ECOLOGY OF MARINE AMPHIPODS IN HONG KONG WITH SPECIAL EMPHASIS ON ITS USE AS TEST ORGANISMS FOR ASSESSING THE TOXICITY OF MARINE SEDIMENTS

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ABSTRACT
This study aimed at the development of a test protocol for sediment toxicity assessment in Hong Kong. An intensive ecological survey on the existence of marine amphipods in the coastal marine environment of Hong Kong was first conducted. Results indicated that abundance of intertidal amphipods were significantly ($p<0.05$) correlated with temperature, salinity and dissolved oxygen of surface water while benthic amphipods abundance was significant ($p<0.05$) correlated with particle size of sediment. Lethal and sub-lethal responses of an indigenous marine infaunal amphipod species (*Melita koreana* Stephensen) to selected toxicants were then evaluated. 10-day median lethal concentration ($LC_{50)}$ values of the test species were 9.78 mg/kg for cadmium, 104.4 mg/L for ammonia, 365.2 mg/kg organic carbon for DDT and 1929.3 mg/kg organic carbon for total PAHs respectively. The same species was further used to assess toxicity of representative marine sediments collected from four representative locations in the coastal environment of Hong Kong. Amphipods subjected to sediment collected near Tsing Yi Island had a significantly ($p<0.05$) higher mortality, avoidance and lower reburial ability than those subjected to the other three sediments (collected from Yam O, Tai Tam and Porter Shelter). This particular amphipod species is currently being considered by the HKSAR Government as a candidate species for toxicity assessment of marine sediments prior to disposal route is selected.

RÉSUMÉ
Ce projet a servi comme essai protocole pour l’évaluation de la toxicité de sédiments à Hong Kong. Un essai écologique intensif a été effectué sur l’existence d’amphipodes marins dans l’environnement côtier marin de Hong Kong. Les résultats ont montré que l’abondance d’amphipodes intertidal était en corrélation significative avec la température, la salinité, et l’oxygène de l’eau de surface, tandis que l’abondance d’amphipodes benthique était significative, ($p < 0.05$) en rapport avec la grandeur des particules du sédiment. Des réponses létales et sub-létales d’une espèce indigène d’amphipode marin infaunal (*Melita koreana* Stephenson) aux toxiques choisis ont été évaluées. La concentration létale moyenne en 10 jours de l’espèce choisie était 9.78 mg/kg pour le cadmium, 104.4 mg/kg pour l’ammoniaque, 365.2 mg/kg pour le carbone organique pour la DDT et 1929.3 mg/kg pour le carbone organique pour la PAH en tout. La même espèce a été employée de nouveau pour évaluer la toxicité des sédiments marins qui ont été ramassés de quatre lieux représentatifs dans les environs côtiers de Hong Kong. Des amphipodes exposés au sédiment ramassé près de l’Île de Tsing Yi avaient la mortalité et l’absence les plus élevées, ainsi qu’une capacité de ré-enfouissement plus faible que ceux qui venaient des trios autres lieux (Yam O, Tai Tam et Porte Shelter). Le gouvernement de Hong Kong SAR est, à présent, en train de considérer cette espèce d’amphipode comme espèce indicatrice pour évaluer la toxicité des sédiment marins, avant de choisir comment en disposer.

1. INTRODUCTION

Hong Kong relies on marine reclamation to provide land for its various infrastructure development and increase in population. Large amounts of marine sediments are dredged from its coastal environment to prepare for firm foundation development every year. Dredging and disposal of marine sediments is also expected to be day-to-day activity in the coastal marine environment of the Pearl River Delta. Marine sediments and its associated contaminants (such as heavy metals and trace organics) could be re-suspended into water column during dredging and dumping at sea (Chapman et al., 1999). This can create various undesirable environmental consequences as unacceptable turbidity and depleted dissolved oxygen in water column resulting in adverse effects to marine benthic communities (Rand 1995).

Assessment of hazard related to sediment disposal in Hong Kong marine waters was initially assessed by means of sediment quality criteria for seven heavy metals (Cd, Cr, Cu, Pb, Hg, Ni and Zn) (Mott MacDonald, 1991). With the promulgation of the new protocol of the London Convention in 1996, the Hong Kong Special Administration Region (HKSAR) Government devised a 3-tier sediment management framework to classify sediments for marine disposal in April 2000 (WBTC 2000). This framework determines more accurately the potential environmental impacts of dumping sediment in the marine ecosystem. Both chemical analysis (trace organics, heavy metals, etc.) and biological testing were included in this dredged / excavated sediment disposal management framework.

