
IEG ADVICE ON EVALUATION OF PORT OF MELBOURNE CORPORATION'S CHANNEL DEEPENING PROJECT DREDGED SEDIMENT ASSESSMENTS, APRIL 2006

IEG ADVICE

A substantial database has now been assembled on the quality of sediments to be dredged as part of the proposed Port of Melbourne Channel Deepening. These data have been used to determine the suitability of the material for disposal at specified sites in Port Phillip Bay used previously for this purpose. There have been a number of evaluations of the data to date and recommendations have been made for additional sampling. This report is an attempt to consolidate these findings and to comment on their conclusions. In particular, comments were to be provided on the questions:

- Can the concentrations of contamination be determined (in chemical, location and volumetric terms) based on the existing data with a reasonable level of certainty?
- Do existing data indicate if contaminants are labile and/or bioavailable? If not, can this be determined by an expert professional judgement?
- Do the concentrations of labile/bioavailable contaminants justify containment of dredged volumes in the context of marine disposal?
- Is capping of contaminated sediments necessary?

As a prelude to this discussion, it is important to put into perspective the science behind the assessment frameworks being used. The National Ocean Disposal Guidelines for Dredged Material (NODG, 2002) is the seminal document underpinning the assessments, supplemented by the Victorian, Best Practice Environmental Management Guidelines for Dredging (BPEMGD). The former draws heavily on the Australian and New Zealand interim sediment quality guidelines (ANZECC/ARMCANZ, 2000) for screening values in the NODG assessment framework. Within the hierarchical NODG framework, exceedence of the guidelines determines the need for elutriate testing and/or acute or chronic toxicity testing, and ultimately whether disposal at sea is permissible.

The NODG guideline values are empirical guidelines derived from a large North American database comparing sediment contaminant concentrations and effects on a limited number of test organisms. The 10th percentile of these concentrations is chosen as the lower guideline value, and the median value as the upper guideline. Sediments in this database frequently had more than one major contaminant, and any observed toxicity was equally ascribed to all contaminants in the sediments. As a consequence, it now appears that guideline concentrations for metals in particular, are frequently too low as a result of toxicity due to organic contaminants (Simpson et al., 2005). For this reason, it has been noted that “guidance is to be expected from these values and not absolute certainty” (Batley et al., 2005). Because the guideline values are not terribly robust, and in some instances may be quite conservative, confirmation of impacts is sought from further investigations, when the values are exceeded. Strict adherence to the guideline values is not the intention of the ANZECC/ARMCANZ (2000) guidelines which recommend the additional use of biological assessment

(ecotoxicology and ecology), but the approach adopted both here and in the NODG (2002) is the use of a hierarchical assessment framework.

The second stage in the current NODG framework is the use of elutriate tests to examine the potential for contaminant release during ocean disposal. In the absence of impacts, this is followed by toxicity testing. Toxicity testing in sediments is not as advanced as it is in waters. Tests have only recently been developed for use in Australia and as they are being applied, a better understanding is being reached of the optimum test conditions and of any limitations. This is at the forefront of developments internationally. For example, more is now known about the effects of sediment grain size and the need to feed organisms in the *Melita* amphipod test. Sub-acute and chronic tests are few and development is slow, so this aspect of the NODG framework cannot be adequately applied. Investigations of pore water chemistry are problematic, because losses of contaminants, particularly organics, to container surfaces can be significant, while changes to the sediment chemistry will affect metal contaminant distributions.

The way these sorts of assessments are increasingly being addressed overseas is through a weight of evidence approach. This combines the use of chemical analyses with multiple toxicity tests, evidence of bioaccumulation with one or two species and some consideration of species biodiversity and abundance. In a port sediment, species diversity is likely to be limited and this would not necessarily be a recommended inclusion. This approach would now be considered best practice. A common weight of evidence approach uses data in a semi-quantitative assessment (Chapman et al., 2004) based on an agreed scoring system. The combined evidence is then used to rank the samples in terms of potential risk. Proposed revisions to both the ANZECC/ARMCANZ sediment quality guidelines and the NODG are expected to recommend a weight of evidence approach.

An example of a semi-quantitative weight of evidence assessment is given in Table 1. Here a ranking system is applied based on the magnitude of the assessment findings, and the overall assessment reaches a conclusion on the basis of all of the individual lines of evidence. This table does not include some measure of bioaccumulation, which is an additionally important line of evidence, especially for organic contaminants.

