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Metal contamination of sediment by paint peeling from abandoned boats, with particular reference to lead

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HIGHLIGHTS

- Fragments of paint have been sampled from abandoned boats in eastern England.
- XRF analysis of fragments reveals variable concentrations of Cu, Pb and Zn.
- Local contamination of sediment is attributed to peeling paint.
- Pb is of greatest concern from both environmental and human health perspectives.

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ABSTRACT

Fragments of flaking paint have been sampled from eighteen boats (including sailing barges, houseboats, a trawler and a ferry) abandoned on the intertidal mudflats of two estuaries in eastern England and analysed for Cu, Pb and Zn by X-ray fluorescence (XRF) spectrometry. Median concentrations of Pb on each boat ranged from about 350 to 35,000 μg g^{-1}, with individual concentrations exceeding 200,000 μg g^{-1} in several cases. Median concentrations of Cu and Zn ranged from about 50 to 1900 μg g^{-1} and 50 to 10,000 μg g^{-1}, respectively, with respective maxima of 172,000 μg g^{-1} and 239,000 μg g^{-1}. Because of peeling paint, local sediment (analysed by ICP following acid digestion) was often measurably contaminated by the metals and, based on median, Al-normalised enrichment factors, in the order Pb > Zn > Cu. Due to its abundance and persistence in old paints, Pb is of greatest concern from both environmental and human health perspectives.

1. Introduction

The abandonment of boats appears to be either a practice that is exempt from any clear or direct legislation or an illegal activity that is essentially unenforceable (Lord-Boring et al., 2004; Lord-Boring and Zelo, 2006; National Association of State Boating Law Administrators, 2009; Washington State Department of Natural Resources, 2013; Stevenson, undated). Consequently, abandoned boats in various states of disrepair are commonly observed on the foreshores, intertidal flats, reefs and mangroves of the coastal zone. As well as an eye sore, and depending on their size, location and state of dereliction, abandoned boats can present both a physical and navigational hazard. From an environmental perspective, they are also responsible for a loss of habitat, pose an entrapment risk to wildlife and can act as a local source of contamination. With respect to the latter, leaking oil and fuel containing a variety of additives present an immediate, albeit significant threat (Lord-Boring and Zelo, 2006), while deteriorating and flaking paint potentially represents a longer-term environmental problem (Turner, 2010).

Studies conducted in the vicinity of shipyards and boatyards have revealed that local sediment is often considerably contaminated by antifouling paint waste containing biocidal components, including inorganic Cu and various organic compounds, that are toxic to marine life (Takahashi et al., 2012; Turner, 2013). Regarding abandoned boats, an additional concern is that old, peeling paint from the hulls and other structural components may contain substances that are currently restricted in use or that have been banned since their original application. Such substances include organotin biocides (e.g. tributyltin) and compounds of lead.

In the present study, metals in paint fragments sampled directly from boats abandoned on the intertidal mudflats of two estuaries in

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eastern England have been measured. Specifically, locations where there are clusters of a variety of decaying wooden vessels have been targeted, and both non-destructive surface mapping and total analysis following acid digestion have been used to determine the distributions and concentrations of metals in samples collected from various structural parts of each boat. Metals in surficial sediment samples surrounding each boat or cluster of boats have also been measured and compared with concentrations in local control sites in order to ascertain the degree and significance of contamination arising from peeling paint on abandoned vessels.

2. Materials and Methods

2.1. Sampling and Sample Locations

Sampling was conducted during December 2012 on the intertidal mudflats of two estuaries in eastern England (Orwell and Blackwater; Fig. 1) at locations where a variety of abandoned boats were known to be present (and, in many cases, have been so for many years) and where there were no obvious confounding sources of contamination (for example, from slipways or boatyards). The Orwell is a mesotidal, coastal plain estuary of 20 km in length and with a shoreline of about 50 km. Here, sampling was undertaken near the community of Pin Mill (PM), located about half way along the southern shores of the estuary (Fig. 1a). The Blackwater is a macrotidal, coastal plain estuary of 21.3 km in length and with a shoreline length of about 110 km. Here, sampling was undertaken in Heybridge Creek (HC) and Heybridge Basin (HB), towards the head of the estuary (Fig. 1b), and in Tollesbury Fleet (TF), an area of saltmarsh on the north bank towards the mouth of the estuary (Fig. 1c).

At each location, paint was sampled from different structural components of accessible boats, as defined and coded in Table 1 and exemplified photographically in Fig. 2, using a pair of plastic tweezers. Samples were carefully cleared of any visible extraneous material (algae, shell debris, grit) before being stored in individual zip-lock bags and in the dark until required for analysis. The name and type of boat, year of commissioning and port of registration were ascertained by visual inspection and/or consultation with the appropriate literature (e.g. The Society for Sailing Barge Research, 2012). The approximate year of boat abandonment was established from the literature or by using the time slider facility in Google Earth.

