Water Monitoring Report

December 1995 - November 1996

Sediment Quality Monitoring of the Port River Estuary

Report No 1

Environment Protection Authority
Department for Environment, Heritage and Aboriginal Affairs

Cover Photograph: Exposed sediment in the Port River near the Port Adelaide treated sewage outfall

November 1997

Document Production
Environment Protection Authority
Department for Environment, Heritage and Aboriginal Affairs
GPO Box 2607
ADELAIDE SA 5001

Telephone: 08 8204 2004
Fax: 08 8204 2050
Free Call: 1800 623 445

ISSN 1328-9896

SUMMARY

This report summarises the sediment quality of the Port Adelaide (Port) River estuary between December 1995 and November 1996.

Samples are collected biannually from the Port River, Barker inlet, Inner Harbour and Outer Harbour and analysed for organochlorine pesticides (including Chlordane, DDT, Dieldrin, Heptachlor, Lindane, Aldrin), polychlorinated biphenyls (PCBs), herbicides (Atrazine), heavy metals (lead, zinc, copper, mercury, cadmium and arsenic) and organotins (tributyltin, dibutyltin and monobutyltin).

The report sets criteria for each characteristic such that sediment quality can be described broadly as good, moderate or poor.

The preliminary findings of the monitoring programme indicate that the overall sediment quality of the Port River estuary is good to moderately contaminated for the following reasons:

1. One site (site 1) has copper concentrations that could cause frequent adverse effects in marine organisms exposed to the sediment, and concentrations of zinc, lead and cadmium that could occasionally cause adverse effects in marine organisms exposed to the sediment. Concentrations at all other sites are low.
2. One site (site 3) has mercury concentrations significantly above detection limits and high enough to cause frequent adverse effects in marine organisms exposed to the sediment. Concentrations at all other sites are low.
3. Tributyltin concentrations are at levels regarded as moderate at two sites but sediment quality is good at all other sites.
4. Chlordane was observed in concentrations above detection limits at site 1 in all replicates during November 1996.

Other organochlorine, polychlorinated biphenyl and herbicide concentrations are encouraging with all measurements taken to date being less than detection levels.

