The response of Melita plumulosa to continuous and pulsed exposures to contaminated sediment: a study of avoidance and toxicity

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Abstract
The distribution of contaminants is seldom homogeneous in aquatic systems and microniches within benthic sediments can make them particularly heterogeneous. Following exposure to 'pulsed' dissolved copper concentrations, toxicity to the epibenthic amphipod, Melita plumulosa, is best described by the time-averaged concentration. In this study we investigated the behavioural response of M. plumulosa, to contaminated marine sediments. Based on the rate at which the organism avoided contamination, we then investigated how toxic effects may occur through pulsed exposures to contaminated sediments. Four field-contaminated marine sediments were collected from the field and characterised as containing potentially toxic concentrations of metals. These sediments and one toxic copper-spiked sediment were used in 0.25 to 10 day exposure assays using 6-8 week old laboratory-cultured M. plumulosa. Initial assays showed that M. plumulosa avoided sediment, moving to clean sediments, as early as 6 h after exposures, with significant differences from controls after 24 and 48 h. This suggested that M. plumulosa is able to detect sediment contamination and choose to inhabit uncontaminated sediment. To explore the implications of this avoidance on the toxic effects elicited during migration across heterogeneous sediments, pulsed sediment exposure bioassays were performed. For sediments that were highly toxic during 10-day exposures, significant toxicity occurred when exposed for period of 2 × and 3 × 48 h, but not for exposures of 3 × 24 h or 1 × 48 h. The study demonstrated that M. plumulosa has the ability to detect and avoid contaminated sediment, and that the frequency and duration of contaminant pulses are important in determining any resulting mortality from the exposure.

Keywords
melita, response, continuous, pulsed, exposures, contaminated, avoidance, toxicity, sediment, study, plumulosa

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The response of *Melita plumulosa* to continuous and pulsed exposures to contaminated sediment: a study of avoidance and toxicity

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1. Introduction

The concentration of contaminants in aquatic environments is often heterogeneous, with temporal and spatial variability resulting from the erratic nature of contaminant inputs. Dissolved contaminant pulses can be toxic to aquatic organisms \cite{1, 2}, with the severity of the toxicity influenced by both the frequency and duration of the pulse. Recent applications of high-resolution analytical methods to sediments has revealed the presence of contaminant ‘micro-niches’ \cite{3} confirming that the biogeochemistry of marine sediments is also heterogeneous.

Currently, toxicity studies using the epibenthic amphipod *Melita plumulosa* have focussed on direct effects caused by metal exposure and not behavioural responses. This research aimed to investigate the ability of *M. plumulosa* to detect and avoid contaminated sediment. The effect of short-term exposures to contaminated sediment was also investigated to assess the impact of a contaminant pulse on a mobile benthic invertebrate.

2. Materials and methods

2.1. Behavioural response of *M. plumulosa*

A two-chamber test vessel was designed to enable the contiguous placement of contaminated and clean sediments without mixing. The design also enabled the system (sediment and overlying water) to be rapidly partitioned to allow the distribution of amphipods to be counted at any given time. In control replicates, adjacent sediments were clean uncontaminated sediment, however in the treatment replicates adjacent sediments were control and contaminated sediments. Contaminated sediments included four field-collected contaminated sediments (Derwent River, Tasmania, and Careel Bay, Sydney) and one laboratory copper-spiked sediment (equilibrated for >1 month).

2.2. Sediment pulses

Mesh cages (250 mL polycarbonate containers with 250 µm nylon mesh) were designed to transfer amphipods between sediments with minimal disturbance to the organisms while still allowing interaction with the sediment. Cages were gently washed between pulses. All pulse experiments were conducted over a 10-day period. During this time, no food was given to the amphipods and overlying water was sampled and changed (daily). Pulse scenarios investigated were 3 × 24 h, 1 × 48 h, 2 × 48 h and 3 × 48 h. Pulses were evenly spaced over the 10-day period, with exposure to uncontaminated sediments between these pulses. Surviving amphipods were counted. Sediment and water samples were analysed for metals using inductively coupled plasma atomic emission spectrometry (ICP-AES).

3. Results and discussion

3.1. Avoidance response of *M. plumulosa* to contaminated sediment

*M. plumulosa* avoided copper contaminated sediment after exposures for 6, 24, 48 and 240 h. The observed avoidance was most significant between 24 and 48 h, and later avoidance experiments were conducted with a 48-h exposure. The five contaminated sediments ranged from highly toxic to non-toxic (based on 10-d static exposures). Full sediment characterisation data will be presented. The number of avoiding organisms was dependant on the toxicity of the sediment, with the most toxic sediment triggering the greatest avoidance response. This suggests that *M. plumulosa* has the ability to detect sediment contamination and choose to inhabit uncontaminated sediment (Figure 1).
3.2. The effect on \textit{M. plumulosa} of intermittent exposure to contaminated sediment

In natural environments, benthic invertebrates encounter various sediments as they move around. These sediments are heterogeneous and effectively resemble pulse exposures to contaminated and clean environments. The effect of short-term exposures to contaminated sediment was investigated to assess toxicity of these pulses to \textit{M. plumulosa}. Pulse durations were based on avoidance times from earlier work (24-48 h). There was no significant reduction in mortality (compared to controls, \( p < 0.05 \)) when \textit{M. plumulosa} was exposed to contaminated sediments for \( 3 \times 24 \text{ h} \) or \( 1 \times 48 \text{ h} \) period/s (92 ± 5 and 95 ± 5 % survival, respectively). However, significant mortality (\( p < 0.05 \)) occurred after \( 2 \times 48 \text{ h} \) and \( 3 \times 48 \text{ h} \) exposure periods (72 ± 7 and 13 ± 5 % survival, respectively). These results indicate that short exposures to contaminated sediment are toxic to this species (Figure 2). Further research on pulse exposures will be presented.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{The distribution of \textit{M. plumulosa} (mean ± SE) following 48-h exposure to contaminated and clean sediment.}
\end{figure}

4. Conclusions

\textit{Melita plumulosa} has the ability to detect and avoid metal-contaminated sediment when exposed for \( \geq 6 \) hours. Therefore, \textit{in situ}, if these organisms come across localised sediment contamination, they have the ability to move to cleaner sediment to avoid the effect of the contaminants. However, repeated exposures may still elicit a toxic response if the contaminated sediment cannot be avoided in less than 48 h. This suggests that the frequency and duration of the contaminant pulse is important in determining the mortality that occurs from the exposure.

5. References


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