Marine Pollution Bulletin xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Baseline

Metal concentration in the tourist beaches of South Durban: An industrial hub of South Africa

E. Vetrimurugan [a], V.C. Shruti [b], M.P. Jonathan [b,*], Priyadarsi D Roy [c], N.W. Kunene [d], Lorena Elizabeth Campos Villegas [b]

[a] *Department of Hydrology, University of Zululand, Private Bag x1001, Kwa Dlangezwa 3886, South Africa*
[b] *Centro Interdisciplinario de Investigaciones y Estudios sobre Medio Ambiente y Desarrollo (CIIEMAD), Instituto Politécnico Nacional (IPN), Calle 30 de Junio de 1520, Barrio la Laguna Ticomán, Del. Gustavo A. Madero, C.P.07340 Ciudad de México, Mexico*
[c] *Instituto de Geología, Universidad Nacional Autónoma de México (UNAM), Ciudad Universitaria C.P. 04510, Coyoacan, Ciudad de México, Mexico*
[d] *Department of Agriculture, University of Zululand, Private Bag x1001, Kwa Dlangezwa 3886, South Africa*

ARTICLE INFO

Article history:
Received 1 January 2017
Received in revised form 9 February 2017
Accepted 14 February 2017
Available online xxxx

Keywords:
Acid leachable metals (ALMs)
Beach sediments
Enrichment factor
Geoaccumulation index
Potential ecological risk
South Durban, South Africa

ABSTRACT

South Durban basin of South Africa has witnessed tremendous urban, industrial expansion and mass tourism impacts exerting significant pressure over marine environments. 43 sediment samples from 7 different beaches (Bluff beach; Ansteys beach; Brighton beach; Cutting beach; Isipingo beach; Tiger Rocks beach; Amanzimtoti beach) were analyzed for acid leachable metals (ALMs) Fe, Mg, Mn, Cr, Cu, Mo, Ni, Co, Pb, Cd, Zn and Hg. The metal concentrations found in all the beaches were higher than the background reference values (avg. in $\mu g\ g^{-1}$) for Cr (223–352), Cu (27.67–42.10), Mo (3.11–4.70), Ni (93–118), Co (45.52–52.44), Zn (31.26–57.01) and Hg (1.13–2.36) suggesting the influence of industrial effluents and harbor activities in this region. Calculated geochemical indexes revealed that extreme contamination of Cr and Hg in all the beach sediments and high Cr and Ni levels poses adverse biological effects.

Coastal zone interfacing between the land and oceans are extremely sensitive to environmental and human induced changes (Clabby, 2010; Wang et al., 2014; Xu et al., 2016a). They are the "sink" for continents as they constantly receive and concentrate pollutants and other negative consequences of developmental activities taking place in the surroundings (Gao and Chen, 2012; Chakraborty, 2017). The coastal zones throughout the world attract a huge number of human populations resulting in disproportionate rapid expansion of economic activities, industries and urban centers consequently posing a major threat to this highly productive zone (Beck et al., 2011; Wilkinson and Salvat, 2012; Barbier, 2016). Trace metal contamination has attained a global attention due to their environmental persistence, non-degradability, biogeochemical recycling and ecotoxicological risks (Forstner and Wittmann, 1979; Sakan et al., 2006; Yang et al., 2012; Xu et al., 2016b). Beach environments supporting variety of economic activities and inhabited by specialized biotic assemblages are exposed to human pressures at various scales and intensities. Beach sediments are excellent reservoirs of trace metals derived through natural weathering processes and anthropogenic inputs like waste disposal, urban effluents discharge and mining activities etc. (El-Sorogy et al., 2016). The accumulation and mobility of trace metals in sediments depends upon various physical and chemical adsorption mechanisms, properties of adsorbed compounds and the nature of sediment matrices (Bastami et al., 2014).