Sediment bioassay methodologies adopted in this framework includes north American amphipod, polychaete and larvae (echinoderm/bivalve) toxicity tests. For more effective implementation of this sediment management strategy, development of sediment toxicity test protocols using local species is considered to be more appropriate as harmful effects of pollutants are often specific to the physical, chemical and biological properties of the local ecosystem.

Marine amphipods meet many important criteria for test organisms for sediment toxicity assessment. It is relative sensitive to contaminants of interest in sediments. Amphipods also directly contact or associate with sediments due to their tube-dwelling or free burrowing and sediment ingesting nature. Amphipods are relatively easy to culture and exist in high numbers in the field. This allows relatively high replication and increases statistical validity (USEPA 1994). Amphipods are taxonomically widespread. Amphipods have short life cycle and high reproductive potential. They are also easy to be handled in testing laboratories (Conlan 1994).

The aims of this study include (1) an investigation on the relationship between habitat characteristics and the population distribution of amphipods in the coastal marine environment of Hong Kong; (2) an evaluation on the lethal and sublethal responses of an indigenous amphipod species, *Melita koreana* Stephenson to selected toxicants (ammonia, cadmium, polycyclic aromatic hydrocarbons and DDT (dichloro-diphenyl-trichloroethanes) in spiked-sediment tests; and (3) an assessment of representative marine sediments collected from coastal marine environment of Hong Kong suing the indigenous amphipod species.

2. MATERIALS AND METHODS

2.1 Ecological survey

During the period between December 1998 and October 1999, a total of ten locations in the coastal environment of Hong Kong were visited. Such locations included Tai Tam (TT), Cape d'Aguilar, Causeway Bay (CB), Wan Chai (WC), Mai Po (MP), Tsim Bei Tsui (TBT), Ma Liu Shiu (MLS), Wu Kai Sha (WKS), Ma Wan (MW) and Sam Mun Tsai (SMT). Temperature (air and water), salinity, dissolved oxygen, pH, conductivity, turbidity and sediment redox potential were measured *in situ*. Water samples were also collected and analysed for BOD_5, alkalinity, total organic carbon, ammonia, total particulate matter and particulate organic matter (APHA, 1995). Sediment samples collected were analysed for particle size (Mudroch and Azcue, 1997), bulk density (Arias and Drake, 1994), water content (Arias and Drake, 1994), organic matter (Thompson and Shin, 1983). Ammonia and hydrogen sulfide in porewater of sediments were analyzed for ammonia and hydrogen sulfide (APHA, 1995), six heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) (APHA, 1995), polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) (Zhou, 1999). Acid volatile sulfide (AVS) (Brouwer and Murphy, 1995) and simultaneously extracted metals (SEM) (Cd, Cr, Cu, Ni, Pb and Zn) of the sediments were also determined. Algae samples were collected for amphipod abundance determination using a 20cm×20cm quadrant. Amphipod abundance was determined by sieving (0.5mm) and the animals retained on the sieve were preserved in 5% formalin for further identification by qualified taxonomist.

2.2 Spiked-sediment toxicity tests

Cadmium stock solution (1000 mg/L) was prepared and spiked in wet control sediment collected from Kau Shat Wan (KSW) to produce sediment with cadmium levels (1, 5, 10, 20 and 40mg/kg) in dry weight basis. Cd-spiked sediments were mixed (Moore et al., 1997) and stored at 4°C for one week before used (DeWitt 1996). Ammonium chloride stock solution (50g/L) was prepared by dissolving AR grade anhydrous ammonium chloride ($NH_4.Cl$) in filtered (0.45 μm) seawater (33 ppt). Seven sediment treatments with nominal porewater ammonia concentration at 750, 500, 250, 125, 62.5, 31.25 and 15.625 mg/L were prepared, mixed (Moore et al., 1997) and stored at 4°C for a week before use (Moore et al., 1997). Stock solution of total polycylic aromatic hydrocarbons (PAHs) was prepared by dissolving 16 PAHs in acetone (AR grade) to produce nominal PAHs-spiked concentrations of 20, 10, 5, 2.5, 1.25, 0.625 mg/kg in sediment (dry weight basis). Stock solution of total dichloro-diphenyl-trichloroethanes, including 2,4'-DDD, 4,4'-DDD, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT and 4,4'-DDT in equal proportion (1:1:1:1:1:1) was prepared by dissolving the six compounds in acetone (AR grade) to produce nominal total DDT-spiked concentrations of 20, 10, 5, 2.5, 1.25, 0.625 mg/kg of sediment on dry weight basis (Swartz et al., 1990). The serial dilutions of above nominal PAHs and DDTs concentrations were spiked in a 2L glass jar containing wet control sediment (KSW) about 1.2L for each treatment. A solvent control sample was also prepared following the same procedures, except that the sediment was spiked with acetone only. Spiked sediments were mixed and then stored at 4°C for about 28 days before used (Swartz et al., 1997).