Table 1. Semi-quantitative ranked assessment of contaminated marine urban harbour sediments ^a

Site	Sediment Chemistry PAH-PCB-metal	AVS /SE M	10-d Amphipod Survival - Avoidance	48-h Bivalve Larvae Survival	20-d Polychaete Survival - Growth	Benthic Community Structure Abundance-diversity	Overall Assessment ^b	
							Abs. risk	Rel. risk
1	2-1-2	2	2-1	1-1	1-2	3-3	3	3
2	1-1-3	1	1-1	2-3	1-1	ND	2	2
3	3-1-2	1	1-1	3-2	1-2	2-1	3	3
4	2-1-2	1	2-1	1-3	1-2	2-1	3	3
5	2-2-2	1	1-1	3-3	1-1	2-1	2	2
6	2-1-2	1	1-1	1-1	1-1	3-1	2	1
Far field sites								
7	2-1-2	1	1-1	1-1	1-1	2-2	2	NA
8	1-1-2	1	2-1	1-1	1-1	3-1	2	NA
9	2-1-2	1	1-1	1-1	1-1	1-1	1	NA

^b Absolute risk is the WOE for various lines of evidence without consideration of far-field background responses (i.e. comparison to negative controls). Relative risk is the absolute risk normalised to the mean response observed at far-field locations.

^a *Explanation of table ranking system*

Parameter	Ranking		
	3	2	1
Sediment chemistry – PAH, PCB, metals	One or more analytes in a given category >5 x SQG	One or more analytes in a given category <5 x SQG	No analytes exceed SQG
Porewater TBT	>5 x WQG	<5 x WQG	<WQG
Toxicity (endpoint relative to negative control)	Reduction >50%	Reduction >20%	Reduction <20%
Benthos (relative to harbour wide background)	Abundance and/or diversity substantially lower	Abundance and/or diversity slightly lower	Abundance and/or diversity not lower
Overall assessment	Significant adverse effects predicted due to: elevated chemistry, >20% reduction in two or more toxicological endpoints, and reduced benthic diversity or abundance	Potential adverse effects predicted due to: elevated chemistry, >20% reduction in two or more toxicological endpoints, or reduced benthic diversity or abundance	No significant adverse effects predicted due to: elevated chemistry, no reduction in re toxicological endpoints, and no reduced benthic diversity or abundance

In the light of the above comments, I have evaluated the many reports to date that have analysed the investigations, together with the original reports by SKM.

SEDIMENT SAMPLING

There is general agreement that the number of samples taken by SKM was adequate for an initial overall assessment. The random sampling selected did not, however, give an accurate representation of contaminant levels in particular in the silt traps (Parry et al., 2005; URS, 2006). The exact size of individual hot spots is likely to have been overestimated, by not relying on mean concentrations as recommended in the NODG. The particular issues relating to the contaminant concentrations and their availability need discussion before reacting to this, and advice on additional sampling needs will be presented later.

SEDIMENT CHEMISTRY

Extensive data have been obtained on a range of contaminants suspected of being present in the samples from the dredge site, based on earlier historical evidence. These comprise metals, PAHs, total petroleum hydrocarbons, TBT, PCBs and organochlorine pesticides.

Sediment samplings were undertaken in 2003, 2004 and 2005. The data for 2003 did not include the upper 95% confidence limits of the mean contaminant concentrations, the measurements that NODG specifies should be used for comparison with the guideline concentrations.

Metals

For metals, a detailed examination of the 2004 data (SKM, 2004) shows that mean concentrations for lead, zinc, nickel, chromium, mercury and arsenic exceeded the lower guideline at a number of sites, while at a few specific sites nickel, lead, mercury and arsenic exceeded the upper guideline. This was an extension of the limited sampling in 2003. It was notable that with the exception of lead in two samples, none of the dilute acid-extractable metal concentrations exceeded the lower guideline values. This is an important finding as this fraction rather than the total metals concentration is the recommended measurement for sediment quality assessment (ANZECC/ARMCANZ, 2000). This is because the dilute acid-extractable fraction more closely represents the bioavailable metals fraction, by excluding the inert fraction that requires hot concentrated acids to make 'available'. The upper 95% of the mean dilute acid-extractable metal concentrations for the 72 samples analysed in 2004, for depths with shear strengths <10 kPa sites, were in all cases below the lower guideline values. Note that this shear strength cut off was chosen to delineate compacted bed materials from recently deposited fine sediments.

A further 34 samples were collected and analysed in 2005. The upper 95% concentrations for total metals analyses on these samples exceeded the lower guideline value at all Yarra River and Williamstown Channel sites for lead, nickel and mercury and three samples for zinc, and one for copper. At only one site was the upper guideline exceeded and then only for zinc. For the dilute acid-soluble fractions, only lead and zinc exceeded the screening values and this was so at most sites. Only in two surface sediment samples was the upper guideline value exceeded and only for zinc.