The Kwazulu-Natal coast of South Africa has a rich and diverse natural asset providing numerous economic benefits such as marine fishing, port and harbor development, tourism and recreational opportunities (Cooper, 1995; Guastella and Smith, 2014). It is also an enticing tourist destination casting some of the finest beaches in the world and supporting a large sector of the economy. Durban ranks third most populous urban areas in South Africa in the Kwazulu-Natal province with a population of 3.4 million (Statistics South Africa, 2011). Durban is a great tourist destination attracting larger number of tourists in recent years (Fig. 1; South African Tourism: www.zulu.org.za). The South Durban area is considered as the economic hub of Kwazulu-Natal contributing approximately 8% of GDP and 30% of Durban GDP (Chetty, 2005). It is home to two major petrochemical refineries, sugar refinery, several waste water works, numerous toxic waste landfill sites, an airport, the busiest port in Africa, a paper manufacturing plant and a multitude of chemical processing industries (Peek, 2002). The Durban harbor exports products such as manganese, chrome ore, coal, sugar and grain (Roos, 2010). This highly industrialized basin is recognized as pollution "*hot spot*" (SDCEA, 2016) and is under the limelight of marine pollution,

* Corresponding author.
E-mail addresses: evetrimurugan@yahoo.co.in (E. Vetrimurugan), mpjonathan7@yahoo.com (M.P. Jonathan).

http://dx.doi.org/10.1016/j.marpolbul.2017.02.036
0025-326X/© 2017 Elsevier Ltd. All rights reserved.

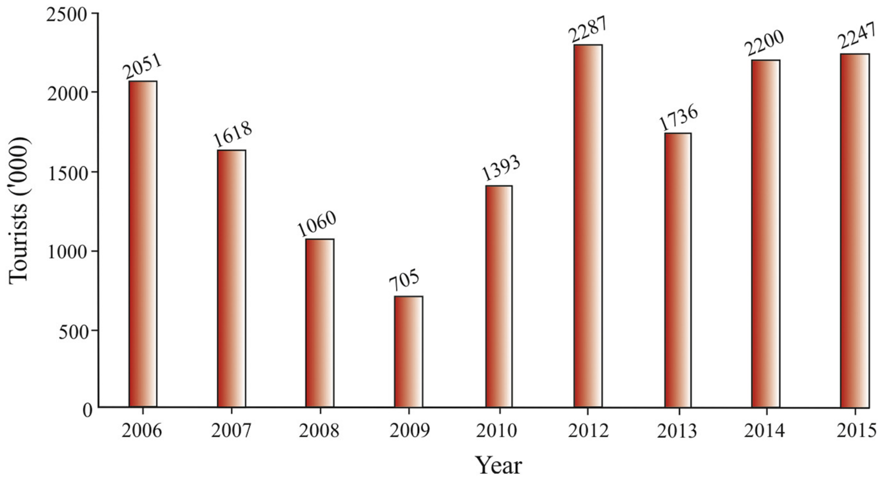

Fig. 1. Graph representing number of tourists visiting Durban, South Africa.

wherein human activities concentrated in the urban zones and industrial activities greatly influence the distribution of toxic metals in marine environments.

The present study is aimed to present a baseline data set on the metal concentrations in beach sediments of South Durban and specifically the main objectives were to: 1) determine the concentration pattern of metal concentrations in beach sediments, 2) evaluate the level of metal enrichment using geoaccumulation index (I_{geo}) and enrichment factor (EF), 3) determine the possible biological effects through potential ecological risk index formulas and, 4) identify the relationship among trace metals and their sources through application of multivariate statistical analysis.

The study area extending between 29° 54′ 26.50″ S, 31° 2′ 11.40″ E and 30° 4′ 19.55″ S, 30° 52′ 32.38″ E, the coastal stretch of South Durban from Bluff beach (in the north) to Amanzimtoti beach (in the south) was covered in the present study. The continental shelf offshore of the Durban is extremely narrow and the distribution of shelf sediments is greatly influenced by the powerful Agulhas current (Martin and Flemming, 1988; Cawthra et al., 2012). Geologically the Natal group of rocks comprising arkosic, quartz-arenitic sandstones and conglomerates overlies the basement rocks of Durban (Smith, 1990; Smith et al., 1993; Singh, 2009). The Dwyka group consisting of tillite that was deposited in a glacial environment by retreating ice sheets about 300 million years ago overlies the Natal group (Visser, 1990). With the melting of ice sheet a major transgression occurred resulting in Ecca group formation constituting carbonaceous shales, silt stone and sand stones (Johnson et al., 2006). The Durban coast experiences a warm subtropical climate characterized with summer rainfall and high air humidity. The average minimum and maximum monthly temperatures are 5.8 and 32.6 °C respectively (Mucina and Geldenhuys, 2006), while the average rainfall is ~1000 mm/year (Jury and Melice, 2000).