Six replicates (5 replicates for biological responses and 1 replicate for water quality monitoring) were prepared for the 10-day toxicity test. Sub-adult amphipods (3 to 5 mm) were selected and acclimatized for 2 days before experiments started (USEPA 1994 and ASTM 1993). One day before experiment started, 175 mL sediment and 800 mL filtered (0.45 μm) natural seawater were added to a 1 L glass jar covered with aluminum foil and allowed to settle for 24 hours. Gentle aeration and continuous light were provided and temperature was maintained at 20 °C (ASTM 1993 and USEPA 1994). On the day when experiments started, 20 subadults amphipods were put into each jar. Temperature, pH, dissolved oxygen and salinity of overlying water and avoidance of amphipods were monitored daily (ASTM 1993 and USEPA 1994). During the 10-d exposure period, water was not changed and the amphipods were not fed. On day 10, surviving amphipods were recorded and were transferred to clean plastic dishes containing 75 mL un-spiked control sediment (KSW) and 342 mL filtered natural seawater for the determination of reburial ability of the amphipods after the 10-day exposure period (ASTM 1999).

2.3 Sediment toxicity test

Surface marine sediment samples were collected from four representative areas in the coastal environment of Hong

Kong. Such areas include Yam O (3 sampling points : YM4, YM6 and YM10), Tsing Yi (3 sampling points: VC2, VC8 and VC15), Porter Shelter (2 sampling points: PM9 and PM10) and Tai Tam (2 sampling points: TT6 and TT7). Control sediment was collected from Kau Shat Wan (KSW), a location in the southern waters of Lantau Island. Sediment samples were collected with a Van Veen Grab Sampler, stored at 4°C in airtight container in the dark prior to chemical analyses. 10-day sediment toxicity test was carried out on these sediments using the method described above.

2.4 Quality assurance/quality control (QA/QC) for toxicity tests

Negative control sediment for QA/QC purpose was collected from Kau Shat Wan. Acceptability criterion for this sediment was mortality < 10 % after the 10-day exposure period. QA/AC was also conducted using cadmium chloride as reference toxicant (ASTM, 1993; USEPA, 1994). Cadmium stock solution (1000 mg/L) was first prepared and a series of 5 concentrations (0.1, 0.5, 1, 3, 6 mg/L Cd) were then prepared in 1 L glass jars. Acceptability criterion for this positive control was the 4-day median lethal concentration, LC_{50}, values of Cd should be within two standard deviations of the mean LC_{50} values archieved.

2.5 Statistical analyses

One-way analysis of variance (ANOVA) followed by Tukey's Comparison Test were used to denote significant difference, if there is any, between quality of water and sediment samples collected from various sampling sites. Pearson product moment correlation coefficient was performed to measure the relationship between the abundance of inter-tidal and benthic amphipods, measured water and sediment parameters. One-way ANOVA was conducted to identify the difference between lethal and sub-lethal response of amphipods in various spiked-sediment toxicity tests using cadmium, ammonia, total DDT and total PAH as toxicants. One-way ANOVA followed by Tukey's Comparison Test were used to identify differences in mortality, avoidance and reburial ability of amphipods in the tested sediments. Pearson product moment correlation coefficient was performed to estimate the relationship between responses of amphipod and sediment characteristics.