As discussed earlier, recent evidence suggests that metal guidelines are extremely conservative because of the fact that in the derivation of empirical guidelines, sediment toxicity that was largely due to co-occurring contaminants was equally ascribed to metals (Simpson et al., 2005). In whole-sediment or water-only tests using the most metal-sensitive amphipods, no toxicity was seen to zinc at the guideline trigger value (King et al., 2006), and a 20% effect was only seen in sediments spiked to 20 times the guideline value. In addition, measurements of acid volatile sulfides (AVS) in these sediments showed that in all cases of high metal concentrations, the simultaneously extractable metals fraction (SEM) was always exceeded by AVS, making toxicity unlikely from pore water metals in any of these sediments.

Mercury was one of the metals of concern. Its toxicity in estuarine sediments was studied by Sferra et al. (1999), who found no toxicity in 32 samples from a Louisiana (USA) estuary below a threshold of 4.1 mg Hg/kg, and this concurs with other findings. The guideline value of 0.15 mg/kg is therefore extremely conservative.

On this basis, the Port of Melbourne sediments could justifiably be considered as non-toxic with respect to all bioavailable metals. This is supported by the lack of cadmium, chromium, copper, mercury, nickel lead and zinc bioaccumulation by mussels in the region, although this bioaccumulation measured water column rather than sediment contamination (SKM, 2004). On the basis of total metals data, the sediments are, however, correctly classified as moderately contaminated.

Organic Contaminants

In the 2004 and 2005 samplings, the mean concentrations of PAH contaminants in the Yarra River and Williamstown Channel were, in all samples, below the minimum screening level, with the exception of fluorene and acenaphthene, which were still more than an order of magnitude below the upper guideline level. The total PAHs concentrations were an order of magnitude below the guideline value. It was notable that the 95% concentrations were typically some 3-4 times the mean, but still well below the minimum screening value (Enesar, 2005).

There is no guideline value for total petroleum hydrocarbons (TPHs), however, Simpson et al. (2006) derived a value of 300 mg/kg based on biological effects of co-occurring TPHs and PAHs. This value was more than twice the measured concentrations for the Port of Melbourne sites, although exceeded in several instances by the 95% values (Kowarsky, 2005). SKM (2004) discounted the measured data in some sites as they were only two times the background concentrations.

Longmore et al. (2003) reviewed the historical data obtained for Hobsons Bay during the Port Phillip Bay Study and noted that PCBs and organochlorine insecticides, particularly DDT and dieldrin, were highest in Hobsons Bay with implications for the Yarra estuary. Analyses for these compounds reported by SKM had a detection limit of 0.5 µg/kg (SKM, 2004, 2005; Enesar, 2005). The trigger value for DDT is 1.6 µg/kg for 1% OC, and the upper guideline is 46 µg/kg. For DDT, in limited instances, values of 10-38 µg/kg were measured (not obvious whether these were carbon normalised) (SKM, 2004). For the 2005 sampling, the 95% concentration of DDT were greatest at depth (0.7-1 m) with a mean around 1/3 of the upper guideline value.

Data reported by SKM for other organochlorine pesticides (SKM, 2004, 2005) included results for dieldrin and chlordane. The dieldrin guideline is 0.02 µg/kg, which is ¼ of the limit of detection. Given that dieldrin had been detected before, a better detection limit is required with further checks for other selected OC pesticides such as chlordane.

Tributyltin concentrations were highest in the Dock areas, with values at selected sites up to half the upper guideline value (SKM, 2004). In the 2005 sampling, TBT was an issue at only one site, with the upper 95% value only 3 x the guideline trigger value, and barely significantly (< 20%) exceeding the guideline in the Yarra

River/Williamstown Channel sites. The TBT guideline was derived using the water quality guideline and equilibrium partitioning estimates for the sediment. The guideline is conservative and this latter sort of exceedence is not seen as significant. In dock areas, TBT is likely to be very heterogeneously distributed, possibly as paint flakes. It has around a 3-year half-life in sediments so will degrade relatively quickly, but may pose a toxic threat for a further decade.

CHEMISTRY SUMMARY

In summary, while by definition the sediments might be classified as moderately contaminated, from a bioavailability standpoint potential toxicity is unknown. Metals do not represent a problem, but TPHs, TBT and organochlorine pesticides are problematic. Hotspots clearly exist where all of the above are present as potential toxicants. TPHs exceed threshold concentrations in some areas, as do TBT and DDT, while other OC pesticides such as dieldrin and chlordane were not determined with sufficient precision to rule them out as potential toxicants.

Analyses of pore waters revealed appreciable concentrations of ammonia. The marine water guideline trigger is 0.91 mg/L total ammonia, whereas the mean porewater concentration was 13.2 mg/L. It is not unusual to have higher ammonia in sediments, and a mean concentration for natural sediments of 9 mg/L of ammonia-N has been reported with 40.7 mg/L for dredged sediments, from an extensive survey of 322 estuarine/marine sediments (reported in ANZECC/ARMCANZ, 2000), so these numbers are not abnormal.