A total number of 43 beach sediment samples were collected from South Durban tourist beaches during August 2014 (Fig. 2). The sampling sites were divided into seven beach regions namely: 1) Bluff beach (S. Nos. 1–8); 2) Ansteys beach (S. Nos. 9–12); 3) Brighton beach (S. Nos. 13–20); 4) Cutting beach (S. Nos. 21–24) [The prime features of these four regions are the presence of Durban harbor, an airport, Mondi Paper mill and two largest oil refineries]; 5) Isipingo beach (S. Nos. 25–28); 6) Tiger Rocks beach (S. Nos. 29–32) [These two regions forms a major industrial area with the presence of South Africa's largest automobile assembly plant and Isipingo River] and 7) Amanzimtoti beach (S. Nos. 33–43) [Popular tourist destination, numerous hotels and resorts in the premises]. The sediment samples were collected from the beach inter-tidal zone using plastic spatula and were placed in polythene plastic bags and later transported to laboratory. The collected samples were oven dried below 40 °C for powdering and further analysis. The acid leachable metals (ALMs) Fe, Mg, Mn, Cr, Cu, Mo, Ni, Co, Pb, Cd, Zn and Hg in beach sediments were analyzed based on modified EPA 3051A method (2007) and Navarrete-López et al. (2011). Dry powdered sample (1 g) were mixed with 2.5 ml of HNO_3, 0.8 ml of HCl and 1 ml of H_2O_2 and were digested using PFA [Poly(tetrafluoroethylene)] vessel at 119 ± 1.5 °C for 40 min and the final solution was made up to 10 ml after filtration. The ALMs were measured by introducing the final solutions in inductively coupled plasma atomic emission spectroscopy (*PerkinElmer* ICP-OES Plasma Optima 8300 DV). All reagents used in the present analysis were of analytical grade (J.T. Baker) and Standard Reference Material (SRM No.691029) Loam soil B (Soil sample) was digested and analyzed along with the samples to check the precision of the equipment and the processing of samples, which was within 1.28 to 3.97%. The relationships between ALMs were identified through processing of data in Statistica (Version 8).

The spatial distributions of ALMs in beach sediments of South Durban are represented in Fig. 3a–l. The metal concentrations in beach sediments decreased in the following order:

1) Bluff beach: Fe > Mg > Cr > Ni > Mn > Co > Cu > Zn > Pb > Mo > Hg > Cd;
2) Ansteys beach: Fe > Mg > Cr > Ni > Mn > Co > Zn > Cu > Pb > Mo > Hg > Cd;
3) Brighton beach: Fe > Mg > Cr > Ni > Mn > Co > Zn > Cu > Pb > Mo > Hg > Cd;
4) Cutting beach: Fe > Mg > Cr > Ni > Mn > Zn > Co > Cu > Pb > Mo > Hg > Cd;
5) Isipingo beach: Fe > Mg > Cr > Ni > Mn > Zn > Co > Cu > Pb > Mo > Hg > Cd;
6) Tiger Rocks beach: Fe > Mg > Cr > Ni > Co > Mn > Cu > Zn > Pb > Mo > Hg > Cd;
7) Amanzimtoti beach: Fe > Mg > Cr > Ni > Mn > Zn > Co > Cu > Pb > Mo > Hg > Cd.

The above sequential order of metal concentrations in all the seven beaches shows a similar decreasing trend except for minor variations. The metal concentrations were compared with UCC (Wedepohl, 1995) values to have a better understanding of the enrichment pattern. It was observed that all the beaches were significantly enriched with (all values in μg g^{-1}) Cr (318; 335; 261; 223; 325; 352; 274), Cu (34; 31.6; 32; 27.6; 34; 42; 33.8), Ni (105; 104; 100; 93; 98; 118; 94), Mo (4.4; 4.2; 3.8; 3.1; 3.9; 4.7; 3.7), Co (48.5; 50.7; 47.7; 45.5; 48.4; 52.4; 46.3) and Hg (1.13; 1.17; 1.89; 2.36; 1.33; 1.14; 1.95) compared to UCC. Higher values of Pb (19.3 μg g^{-1}) were observed in Tiger Rocks beach, where as Cutting beach presented higher concentrations of zinc (57 μg g^{-1}).

The coastal stretch of South Durban is naturally enriched in Cr, Cu, Ni, Mo and Co due to weathering of the dark coloured carbon-rich