3. RESULTS AND DISCUSSION

3.1 Ecological survey

Inter-tidal amphipods (*Maera pacifica, Parhyale plumulosa* and *Stenothoe qingdoensis*) associated with macroalgae were recorded from Ma Wan, Sam Mun Tsai, Tai Tam and Wan Chai. No amphipod or alga was found in intertidal column of Cape'd Aguilar, Causeway Bay and Deep Bay areas (Mai Po and Tsim Bei Tsai). Amphipod abundance in algae collected from Tai Tam were 4.9, 16.27 and 16.5 individuals/gram of algae (dry weight basis) in January, March and June respectively. Amphipod abundance in algae collected from Ma Wan were 7.9, 86.7 and 46.0 individuals/gram (dwb) of algae in January, March and June respectively. Abundance of amphipods alga collected from Sam Mun Tsai were 29.3, 69.8 and 23.9 indiviudals/gram (dwb) of algae in January, March and June respectively. Moreover, abundance of amphipods algae collected from Wan Chai were 2.4 and 5.6 individuals/gram (dwb) of algae in January and March respectively. Neither amphipod nor alga could be found in all studied sites in September. According to this study, numbers of amphipods increased from January and reached maximum in March. Amphipod populations declined slightly in June and then disappeared completely in September. It could be due to hot weather (temperature around 30°C) and heavy rainfall during summer months. Such conditions were not suitable for algal growth and when algae disappeared amphipod disappeared (Buschmann 1991). Amphipods could have found somewhere to hide during summer period in order to avoid unfavorable conditions. Results also indicated that abundance of amphipods in algae were higher in Ma Wan and Sam Mun Tsai than in Tai Tam and Wan Chai. This could be due to high levels of nutrients in mariculture areas. High algae density provided food and habitat for amphipods (Conlan 1994). Algae also provided shelter for amphipods for them to hide away from their predators (Buschmann 1991 & Conlan 1994).

Amphipods were found in sediments collected from Tai Tam and Wan Chai only. Results showed that density of amphipods in sediment collected from Tai Tam was 508, 930 and 172 individuals/m^2 in January, March and June respectively. Density of amphipods collected from Wan Chai were 422 and 328 individuals/m^2 in March and June respectively. Benthic amphipods (*Corophium acherusicum, Grandidierlla japonica* and *Ericthonius* sp.) were recorded in this study. No amphipods could be found in sediments collected in Tai Tam and Wan Chai in September. Abundance of amphipods in sediments however did not show any seasonal pattern. This agreed with Esselink et al., (1989) who also reported no particular seasonal pattern of benthic amphipods.

There was no significant correlation ($p > 0.05$) between abundance inter-tidal amphipods and various water quality parameters (such as biological oxygen demand, alkalinity, ammonia, total organic carbon, total particulates matter, particulates organic matter, pH, turbidity and conductivity). However, there was significant ($p<0.05$) correlation between the abundance of inter-tidal amphipods with temperature, salinity and dissolved oxygen in the surface water. Such results indicated no significant correlation between abundance of amphipods in algae and water parameters in middle layer and bottom surface of water column. There was significant ($p<0.05$) correlation between abundance of benthic amphipods and the particle size of the sediment. No significant ($p>0.05$) correlation was found between abundance of benthic amphipods and measured parameters of sediments, such as bulk density, water content, organic matter, porosity, redox potential, interstitial ammonia, interstitial hydrogen sulphide, heavy metals and trace organics in sediments. There were significant ($p<0.05$) correlations between abundance of amphipods and percentage of clay ($r = 0.8205$, $p = 0.001$), sand ($r = -0.535$, $p = 0.0483$) in sediments.

3.2 Spiked sediment toxicity tests

Mortality in negative control sediment in the three spiked sediment toxicity tests were all < 10%. 4-d Cd LC_{50} values in the positive controls ranged between 1.2 and 1.3 mg/L and these values were within the acceptability range (two standard deviations of the mean LC_{50} values. 10-d LC_{50} value for the cadmium-spiked experiment was 9.8 μg/g (dwb) with 3.2 μg/g to 32.1 μg/g as the 95% confidence intervals. Other studies reported LC_{50} values of cadmium-spiked toxicity to amphipods were 9.8 mg/kg for *Rhepoxynius abronius* (Mearn *et al*., 1986), 6.9 mg/kg for *R. abronius* (Swartz et al., 1985), 2.4 mg/kg *Leptoscheirus plumulosus* (DeWitt et al., 1996), 18.3 mg/kg for *Paracorophium excavatum* and >23 mg/kg for *Proharpinia hurleyi* (Hickey et al., 1992), 290 mg/kg for *R. hudsoni* and 1070 to 2850 mg/kg for *Ampelisca abdita* (Di Toro et al., 1990). Results showed that there was a wide range of LC_{50} values of cadmium to different species of amphipods and different species have different tolerant limits to cadmium. Besides, the same species could have very different LC_{50} values under different environmental conditions.

