morkoç et al., 1996; Tellı-Karacoç et al., 2002). Marine pollution has increased since the 1960s, associated with industrial and urban development around the bay (Morkoç et al., 2008). Within the last 20 years, industrial loads have been reduced by treatment and waste minimization (80% of organic matter has been removed from industrial wastewaters; Morkoç et al., 2008), but domestic wastes have doubled, due to the increasing population (Morkoç et al., 2008). Therefore, the total discharge load has not changed significantly (Morkoç et al., 2001). Additionally, hazardous wastes and toxic substances in industrial and complex wastewaters are to a large