ELUTRIATE TESTS

Elutriate tests measure the potential contribution of contaminants to the overlying water during sea disposal. Our experience has been that metals are seldom an issue once likely dilution is taken into account. For organics, partitioning to waters is generally unfavourable, compared to sediments, and there is the additional problem of obtaining adequate detection limits on the water samples. Comparing elutriate concentrations directly against water quality guidelines, as was done by SKM (2004), is not appropriate without considering potential dilution (typically 1/100). On this basis, both metal and organic contaminant concentrations did not indicate releases of concern during dredging or disposal.

Enesar (2005) made the comment that insufficient sample numbers had been subjected to elutriate testing.

SEDIMENT TOXICITY

There have clearly been confounding results from the toxicity tests undertaken to date. There is a need to repeat these for key sites using the latest best practice, and additional test species. Obvious problems with positive results from reference sites need to be sorted out, so that the sources of toxicity can be unambiguously determined. Full information on the nature of the samples, adoption of prescribed holding times, and clear knowledge of matching chemistry data on the test samples is required. It is important to demonstrate that toxic effects are due to contaminants and not to the physical properties of the sediments (e.g. grain size, or the presence of

food). For this reason full characterisation of the sediments is important as is the selection of appropriate control or reference sites.

Enesar (2005) noted that ‘there is some uncertainty in translating toxicity tests to ecological impacts upon unconfined disposal since at the disposal site, studies showed no evidence that benthic faunal abundance is less than in the central region of the bay.’

CONTAMINANT BIOACCUMULATION

Because of the difficulties in measuring some of the organic contaminants, assessment of tissue bioaccumulation in selected organisms in laboratory or field deployments might be useful. Advice on this is provided in Simpson et al. (2005). Using a bivalve and/or a polychaete worm is recommended, preferably in 10-28 day laboratory tests. Field collection of mussels was undertaken by SKM (2004), but they were only analysed for metals (as discussed above) and not organics.

KEY QUESTIONS

- 1) *Can the concentrations of contamination be determined (in chemical, location and volumetric terms) based on the existing data with a reasonable level of certainty?*

What is lacking at the moment is an indication of the extent of variability of the concentrations of key contaminants in the vicinity of particular test sites, where an upper guideline is exceeded by the 95 % value. This was noted by URS (2006) who commented that (i) the extent of potentially toxic sediment had not been adequately addressed, particularly in the Yarra River and Williamstown Channel, and (ii) the lateral and vertical distribution of samples for toxicity testing and the number of species tested was inadequate. They recommend a combination of multiple acute and sub-lethal tests in a weight of evidence approach.

Additional sampling at hotspots will give a better estimation of the extent of contamination and an indication of the amount by which the elevated concentrations in a particular area might be volumetrically diluted during the dredging operation.

- 2) *Do existing data indicate if contaminants are labile and/or bioavailable? If not, can this be determined by an expert professional judgement?*

Existing data only demonstrate that a large fraction of the metals are unlikely to be in bioavailable forms. It is assumed that organics are in bioavailable forms to sediment-ingesting organisms, but not particularly available to organisms that are exposed to contaminants mainly via pore waters.

- 3) *Do the concentrations of labile/bioavailable contaminants justify containment of dredged volumes in the context of marine disposal?*

The dredged sediment disposal site area already has in its sediments the contaminants that are present in the material to be dredged. Confined disposal is recommended for some of the dock sediments and those from the upper Yarra. Selected disposal of

these sediments first followed by overlaying with less contaminated sediments later would minimise any potential impacts on benthic biota.

4) Is capping of contaminated sediments necessary?

Capping will be necessary if the findings from more detailed sampling around hotspots indicate that contamination is not localised and unlikely to be diluted by surrounding material. Any capping is best done with silty sediments from less contaminated dredged areas. Sand is a poorer capping material as it has no binding capacity so contaminants can readily leach into overlying water. This difference was demonstrated by recent trials in our laboratory (Simpson et al., 2002).

ADDITIONAL STUDIES

The proposed additional studies of chemical and toxicity assessment outlined by the Port of Melbourne Corporation for the Northern Channels (Port Melbourne and Williamstown Channels and Yarra River) should provide the additional information needed to define the sediment disposal options. Consideration could also be given to some measure of contaminant bioaccumulation at the most impacted sites. The process logic provided by the Corporation is essentially correct, but the significance of some of the contaminant concentrations needs to be considered in relation to the comments provided above.

Existing data show that contamination is far lower in the Southern Channel. Additional sampling should give better spatial coverage to support these findings.

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