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Impact of industrial pollution on recent dinoflagellate cysts in Izmir Bay (Eastern Aegean)

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ABSTRACT

The spatial distribution of dinoflagellate cysts was studied to understand the impact of industrial pollution on the surface sediment of Izmir Bay, Turkey. Forty two dinoflagellate cyst morphotypes belonging to 12 genera were identified and qualified at 12 sampling points. The cyst of *Gymnodinium nolleri* dominated the bay and had the highest abundance in most of the stations, following *Spiniferites bulloideus* and *Lingulodinium machaerophorum*. The highest cyst concentration was recorded in the inner part of the bay. Cyst concentration ranged between 384 and 9944 cyst g^{-1} dry weight of sediment in the sampling area. Sediment metal concentrations were determined. Heavy metal levels in Izmir Inner Bay were higher than the Middle and Outer Bay. *L. machaerophorum*, *Dubridinium caperatum* and *Polykrikos kofoidii* showed significant positive correlation with some metals (Cd, Pb, Cu, Zn) and organic carbon content. However, there was no significant correlation between dinoflagellate cyst abundance and sediment type.

1. Introduction

Phytoplankton is the most important primary producer in aquatic ecosystems. It is sensitive to environmental changes, which are indicated by fluctuation of species composition and abundance (Liu et al., 2012). Many dinoflagellate species (approximately 10%) are capable of producing resting cysts to increase the survival capacity of the vegetative cell of the species (Head, 1996). These cysts are extremely resistant to environmental conditions (e.g. surface salinity, temperature, nutrients). Dinoflagellate cysts have become a valuable proxy both as an effective biological indicator and also for investigating past environmental changes due to the encystment of dinoflagellate species in the sea, which is mainly affected by environmental changes and nutrient enrichments (Marret and Zonneveld, 2003; Pospelova and Kim, 2010; Kim et al., 2012; Zonneveld et al., 2013).

Metals are among the most important pollutants causing environmental deterioration in marine environments and therefore, a world-wide problem. Marine sediments can be a sensitive indicator for both spatial and temporal monitoring of metal contaminants (Larsen and Jensen, 1989). When dissolved metals from natural or anthropogenic sources come in contact with saline water, the metals are quickly adsorbed onto particulates and eventually removed to the bottom sediments (Schropp and Windom, 1988). Particle size distribution has a significant effect on the transport of metals (Ren and Packman, 2004, 2005). Heavy metal adsorption rises with decreasing grain size of the sediment, and metal concentrations are notably enriched in fine-grained sediment rich in clay minerals (Abrahim et al., 2007).

As micronutrients, trace metals are known to be an important factor of phytoplankton composition and biomass in ocean and neritic waters (Mitrovic et al., 2004 and references therein). For example, Fe has importance in controlling the location of phytoplankton blooms and this metal affects productivity, phytoplankton biomass and nutrient drawdown in coastal areas (Fitzwater et al., 2000). Zn is also a part of several enzyme systems (e.g. carbonic anhydrase activity) that rely on phytoplankton as an essential nutrient (Jing et al., 2011). Heavy metal sensitivity of the phytoplankton community has been studied before and some phytoplankton mechanisms have been utilized (Jing et al., 2011; Echeveste et al., 2014). However, a high level of metals can be toxic for some dinoflagellates and resting cysts can be an important strategy to survive under metal stress condition (Okamoto et al., 1999). Although the relationship between cyst and nutrient enrichment has been studied in many areas, especially on eutrophic coasts (Holzwarth et al., 2007; Dale, 2001, 2009), few studies are available to understand the response of dinoflagellate cyst to metal pollution. Pospelova et al. (2005) and Liu et al. (2012) studied the impact of different pollution sources, such as heavy metals, on

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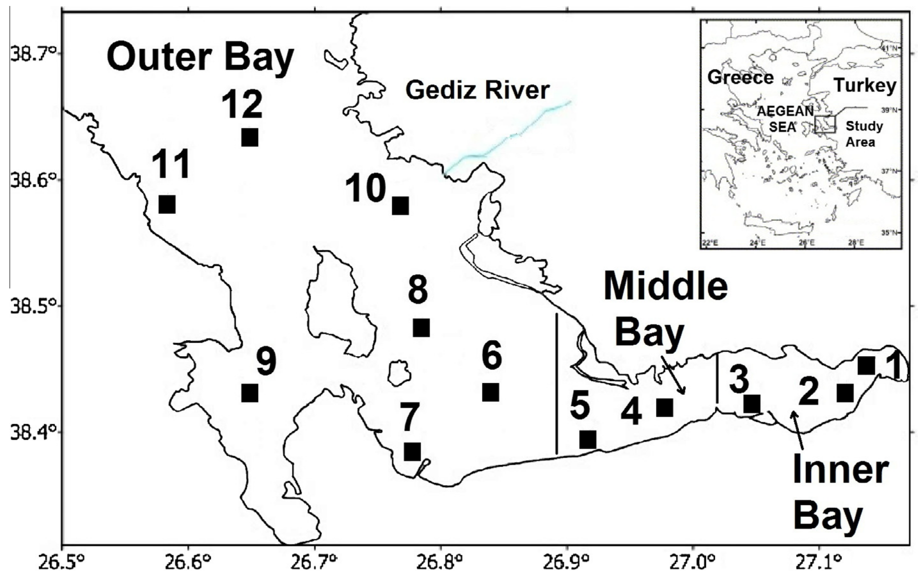

Fig. 1. Location map of the sampling points in Izmir Bay (Eastern Aegean Sea).