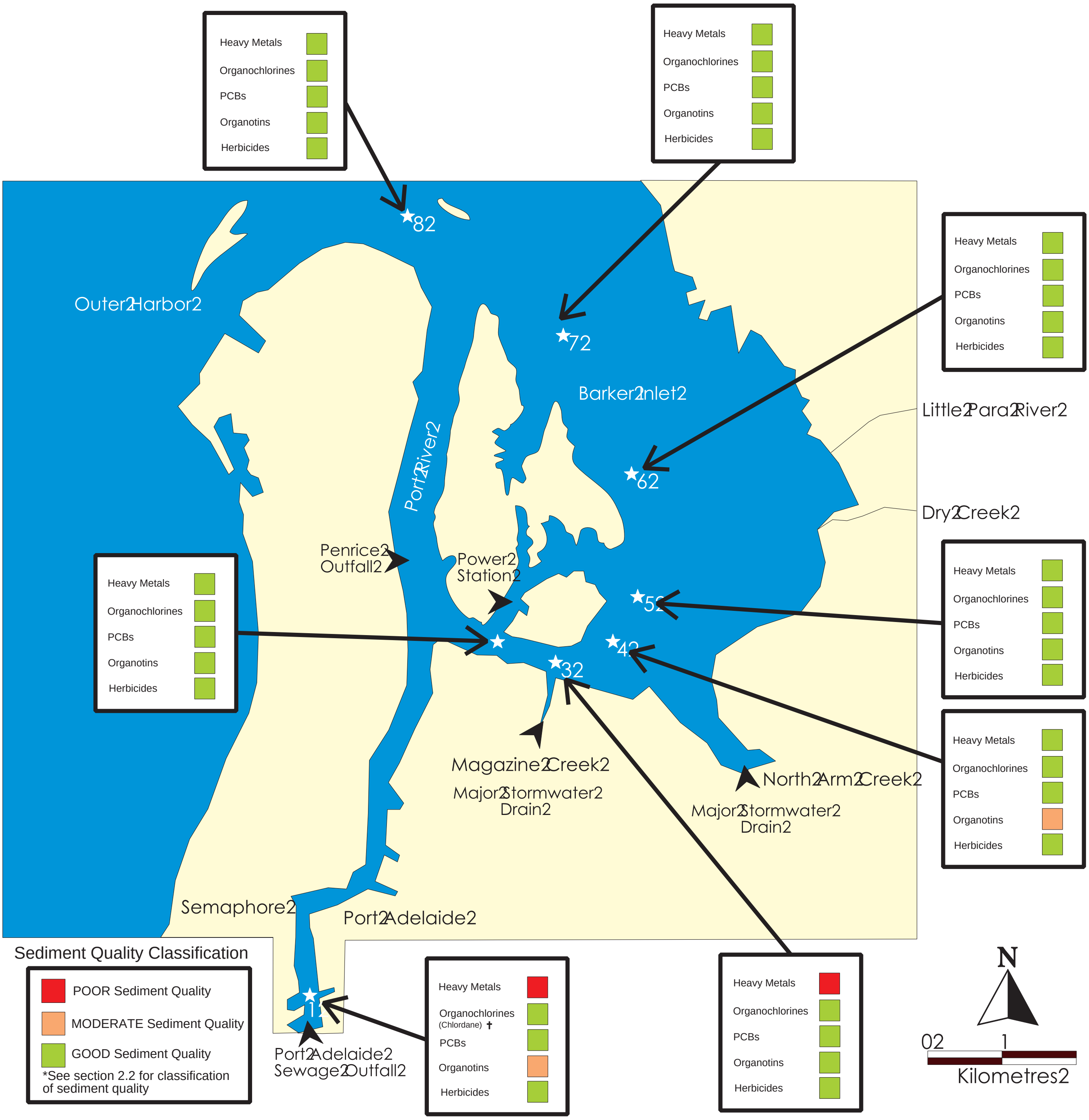
A number of initiatives in the Port River estuary should improve water and sediment quality over time. These include effluent reuse programmes for the sewage treatment works, environmental improvement programmes being established by industry in the area, and the development of extensive wetlands to treat stormwater. These initiatives should reduce metal and other toxicants from entering the estuary and prevent their accumulation in sediment.

Updates of these results will be published annually.

CONTENTS

Figure 1

Sediment Quality Monitoring Sites - Port River



† See section 4.1 for information on Chlordane contamination

1 INTRODUCTION

The Environment Protection Authority is undertaking a monitoring programme designed to provide a long term assessment of sediment quality in the Port Adelaide (Port) River estuary. The programme began in December 1995 and consists of samples being taken and analysed twice yearly from eight key sites (figure 1). The sites and characteristics chosen are based on environmental issues for the estuary. This report summarises the preliminary results of the programme. The results in this report are indicative of sediment quality over the period from December 1995 to November 1996.

The objectives of the sediment monitoring programme are to:

- provide a qualitative and quantitative assessment of the Port River estuary sediment quality
- determine statistically significant changes or trends in the key characteristics of sediment quality
- provide data to assess the long term ecological sustainable development of the Port River estuary.

1.1 The Port River estuary

The Port River estuary consists of West Lakes, the Port River, the North Arm, and the Angas and Barker inlets. All these areas are subject to a number of uses and environmental impacts. Recreational activities include boating, fishing and swimming. Industrial uses include loading and unloading ships, and the estuary water is used for cooling purposes by the power station on Torrens Island. The estuary contains extensive mangrove and seagrass beds, and is an important feeding and nursery ground for fish, crustaceans, molluscs and migratory birds. The area also contains two aquatic reserves.

The environmental values for the estuary are therefore protection of:

- water and sediment quality to support the aquatic ecosystem
- water quality for recreation and aesthetic uses
- water quality for industrial uses of the water.

Sediment quality is of interest because it can impact either directly or indirectly on water quality, and on marine and aquatic plants and animals.

