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Baseline

Concentrations of metallic elements in kidney, liver, and lung tissue of Indo-Pacific bottlenose dolphin *Tursiops aduncus* from coastal waters of Zanzibar, Tanzania

Edgar C. Mapunda[a], Othman C. Othman[a], Leonard D. Akwilapo[a], Hindrik Bouwman[b], Haji Mwevura[c,*]

[a] Chemistry Department, College of Natural and Applied Sciences, University of Dar es Salaam, P.O. Box 35061, Dar es Salaam, Tanzania
[b] Research Unit: Environmental Sciences and Management, North-West University, P Bag X 6001, Potchefstroom 2520, South Africa
[c] Department of Natural Science, State University of Zanzibar, P.O. Box:146, Zanzibar, Tanzania

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ABSTRACT

Concentrations of metallic elements in kidney, liver and lung tissues of Indo-Pacific bottlenose dolphins *Tursiops aduncus* from coastal waters of Zanzibar were determined using inductively coupled plasma – optical emission spectroscopy. Cadmium, chromium, copper, and zinc were quantifiable in all tissues at concentration ranges of 0.10–150, 0.08–3.2, 1.1–88 and 14–210 μg/g dry mass, respectively. Copper and zinc was significantly higher in liver, and females had significantly higher Cd in liver, and chromium in lung. Generally, *T. aduncus* dolphins from coastal waters around Zanzibar carry low concentrations of metals compared with dolphins from other areas. Cadmium increased significantly with age in kidney and lung. Copper decreased significantly with age in liver, probably due to foetal metallothionein. This study supplied baseline data against which future trends in marine mammals in the Indian Ocean, the world's third largest, can be assessed.

1. Introduction

The coastal waters of Tanzania are inhabited by a number of marine mammals including dolphins, whales, and dugong. Seven species of dolphins appear regularly around Zanzibar Island (Fig. 1), of which the Indo-Pacific Bottlenose Dolphin (*Tursiops aduncus*) is the most abundant (Amir et al., 2005). Dolphins play an important part in the tourism industry of Zanzibar Island, attracting tourists that watch and or swim with the dolphins in nearshore waters. Nevertheless, the dolphin populations are threatened by a number of factors such as fishing by-catch and environmental pollution.

Marine mammals have a number of traits that make them prone to the accumulation of contaminants. Lipid-rich blubber and feeding at a high trophic level, coupled with a high food consumption rate may result in the ingestion and accumulation of significant amounts of chemical contaminants via food (Boon et al., 1994). Dolphins from Zanzibar waters contain particularly high concentrations of methoxylated polybrominated diphenylethers (Mwevura et al., 2010). Metallic element contamination in dolphins is of concern throughout the world (Cardellicchio et al., 2002; Storelli et al., 1999; Holsbeek et al., 1998). These studies advanced the knowledge of the accumulation of potentially toxic elements in aquatic mammals at high trophic levels. The ability of dolphins to accumulate some metals, reflecting natural background and pollutants in the marine ecosystems, qualify dolphins as sentinel species for the assessment of environmental pollution of marine ecosystems (Zhou et al., 2001; Borrell et al., 2015).

Metal sources that occur naturally are volcanic activities, geological weathering, and forest fires that release metals previously bound (Anon, 2007). Anthropogenic sources (e.g., mining, heavy industries, agricultural activities, urban effluents, port activities, oil spillage, emissions from engines, and leaching from solid waste dumps) contribute directly to metals in the environment, or from secondary inputs such dry and wet deposition and surface runoff (Anon, 2007; Zhou et al., 2001).

In elemental form, metals are non-biodegradable. Some occur in hydrophobic forms, rendering them the capacity to accumulate in the bodies of organisms. In dolphins, uptake of pollutants is mainly through ingestion. The effects of metal pollutants to organisms vary considerably and depend on both the element and its concentration. However, at sufficiently high concentrations, many metals are toxic and can cause various effects such as impaired reproduction and influencing their wellbeing (Beck et al., 1997; Zhou et al., 2001).

* Corresponding author.
E-mail address: haji.mwevura@suza.ac.tz (H. Mwevura).