Sediment was sampled at three locations within a few metres of each boat or, where boats were close and/or access limited, at locations between pairs of boats (PM2/PM3 and HC2/HC3). Control samples (coded 0 in Fig. 1a to c) were collected in triplicate from each environment at locations between about 100 m and few hundred metres away from the abandoned boats. In each case, about 100 ml of brown, surface (<5 mm), oxic mud was scraped into a zip-lock bag with the aid of a plastic spatula and the contents were transported to the laboratory in Plymouth in a cool box before being stored frozen pending digestion and analysis.

2.2. XRF Analysis

The surfaces of the paint fragments were analysed for a variety of metals, of which Cu, Pb and Zn are the focus of the present study, by energy dispersive X-ray fluorescence (XRF) spectrometry using a

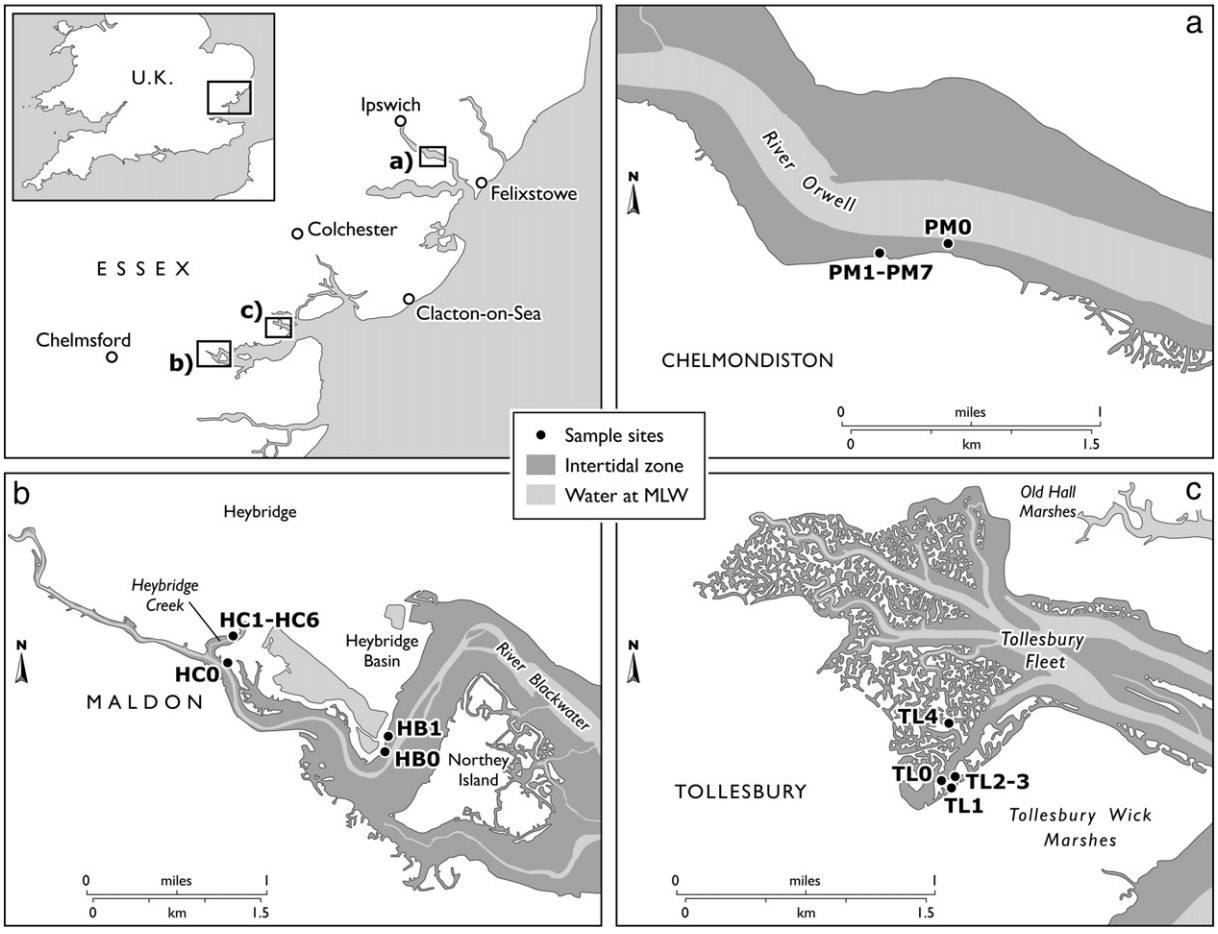

Fig. 1. Locations of the estuaries and the sampling sites therein [a) River Orwell estuary and Pin Mill, b) the Heybridge Basin and Heybridge Creek regions of the River Blackwater estuary, and c) the Tollesbury Fleet region of the River Blackwater estuary]. Sample codes are explained in the text and in Table 1.