1.2 Sediment quality indicators

The characteristics used to assess sediment quality at each of the eight sites over the period are:

- organochlorine pesticides (including Chlordane, DDT, Dieldrin, Heptachlor, Lindane, Aldrin)
- polychlorinated biphenyls (PCBs)
- herbicides (Atrazine)
- heavy metals (lead, zinc, copper, mercury, cadmium and arsenic)
- organotins (tributyltin, dibutyltin and monobutyltin).

Each of these characteristics, and their likely sources and impacts, are discussed in more detail later in this report.

2 ASSESSMENT METHODS

2.1 Statistical methods

The purpose of the sediment quality monitoring programme is to assess the overall sediment quality of the estuary by taking small and representative samples from selected sites occasionally. It is clearly an uncertain process and if the data are to represent the true situation, the degree of uncertainty must be quantified. The confidence interval (a known degree of confidence that the interval covers the true value) is an important component of this understanding.

At each site, three samples were taken and treated as separate results to measure 'within sample' and 'between site' variability. The average derived from the three replicates provides one value for each site per sampling event. Tables of values listed in this report quote the mean of all sampling events and the 95% confidence intervals for these means. Other statistical parameters used are the median, the geometric mean and the 95% upper and lower confidence intervals for the geometric mean which is given in the range, GM_L–GM_U. An explanation of the use of the geometric mean is given in section 4.4 (heavy metals).

2.2 Classification of level of contamination

Sediment guidelines are not available yet in Australia. Classification was therefore based on effect ranges (low (ERL) and median (ERM)) described by Long *et al* (1995).

A. The amount of each compound measured at each site has been classified as follows:

- GOOD: Geometric mean below the ERL
- MODERATE: Geometric mean above the ERL but lower than the ERM
- POOR: Geometric mean greater than the ERM.

The classification indicates that adverse biological effects on marine organisms, in frequent contact with the sediment, may occur rarely if ever (good), occasionally (moderate) or frequently (poor). The tables in section 3 quote the number of times the ERL has been exceeded at each site for each heavy metal.

B. The following classification of the amount of TBT measured at each site has been adapted from Waite *et al* (1991).

- GOOD: <50 µg/kg
- MODERATE: 50–300 µg/kg
- POOR: >300 µg/kg

TBT contamination is described as good, moderate, or poor if the geometric mean falls within one of the three classifications.

This classification scheme has been used in the summary tables and the map of the area (figure 1) to broadly indicate quality at different sites.

2.3 Differences between sites

It is important to determine whether there are statistically significant differences between monitoring sites. The variation in some data can be substantial but may not be significant from a statistical viewpoint. Paired t-tests were used to test for differences at the 5% level of significance (P=0.05). At this level there is a probability of only 1 in 20 that a difference in means could have arisen by chance.

3 ASSESSMENT OF THE DATA

Figure 1 shows the location of monitoring sites and summarises the sediment quality conditions at each location.

3.1 Organochlorine pesticides

Organochlorine pesticides (OCs) are synthetic compounds produced since the 1940s that had wide use in Australia. Many of these compounds are no longer authorised for use in Australia but unlawful use still occurs. The properties of OCs that cause greatest concern are their high toxicity and long term persistence in the environment and their potential for bioaccumulation.

Sources

OCs enter the environment from point sources (arising from a single source or location) such as sewage outfalls, factory discharges and streams discharging directly into the estuary. Diffuse (widespread) sources include atmospheric fallout, runoff from land and ground water leaching.

Impacts

OCs are a long term problem because they are relatively insoluble in water and highly soluble in fat. The compounds preferentially transfer and accumulate in the fats of aquatic plants and animals, resulting in concentrations of 500,000 times more than in surrounding waters.

Results

Only Chlordane was detected at site 1 on one occasion. No other OCs were detected above the detection limit of 0.05 mg/kg.

Chlordane is an insecticide used until quite recently for the control of termites. It was detected in all replicates at site 1 in November 1996 at a mean concentration of 0.22 mg/kg. The source of the contamination is not known. It is not possible to classify organochlorine concentrations at this stage as there are no guidelines for sediment.