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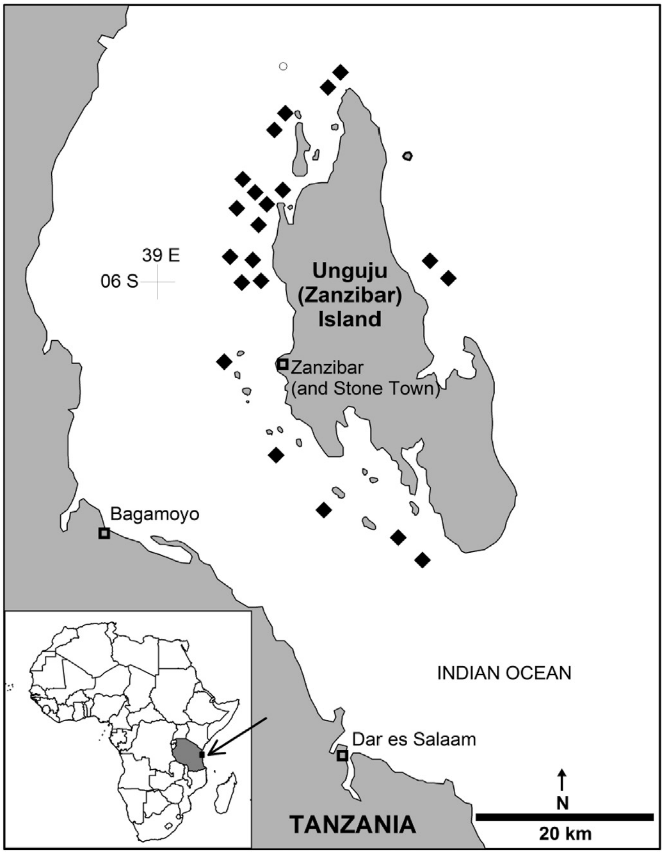

Fig. 1. Sample localities of accidentally entangled Indo-Pacific Bottlenose Dolphins *Tursiops aduncus* in nets of the coast of Zanzibar, Tanzania.

Although several studies on heavy metal accumulation in dolphins have been conducted in various parts of the world, data on the occurrence of heavy metals in the dolphins from Tanzania and along the East African coastal waters are scarce. Although the occurrence of metals in Zanzibar dolphins are likely already partially attributable to anthropogenic sources, the current concentrations may serve as a baseline with which future concentration changes may be related and environmental protection actions assessed. This study was conducted to establish the current concentrations of cadmium (Cd), chromium (Cr), copper (Cu) and zinc (Zn) in kidney, liver and lung tissues of the Indo-Pacific Bottlenose Dolphin *T. aduncus* from accidental by-catch.

Kidney, liver, and lung samples were obtained from apparently healthy Indo-Pacific Bottlenose Dolphins accidentally entangled in bottom-set gillnets, collected between 2000 and 2004 for scientific purposes by the Institute of Marine Sciences (IMS), Zanzibar. Twenty-one individuals, nine female and twelve male, of different ages (0.1–28 years) varying from calve to adult, comprised the sample for this study. For female dolphins, the ages ranged from 0.7–28 years (av. 8.9 years), and the age range for males was 0.1–25 years (av. 7.5 years). Dolphins were measured for physical and biological parameters including length, mass, and sex before being dissected for sampling. Age determination was done by counting growth layers of the tooth dentine for each dolphin. Physical and biological data measurements were performed by technical staff at the IMS, Zanzibar. For materials, analytical methods, quality assurance and control, and individual data, see the Electronic Supplement S1–S3. Cadmium (Cd), chromium (Cr), copper (Cu) and zinc (Zn) were quantifiable in all samples with varying concentrations within and between the analysed tissues (Table 1).

Cadmium concentrations ranged from 0.10 to 140 μg/g dm in kidney, 0.15 to 150 μg/g dm in liver, and 0.11 to 23 μg/g dm in lung (Table 1 and Fig. 2a). Mean concentration was highest in kidney (25 μg/g dm), followed by liver (14 μg/g dm), and lung (2.7 μg/g dm). There were no significant differences (one-way ANOVA) between any of the three tissues (Fig. 2a). Cadmium is not known to have any physiological function and its presence in the dolphin tissues therefore is an indication of exposure to cadmium. A further indication is that the %CVs for Cd (Table 1) were the highest of all elements in all three tissue types. This suggests that this metal is not regulated as an essential element, and that the large differences come from individual histories.