Results of the ammonia-spiked toxicity test reported the 10-d LC_{50} value for interstitial total ammonia as 104.4 mg NH_3-N/L with 95% confidence intervals at 75.2 to 144.6 NH_3-N/L. Such value was comparable to results of other studies such as 98.8 mg NH_3-N/L for *Leptocheirus plumulosus* (Moore et al., 1997), 122 mg NH_3-N/L for *Ampelisca abdita* (Hyne et al., 1998) and 82 mg NH_3-N/L for *Hyalella azteca* (Whiteman, 1996). The amphipod species used in this study, *Melita koreana,* was relatively more sensitive to ammonia than the other species. USEPA provided species-specific application limits on acceptable range of ammonia in 10-d sediment toxicity tests with marine amphipods (USEPA 1994). Such limits (no observable effect concentration, NOEC) for *L. plumulosus* were ≤ 60mg/L (total ammonia) and ≤ 0.8 mg/L (unionized ammonia) in sediment porewater. USEPA guidance indicated that amphipods should not to be added to the test system until ammonia levels in the porewater are below these application limits.

Trace organics spiked sediment test reported 10-d LC_{50} values for total DDTs and total PAHs as 0.99 μg/g (365.2 μg/g organic carbon OC) and 5.25 μg/g (1929.3 μg/g OC) respectively. 95% confidence intervals for total DDTs were 0.83 to 1.37 μg/g (305 to 503.2 μg/g OC) while those for total PAHs were 3.29 to 8.26 μg/g (1208.8 to 3038.5 μg/g OC) respectively. Swartz et al. (1994) reported various 10-d LC_{50} values. For total DDT in field-collected sediment, it was 2500, 1040 and 2580 μg/g OC for *Eohaustorius estuaries, Rhepoxynius abronius* and *Hyalella azteca* respectively. LC_{50} value of DDTs to the test species in this study was at least 2-folds lower than those reported by others. Such differences could be due to differences in methods used in spiking DDTs to the sediments. Other studies used field collected DDTs contaminated sediment while laboratory spiked sediment was used in this study. Although the usage of DDTs were ban for a many years now, large amount of DDTs still present and are concentrated in seabed sediments. These can cause acute or chronic effects to benthic organisms when such sediment is disturbed. For PAH spiked sediment toxicity test, many studies focused on one or two species of PAHs such as fluoranthene and anthracene. Hatch (1999) reported LC_{50} of *H. azteca* to anthracene and fluoranthene as 3333 μg/kg (850 μg/g OC) and 3248 μg/kg (829 μg/g OC) respectively. Swartz et al. (1997) reported LC_{50} values for *R. abronius* to acenaphthene, phenanthrene, fluoranthene and pyrene as 2110, 3080, 2320 and 1220 μg/g OC respectivel. Swartz (1990) reported LC_{50} value for *R. abronius* to fluoranthene as 2097 μg/g OC while those for *C. spinicorne* to fluoranthene was 2833 μg/g OC. Although total PAHs was spiked into sediment in this study, LC_{50} value did not show great difference with those values reported by other researcher who used a few species of PAHs in their studies. This could be due to different species of amphipods used and some species of PAHs did not cause significant acute toxicity to the test amphipods. Differences in responses of test organisms within or between laboratories may result from several factors including the quality of dilution water, genetic strain of test organisms, and training and experience of technical staff (McNulty, 1999).

Results of sub-lethal response (avoidance) showed that there was significant increase (one-way ANOVA, $p < 0.05$) in the number of amphipods emerged from spiked-sediments with increasing concentrations of cadmium, ammonia, total DDT and total PAHs. Amphipods tended to stay in overlying water or lied on sediment bed rather than burrow in sediment in order to reduce their contact with highly contaminated sediments. Our observations on the emergence of amphipods support the conclusions drawn by Swartz et al. (1985) and Moore (1997) that amphipods burrow or swim away from sediments containing high concentrations of metals, ammonia and trace organics. Emergence from contaminated sediments may therefore result from debilitation rather than a sensory recognition of unfavorable conditions (Swart et al., 1985). Behavioral avoidance may protect portions of, but not entire, amphipod populations from toxic sediment conditions. The results of sub-lethal response (reburial ability) of amphipods showed that the percentage of reburial ability of amphipods significant decreased (ANOVA $p<0.05$) with increasing spiked-sediment concentrations of cadmium, ammonia, total DDT and total PAHs. Amphipods preferred to stay in overlying water in order to reduce their contact with the contaminated sediment even they were put back to clean sediment. Reburial ability of amphipods decreased after exposed to high concentration of metal and ammonia spiked-sediments (Swartz et al., 1985; Moore, 1997). Reburial ability may be lost when amphipods were exposed to high concentration of contaminants in sediments resulting from sensory recognition of unfavorable conditions. Behavioral end points are rapid, sensitive at low contaminant levels. They operate at lower level of organization in the organisms (Ingersoll et al., 1998). Behavioral changes are identified at concentrations where lethal responses were achieved in prolonged exposure and they are useful as a warning of stress at low concentrations of toxicants. Behavioral responses (avoidance and reburial ability) also serve as significant ecological responses (Swartz, 1987).