3.2 Polychlorinated biphenyls

Polychlorinated biphenyls (PCBs) are a group of synthetic organochlorine chemicals, first manufactured in 1929 in response to the electrical industry's need for a safe cooling and insulating material. By the 1960s the hazards of PCBs because of their environmental persistence and toxicity were realised.

PCBs are very stable and environmentally hazardous because they do not break down by natural processes in the environment and are highly soluble in fat. They are mostly insoluble in water, so they tend to accumulate in the fatty tissue of plants and animals.

Sources

Because of their heat stability, PCBs were commonly used in electrical capacitors and transformers. PCBs can enter the environment from leakage from industrial and electrical equipment, from landfills or from previously contaminated sediments. Their use in Australia was restricted in 1975 to 'closed systems' where contact with the environment was unlikely.

Impacts

PCBs have high acute toxicity to aquatic life and bioaccumulate in organisms, concentrating in fatty tissue. PCBs are known to cause birth defects and changes in reproductive behaviour in higher level organisms.

Results

Concentrations for total PCBs at each of the sites in the Port River estuary were below the detection limit of 1.0 mg/kg.

3.3 Herbicides

Atrazine

Atrazine is a herbicide that controls weed growth by disrupting the process of photosynthesis and is used to control broad leaf weeds and some annual grasses in crops, fallow land, fruit crops, nurseries and lawns.

Sources

Herbicides enter water bodies from accidental drift from sprays during application, accidental release during transport, release during storage and from surface runoff from land where herbicide has been applied.

Impacts

Atrazine has a slight tendency to bioaccumulate but is usually rapidly transformed to non-toxic metabolites before being excreted. Atrazine is moderately persistent in soil and highly mobile, tending to tightly bind to soil particles. In water, Atrazine is only slightly soluble and will readily accumulate in organic matter and sediment.

Results

Atrazine concentrations at each of the sites in the Port River estuary were below the detection limit of 0.1 mg/kg.

3.4 Heavy metals

In estuaries, heavy metals are enriched in suspended and bottom sediments. In the absence of Australian guidelines for heavy metals in sediments the criteria used in each table for heavy metals are the ERL and ERM values for metals based on incidences of biological effects (Long *et al* 1995).

Sources

Industrial and port activities, stormwater runoff and sewage discharges are the major sources of such metals as zinc, lead and copper.

Impacts

Heavy metals in sediment are of concern because of the long-term problems caused by the bioaccumulation of metals by marine organisms. The metals work their way up the food chain and concentrations become magnified with each step. Dredging of contaminated sediments can resuspend and oxidise heavy metals to more soluble forms.

Three replicate samples taken at each site are analysed separately for heavy metals and the results averaged to give a single value for the site. This enables 'within site' and 'between site' variations to be quantified.

The tables below show generally large confidence intervals for the means, and substantially different means and medians indicating a skewed data set. The geometric mean is considered to be a better indication of the level of contamination at the sites and is therefore used to classify the overall level of contamination. The large confidence intervals make classification of the sites difficult.

Copper

The results (table 1) indicate that sediment quality is poor at site 1, moderate at site 3 and good at all other sites based on the criteria described in section 2.2A.

Table 1. Copper in the Port River estuary sediment

Site number **Statistics** (mg/kg)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Sediment quality classification	Poor	Good	Moderate	Good	Good	Good	Good	Good
Geometric Mean	174.6	15.5	43.3	18.2	23.9	21.0	9.0	6.8
Confidence Interval GM_L - GM_U	104 - 293.2	10.0 - 24.1	6.0 - 314.2	4.1 - 81.1	14.8 - 38.6	13.5 - 32.7	3.5 - 23.2	4.2 - 11.2
Median	222.5	19.3	39.0	33.3	21.7	17.0	10.0	7.4
Mean	185.5	16.2	100.2	27.2	25.3	22.1	11.1	7.2
± Confidence interval	99.9	7.6	188.8	29.2	15.5	12.9	11.0	4.0
Standard deviation	70.7	5.4	133.5	20.6	11.0	9.1	7.8	2.9
No. exceed ERL	3	0	2	1	1	0	0	0
Number of values	3	3	3	3	3	3	3	3

Classification based on Geometric mean: good: <34 mg/kg ; moderate: 34-70 mg/kg ; poor: >70 mg/kg
ERL: 34 mg/kg **ERM**: 70 mg/kg
Note: Site 1 is significantly different to sites 5 and 8, P<0.05

Zinc

The results (table 2) indicate that sediment quality is moderate at site 1 and good at all other sites based on the criteria described in section 2.2A.

