Marine Pollution Bulletin xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

Assessing the seawater quality of a coastal city using fecal indicators and environmental variables (eastern Aegean Sea)

Asli Kacar*, Burcu Omuzbuken

Dokuz Eylul University, Institute of Marine Sciences and Technology, Inciralti-Izmir, Turkey

ARTICLE INFO

Keywords:
Coastal city
Indicator bacteria
Fecal coliform
Fecal streptococci
Eastern Aegean Sea

ABSTRACT

The presence of fecal bacteria in seawater is one of the most important bio-indicator parameters of fecal pollution. In this study, the Bay of İzmir (in the eastern Aegean Sea), which is a critical area because of its relationship with marine transportation and industrial and commercial activities, was evaluated for its microbiological and physicochemical parameters through a monitoring program. The data were obtained from seasonally assembled surface seawater samples from 2015 to 2017 at 23 sampling stations. Bacteriological investigations were performed by membrane filtration technique. During the monitoring period, for stations at the inner and middle-outer part, it was found that the inner part is exposed to more number of fecal coliforms (8.8×10^2 cfu/100 mL) and fecal streptococci (1.1×10^3 cfu/100 mL). The monitoring analysis performed in this study showed that there was negative correlation between physicochemical parameters and the level of fecal bacteria, but no significance was recorded by the Pearson correlation test. Fecal contamination parameters should be routinely monitored for improving the environmental conditions of coastal cities.

The public's requirements and economical, ecological, and recreational values are provided by the bays and estuaries of coastal cities. However, they are increasingly under strain because of planned or unplanned urbanization, population extension, and climate change (Walsh, 2000; Shang et al., 2016). Marine pollution caused by human presence increases global problems related to the environment, health, and social welfare. It is a well-known fact that environmental pollution is a potential global problem (Clark et al., 2013) and that the marine environment is increasingly contaminated by microorganisms. This due to the effects of recreational activities, sewage discharges, the number of drains, and point or non-point pollution sources on the coastal city waters (Abdelzaher et al., 2010; Korajkic et al., 2011; McQuaig et al., 2012; Wong et al., 2009; Lamparelli et al., 2015).

Over time, the criteria for water quality have become more strict (United States Environmental Protection Agency, 2012; WHO, 2003), and seawater quality has been successfully analyzed using indicator methods that evaluate the presence and abundance of bacteria. Worldwide implementations of water quality criteria using fecal indicator bacteria are frequently preferred when considering the prospects for human health in coastal city waters (Shang et al., 2016). Moreover, various community health problems can be caused depending upon how high the indicator bacterial levels are compared to standard measurements (Bonilla et al., 2007). Fecal bacteria are the most abundant at the surface of the seawater where they can be affected by rain (Ferguson et al., 1996; Mallin et al., 2001). Depending on their rate of decay and processing through precipitation, their density decreases and vanishes in the water column over time. In this way, they accumulate in large masses within the sediment (Stevenson and Rychert, 1982; Bergstein-Ben Dan and Stone, 1991). In addition, they can be repeatedly suspended in surface waters by many different environmental factors (water streams, temperature etc.) and recreational activities (Crabill et al., 1999). All these circumstances affect the fecal bacteria density in marine environments.

Routine monitoring of contaminants and control strategies for marine environments are important (Kucuksezgin et al., 2010). In particular, data obtained through the regular monitoring of water quality allows to forecast pathogens related to water-borne disease (Kalkan and Altug, 2015).

The main aim of this study was to assess the density of fecal indicators and evaluate their correlation with marine environmental variables in different parts of the Bay of İzmir.

The Bay of İzmir, located in the eastern Aegean Sea (Turkey), is surrounded on three sides by the coastal city of İzmir. This coastal city is a densely populated residential area containing tourist areas, beaches, a harbor and marinas, agricultural lands, chemical and food industries, and domestic discharge outlets. The physical properties of the bay are characterized by a total surface area of over 500 km^2, a water capacity of 11.5 billion m^3, and a total coastline length of 64 km. It is

* Corresponding author at: DEU, Institute of Marine Sciences and Technology, 35340 Izmir, Turkey.
E-mail address: asli.kacar@deu.edu.tr (A. Kacar).

http://dx.doi.org/10.1016/j.marpolbul.2017.08.052
Received 12 June 2017; Received in revised form 16 August 2017; Accepted 23 August 2017

Fig. 1. Location of sampling stations in İzmir Bay.
(from Google Earth).

divided into different sections (outer, middle, and inner) and is open to the Aegean Sea on one side. The depth of the water in the middle-outer part is approximately 20–70 m, and it decreases toward the inner part where there are a high number of domestic and industrial wastewater discharge points from the city of İzmir in comparison to the other parts of the bay (Sayin, 2003; Kucuksezgin et al., 2006).

The physicochemical and microbiological data were evaluated from seasonally collected surface samples during cruises on the R/V Koca Piri Reis from 2015 to 2017 as part of the İzmir Bay Oceanographic Research Project supported by the Metropolitan Municipality of İzmir. Twenty-three stations were chosen to represent areas where routine monitoring has shown notable levels of fecal coliforms (FC) and fecal streptococci (FS): 14 stations in the inner part and another 9 in the outer-middle part of İzmir (Fig. 1).

Seawater samples were collected from 20 cm below the surface from the 23 sampling stations. The physicochemical variables of the water column (temperature, salinity, and pH) were measured using a Sea-Bird (Model 9) with a rosette system.

The membrane filter technique was used for the enumeration of fecal indicator bacteria (FC and FS). Sub-samples were obtained by immediately filtering onboard using a sterile metal vacuum filtering set (APHA, 1999; Isobe et al., 2004; Hamze et al., 2005).

For analyses of FCs, membrane filters were transferred to petri plates that contained m-FC medium (Merck, Germany) and incubated for 24 h at 44.5 °C. In addition, FS filters were transferred to the petri plates containing azide dextrose selective medium (Merck, Germany) and incubated at 37.5 °C for 48 h.

The relationship between fecal bacteria and other environmental variables was analyzed using Pearson correlation test. Additionally, analysis of variance (ANOVA) was used to compare the changes in the coastal water quality caused by bacterial indicators. A three-way ANOVA test was used to compare fecal bacteria concentrations among seasons, sampling locations, and years using the Statistica 9.0 software (Statsoft, USA). Whenever factors were identified as significant, an Unequal N HSD (Honestly Significant Difference) test was performed.

When microbial pollutants discharge into shallow coastal waters, they are diluted or diffuse in the water column; however, they still represent a potential risk for public health. A summary of water quality

Table 1
Ranges and mean values of physicochemical and microbiological variables recorded during 2015–2017.

Variables	Inner part (n = 14)			Middle-outer part (n = 9)		
	Min.	Max.	Mean ± S.d.	Min.	Max.	Mean ± S.d.
Physicochemical						
Temperature (C°)	9.8	30.2	18.9 ± 5.9	8.3	27.1	18.8 ± 4.9
Salinity (psu)	25.7	41.2	38.1 ± 2.1	31.5	40.3	38.5 ± 1.5
pH	7.8	8.6	8.2 ± 0.1	8.0	8.3	8.2 ± 0.1
Microbiological						
Fecal coliform (cfu/100 mL)	1	8.8×10^2	1.5×10^2 ± 214.7	1	3.9×10^2	4.1×10^1 ± 80.7
Fecal streptococci (cfu/100 mL)	< 1	1.1×10^3	1.4×10^2 ± 250.5	< 1	1×10^3	6.3×10^1 ± 172.1

S.d.; standard deviation.