3.3 Sediment toxicity test

Mortality in negative control (control sediment) of the sediment toxicity test was < 10%. 4-d LC_{50} value of Cd in the positive control was 1.09 mg/L, within the acceptability range (two standard deviations of the mean LC_{50} values archived. Results of 10-d mortality test reported average amphipod mortality from three sampling points in Tsing Yi as 63%. This value was ($p<0.05$) significantly higher than those of Yam O (42.3%), Porter Shelter (16.5%), Tai Tam (4.5%), and Kau Shat Wan (1%). Sediments collected from Tsing Yi, VC2 (74%) and VC8 (65%) had the highest percentage of mortality of amphipods. Mortality of amphipods in Tai Tam (3 to 6%) and control sediments (KSW, 1%) were significantly lower than 10%. The tested sediments, in terms of their toxicity to amphipods, were ranked (with increasing toxicity level) as follows : KSW < TT 6 < TT 7 < PM 10 < PM 9 < YM 6 < YM 10 < YM 4 < VC 15 < VC 8 < VC2. Results of sub-lethal responses (avoidance) of amphipods to different sediments indicated that there were significantly ($p<0.05$) higher number of amphipods emerged from Tsing Yi (4.5 to 4.8) sediment than other locations (0.2 to 2.8). Percentage of reburial ability of amphipods from Tsing Yi sediments (37.5 to 61.0%) were significantly ($p<0.05$) lower than those of other locations (72.5 to 99.0%). Percentage of amphipods capable to rebury into sediments from Kau Shat Wan, Tai Tam and Porter Shelter were over 90%.

Results of correlation indicated that there were strong positive relationships ($p < 0.001$) between amphipod mortality and concentrations of sulphide, ammonia, chromium, copper, nickel, zinc and PCBs in sediments. This demonstrated that mortality of amphipods was directly related to concentrations of heavy metals, trace organics, sulphide and ammonia in sediment. Correlation analyses (using avoidance data) indicated positive correlation ($p < 0.05$) between amphipod avoidance and concentrations of sulphide, ammonia, chromium, copper, nickel, zinc and PCBs in sedimnets. Correlation analyses (using rebury data) indicated negative correlation ($p < 0.05$) between reburial ability of amphipod and concentrations of sulphide, ammonia, chromium, copper, nickel lead, zinc and PCBs in sediments. No significant correlation ($p > 0.05$) could be established between both lethal and sub-lethal responses of amphipods and some sediment properties (particle size, water content, organic matter and bulk density). This indicated that the test amphipod species, *Melita koreana,* used in this study can tolerate to wide range of particle size, water content and bulk density of test sediments.

4. CONCLUSIONS

Inter-tidal amphipods were found associated with algae in four sites and their existence was found correlated with air and water temperature, salinity and dissolved oxygen of surface water. Benthic amphipods were found in sediments in two sites and their existence was found correlated with particle size of sediments. Both inter-tidal and benthic amphipods were found most abundant in January, March and June but not in September. Survivorship and behavioral responses (emergence and reburial ability) of *Melita koreana* were found to correlate with concentrations of various spiked-contaminants (Cd, ammonia, total PAHs and total DDTs) in the sediments. LC_{50} values of the tested amphipod species were 9.8 mg/kg for Cd; 104.4 mgN/L for ammonia; 5.2 mg/kg (1929 mg/kgOC) and 1.0 mg/kg (365 mg/kgOC) for PANs and DDTs respectively. Higher mortality and avoidance behavior and lower reburial of amphipods was found in sediments collected from Tsing Yi and Yam O. Lower mortality and avoidance but higher reburial ability of the tested amphipods were found in sediments collected from Tai Tam, Porter Shelter and Kau Shat Wan. Results of this study had demonstrated that the tested amphipod species, *Melita koreana,* has potential to be developed as a test species for toxicity assessment of sediments arising in the Hong Kong marine environment.

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