Table 2. Zinc in the Port River estuary sediment

Site number **Statistics** (mg/kg)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Sediment Quality Classification	Moderate	Good	Good	Good	Good	Good	Good	Good
Geometric Mean	387.1	60.5	94.3	60.8	51.1	66.1	34.3	24.0
Confidence Interval GM_L - GM_U	261.2- 573.4	46.3 - 79.1	21.6 - 411.6	12.2 - 303.1	15.7 - 165.9	42.1 - 103.8	13.9 - 84.4	8.5 - 67.2
Median	355.0	56.7	108.3	103.3	70.0	56.0	50.0	31.0
Mean	402.7	61.7	148.8	96.4	67.7	69.8	40.6	30.0
± Confidence interval	164.9	17.1	171.5	93.1	58.0	33.7	26.9	23.8
Standard deviation	142.8	14.8	148.5	80.6	50.2	29.2	23.3	20.6
No. exceed ERL	3	0	2	1	0	0	0	0
Number of values	3	3	3	3	3	3	3	3

Classification based on Geometric mean: good: <150 mg/kg ; moderate: 150-410 mg/kg ; poor: >410 mg/kg
ERL: 150 mg/kg **ERM**: 410 mg/kg
Note: Site 1 is significantly different to sites 5 and 6, P<0.05

Lead

The results (table 3) indicate that sediment quality is moderate at site 1 and good at the other seven sites based on the criteria described in section 2.2A.

Table 3. Lead in the Port River estuary sediment

Site number Statistics (mg/kg)	1	2	3	4	5	6	7	8
Sediment Quality Classification	Moderate	Good	Good	Good	Good	Good	Good	Good
Geometric Mean	122.3	18.2	39.5	26.9	24.2	10.4	7.1	9.8
Confidence Interval GM_L - GM_U	45.5 - 328.9	10.9 - 30.4	7.9 - 197.9	5.7 - 126.1	12.1 - 48.3	15.5 - 53.7	11.5 - 31.4	6.2 - 15.5
Median	115.0	21.7	44.3	49.3	26.3	20.7	12.3	12.0
Mean	155.1	19.3	67.9	41.0	27.0	25.1	14.2	10.3
± Confidence interval	145.9	8.6	84.6	36.9	16.9	30.7	16.5	4.1
Standard deviation	126.4	7.4	73.3	31.9	14.6	26.6	14.3	3.6
No. exceed ERL	3	0	1	2	0	1	0	0
Number of values	3	3	3	3	3	3	3	3

Classification based on Geometric mean: good: <46.7 mg/kg ; moderate: 46.7-218 mg/kg ; poor: >218 mg/kg

ERL: 46.7 mg/kg **ERM**: 218 mg/kg

Note: Sites not significantly different, P>0.05

Mercury

Sediment quality is classified as poor at site 3 based on a mean of 1.8 mg/kg for replicates at site three in May 1996. All replicates for this sample were similar in value. Concentrations above the detection limit were also observed in one replicate at sites 4 and 5 in the same sampling period. All other results at all sites were below the detection limit and are hence classified as having good sediment quality.