Although some of the dolphins in this study had cadmium concentration as high as 140 μg/g dm (Table 1), these were low compared to concentrations from elsewhere. Szefer et al. (2002) reported cadmium concentrations of 210 μg/g wm (equivalent to 910 μg/g dm) in kidney tissues of the Harbour Porpoise (*Phocoena phocoena*) from South West Greenland. Indo-Pacific Bottlenose Dolphins from South Australia had cadmium concentrations up to 370 μg/g dm (Butterfield and Gaylard, 2005). Honda et al. (1983) reported cadmium concentrations of up to 300 μg/g dm in *Stenella coeruleoalba* from Japan. Cd concentrations below 60 μg/g dm are regarded as low, 60–150 μg/g dm as moderate, and above 150 μg/g dm as high (Butterfield and Gaylard, 2005). Hence, the mean cadmium concentrations in Indo-Pacific Bottlenose Dolphins from Tanzanian coastal waters we consider as low, indicating low levels of cadmium in their food and, probably, in the ambient waters.

Chromium concentrations ranged from 0.09 to 2.2 μg/g dm in liver, from 0.14 to 1.4 μg/g dm in kidney, and from 0.08 to 3.2 μg/g dm in lung (Table 1 and Fig. 2b). Mean concentrations were 0.54 μg/g dm in liver and kidney, and 0.61 μg/g dm in lung, with no statistically significant differences between tissues (one-way ANOVA, Fig. 2c). However, the %CVs were consistently the second largest for all four metals the three tissue types (Table 1), again suggesting lack of physiological regulation of this non-essential element.

The Cr concentrations found in this study were comparable to the concentrations of chromium in cetaceans obtained in other studies. A maximum chromium concentration of 1.4 μg/g wm (6.7 μg/g dm) was reported in lung of Risso's Dolphin (*Grampus griseus*) from the South Adriatic sea, Italy (Storelli et al., 1999). Cardellicchio et al. (2002) observed a maximum of 3.7 μg/g dm in lung tissue of Stripped Dolphins (*S. coeruleoalba*) from the Mediterranean Sea off Southern Italy. Generally, chromium levels reported in marine mammals are below 4.8 μg/g dm (Storelli et al., 1999). Chromium levels higher than this value could be due to levels elevated above natural background, presumably by pollution. None of the examined dolphins from Tanzanian coastal waters exceeded this level; the sampled dolphins' exposure to and uptake of chromium we therefore consider low.

Copper is an essential element, which is important for the formation or functioning of several enzymes in mammals. Cu concentrations are, therefore, controlled by metabolic processes (Lailson-Brito et al., 2002). Copper was quantified in all samples at concentration ranges of 1.1 to 88 μg/g dm in liver, 7.6 to 18 μg/g dm in kidney and 1.9 to 27 μg/g dm in lung (Table 1 and Fig. 1c). Mean concentrations were 32 μg/g dm in liver, 12 μg/g dm in kidney, and 5.0 μg/g dm in lung. One-way ANOVA with Tukey's post test revealed that liver and kidney concentrations were significantly higher ($p < 0.05$) than in lung, but not between kidney and liver (Fig. 1c). Except for kidney, copper had the third lowest %CV of all four metals in all three tissues, indicating that copper is better regulated than the non-essential elements we investigated.

The Cu concentrations reported in this study were similar to copper concentrations in *T. truncatus* (maximum of 86 μg/g dm) and *S. coeruleoalba* (maximum of 75 μg/g dm) from the Mediterranean coast of Israel (Roditi-Elasar et al., 2003). However, other studies reported higher Cu concentrations than we found. Beck et al. (1997) reported 280 μg/g dm of Cu liver of Bottlenose Dolphin (*T. truncatus*) stranded along the coast of South Carolina, USA.

It has been suggested that the tolerance range for copper concentration in the liver is between 11 and 111 μg/g dm (Law et al., 1991), a range where homeostatic control is functioning. This range for