Table 1
Geographical coordinates of sampling sites with water depth (m) and relative proportions (%) of sediment grain size: clay (<2 µm), silt (2–63 µm), sand (>63 µm) in Izmir Bay.

Station no.	Latitude (*N*)	Longitude (*E*)	Water depth	Clay	Silt	Sand
1	38°27.08′N	27°08.28′E	8	23.12	75.72	1.16
2	38°25.86′N	27°07.14′E	15	36.3	61.53	2.17
3	38°25.18′N	27°02.85′E	11	26.5	69.78	3.72
4	38°25.33′N	26°58.63′E	25	27.52	69.14	3.34
5	38°23.54′N	26°55.00′E	24	27.3	71.9	0.8
6	38°25.99′N	26°50.40′E	49	45.9	46.46	7.64
7	38°23.09′N	26°46.70′E	25	18.79	60.64	20.57
8	38°29.00′N	26°47.08′E	50	59.63	40.17	0.2
9	38°26.00′N	26°38.93′E	27	25.11	60.51	14.38
10	38°34.90′N	26°46.07′E	36	43.74	56.01	0.25
11	38°34.99′N	26°35.02′E	44	9.99	29.64	60.37
12	38°38.10′N	26°38.96′E	67	37.64	57.32	5.04

dinoflagellate cyst distribution and abundance. Horner et al. (2011) found that *Alexandrium catenella* cyst abundance was positively correlated with Cd concentration.

Izmir Bay is a natural bay in the Eastern Aegean. Physicochemical studies have been carried out before and after eutrophic conditions and industrial pollution appeared in the bay (Kontas et al., 2004; Kucuksezgin et al., 2005, 2006, 2011). The bay has been polluted by urban and industrial wastewater discharges for many years. Previous studies have mentioned high concentrations of industrial pollutants, such as heavy metals, and organic pollutants in the sediment of Izmir inner bay (Atgin et al., 2000; Cihangir and Küçüksezgin, 2003; Kucuksezgin et al., 2006, 2011; Guven and Akıncı, 2008). Koray (1984) and Koray et al. (1992) reported harmful algal blooms in the bay. The composition and abundance of phytoplankton species has been studied by several researchers (Sabancı and Koray, 2001; Sabanci and Koray, 2005, 2012; Gencay and Buyukısık, 2004). Uzar et al. (2010) and Aydin et al. (2011) performed the first detailed studies on the abundance, distribution and assemblages of dinoflagellate cysts in the surface sediments of Izmir Bay. They pointed out that more detailed studies were necessary to understand the distribution and abundance of dinoflagellate cysts utilizing present-day environmental data regarding the bay.

This study provides a detailed investigation of the distribution and abundance of modern dinoflagellate cysts in the surface sediments of Izmir Bay. The purpose of this study was to evaluate the spatial distribution of dinoflagellate cyst abundance, to determine whether the dinoflagellate cysts in the surface sediment contained any metal pollution, and to investigate possible correlations between sediment type and metal concentrations. To our knowledge, this is the first study on the impact of industrial pollution with contemporary data concerning modern dinoflagellate cyst distribution in the Eastern Aegean Sea.

2. Materials and methods

2.1. Study area

Izmir Bay is located in Western Turkey on the Eastern Aegean coast. It consists naturally of three sections: the inner, middle and outer bays. The outer bay extends between Karaburun and Foca headlands in a NW-SE direction. The depth of the outer bay is about 70 m, which decreases towards the inner part of the bay. Izmir Bay has limited freshwater input and climatically exhibits typical subtropical characteristics. The main fresh water flowing into the bay is the Gediz River, located in the outer part of the bay. The inner part of the bay is heavily polluted by nutrients and other pollutants such as domestic and industrial materials. A number of studies have been carried out on the bay's physical oceanographic characteristics (Sayin, 2003).

2.2. Sampling methods

Surface sediments were collected with a Van Veen grab sampler carried on the boat *R/V K. Piri Reis* from 12 stations in the Izmir Bay once in 2014 (Fig. 1 and Table 1).

2.3. Metal analysis

The top 1 cm of all sediment samples were taken and stored at −20 °C until analysis, then dried in a freeze dryer, sieved through a 63 µm stainless steel sieve, and homogenized. The samples were digested in a microwave digestion system (Milestone 1200) with