Table 4. Mercury in the Port River estuary sediment

Site number Statistics (mg/kg)	1	2	3	4	5	6	7	8
Sediment Quality Classification	Good	Good	Poor	Good	Good	Good	Good	Good
Geometric Mean	0.6	0.6	1.0	0.6	0.8	0.6	0.6	0.6
Confidence Interval GM_L - GM_U	0.4 - 1.0	0.4 - 1.0	0.5 - 2.0	0.4 - 1.0	0.4 - 1.0	0.4 - 1.0	0.4 - 1.0	0.4 - 1.0
Median	0.5	0.5	1.0	0.5	0.5	0.5	0.5	0.5
Mean	0.7	0.7	1.1	0.7	0.8	0.7	0.7	0.7
± Confidence interval	0.3	0.3	0.8	0.3	0.3	0.3	0.3	0.3
Standard deviation	0.3	0.3	0.7	0.3	0.3	0.3	0.3	0.3
No. exceed ERL	0	0	1	0	0	0	0	0
Number of values	3	3	3	3	3	3	3	3

Classification based on Geometric mean: good: <0.15 mg/kg ; moderate: 0.15-0.71 mg/kg ; poor: >0.71 mg/kg

ERL: 0.15 mg/kg **ERM**: 0.71 mg/kg

Note: Sites not significantly different, P>0.05

Detection limit: 1.0 mg/kg in December 1995 and 0.5 mg/kg for May and November 1996.

Arsenic

Results (Table 5) indicate that sediment quality is slightly elevated at site 1 but good at all sites based on the criteria described in section 2.2A.

Table 5. Arsenic in the Port River estuary sediment

Site number **Statistics** (mg/kg)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Sediment Quality Classification	Good	Good	Good	Good	Good	Good	Good	Good
Geometric Mean	7.4	5.1	5.9	5.4	5.3	5.7	5.0	5.7
Confidence Interval GM_L - GM_U	5.6 - 9.7	5.0 - 5.2	4.5 - 7.6	4.7 - 6.0	4.8 - 5.7	5.7 - 5.8	5.0 - 5.0	4.6 - 7.2
Median	7.5	5.1	5.9	5.4	5.3	5.8	5.0	5.8
Mean	7.5	5.1	5.9	5.3	5.3	5.8	5.0	5.8
± Confidence interval	2.5	0.1	1.9	0.8	0.5	0.03	0	1.6
Standard deviation	1.7	0.1	1.3	0.5	0.4	0.02	0	1.1
No. exceed ERL	1	0	0	0	0	0	0	0
Number of values	2	2	2	2	2	2	2	2

Classification based on Geometric mean: good: <8.2 mg/kg ; moderate: 8.2-70 mg/kg ; poor: >70 mg/kg
ERL: 8.2 mg/kg **ERM**: 70 mg/kg
Note: Sites not significantly different, P>0.05
Detection limit: 5 mg/kg.

Cadmium

Results (Table 6) indicate that sediment quality is moderate at site 1 and good at the other seven sites based on the criteria described in section 2.2A.

Table 6. Cadmium in the Port River estuary sediment

Site number **Statistics** (mg/kg)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Sediment Quality Classification	Moderate	Good	Good	Good	Good	Good	Good	Good
Geometric Mean	2.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Confidence Interval GM_L - GM_U	1.5 - 3.9	1.0 - 1.0	1.0 - 1.0	1.0 - 1.0	1.0 - 1.0	1.0 - 1.0	1.0 - 1.0	1.0 - 1.0
Median	2.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Mean	2.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0
± Confidence interval	1.3	0	0	0	0	0	0	0
Standard deviation	0.9	0	0	0	0	0	0	0
No. exceed ERL	3	0	0	0	0	0	0	0
Number of values	3	3	3	3	3	3	3	3

Classification based on Geometric mean: good: <1.2 mg/kg ; moderate: 1.2-9.6 mg/kg ; poor: >9.6 mg/kg
ERL: 1.2 mg/kg **ERM**: 9.6 mg/kg
Note: Sites not significantly different, P>0.05
Detection limit: 1.0 mg/kg

3.5 Organotins

Tributyltin (TBT) is the active ingredient in marine antifouling paints applied to ships and has been used in Australia since the 1970s. The paint leaches TBT at about 4 µg/cm^2 per day (Batley 1996).

In South Australia the release rate for antifoulants should not be greater than 5 µg TBT/cm^2 per day. The half life of TBT in sea water is approximately six hours. It then rapidly partitions to either suspended sediments or to the surface microlayer. Once in the sediments, its half life is approximately 3.5 years. The ANZECC guideline for marine waters is 0.002 µg/L.

In the absence of Australian guidelines for TBT in sediments the criteria for classifying the level of contamination used by the WA EPA (adopted from Waite *et al* 1991) were applied.

TBT is degraded primarily to dibutyltin and also to monobutyltin and inorganic tin. Dibutyltin and monobutyltin have a comparatively minor impact on the environment and are substantially less toxic than TBT.

Sources

Butyltins can enter the water column from sources other than paint. For example, dibutyltin is used as a catalyst in the plastics industry and TBT is used as an algaecide in boiler and cooling circuits. Other organotin compounds such as alkyltins are also used in pesticide formulations but are unlikely to be found in coastal waters.

Impacts

The biggest impact of TBT is its effect on oysters and other bivalves through bioaccumulation. Shell growth is enhanced at the expense of tissue, leading to the thickening of the shell. There has also been the observation in gastropods of imposex (the induction of male reproductive organs in female animals) caused by TBT.

Tributyltin

Results (table 7) indicate that sediment quality is moderate at two sites and good at six sites based on the criteria described in section 2.2B.

Table 7. Tributyltin in the Port River estuary sediment

Site number Statistics (µg/kg)	1	2	3	4	5	6	7	8
Sediment Quality Classification	Moderate	Good	Good	Moderate	Good	Good	Good	Good
Geometric mean	84.7	22.0	22	54.8	16.1	13.6	27.8	3.9
Confidence Interval GM_L - GM_U	22.0 - 326.5	2.0 - 247.8	9.6 - 50.5	9.2 - 323.7	6.6 - 39.3	4.4 - 42.0	9.9 - 77.6	0.2 - 68.6
Median	120.0	55.0	26.0	27.0	14.0	8.0	45.0	4.8
Mean	121.0	51.3	25.7	122.0	19.7	19.2	34.3	15.7
± Confidence interval	81.6	34.3	12.2	239.2	18.8	0.3	31.0	3.7
Standard deviation	70.7	29.7	10.6	207.2	16.2	0.3	26.9	3.1
Number of values	3	3	3	3	3	3	3	3

Classification based on Geometric mean: good: <50 µg/kg; moderate: 50-300 µg/kg; poor: >300 µg/kg.

Note: Sites not significantly different, P>0.05

Dibutyltin

It is not possible to classify dibutyltin concentrations at this stage as there are no guidelines for sediment.

Table 8. Dibutlytin in the Port River estuary sediment

Site number Statistics (µg/kg)	1	2	3	4	5	6	7	8
Geometric mean	100.6	3.6	0.9	7.1	1.8	1.7	1.5	0.9
Confidence Interval GM_L - GM_U	24.3 - 415.8	0.8 - 15.8	0.1 - 7.8	0.8 - 63.5	0.3 - 12.5	0.2 - 14.6	0.1 - 13.9	0.1 - 8.0
Median	97.0	3.6	0.3	2.8	2.6	1.4	0.8	0.3
Mean	159.0	5.9	2.8	22.6	3.6	4.6	4.7	2.9
± Confidence interval	206.6	7.67	6.1	49.2	4.3	0.9	0.4	5.1
Standard deviation	178.9	6.6	5.3	42.6	3.7	0.8	0.4	4.4
Number of values	3	3	3	3	3	3	3	3

No guidelines available

Note: Sites not significantly different, P>0.05

Monobutyltin

It is not possible to classify monobutyltin concentrations at this stage as there are no guidelines for sediment.

Table 9. Monobutyltin in the Port River estuary sediment

Site number Statistics (µg/kg)	1	2	3	4	5	6	7	8
Geometric mean	17.2	15.3	2.0	3.9	12.2	1.9	5.4	1.7
Confidence Interval GM_L - GM_U	3.9 - 74.8	1.2 - 190.0	0.05 - 82.5	0.1 - 138.3	0.4 - 413.1	1.6 - 2.5	0.3 - 89.9	0.3 - 9.8
Median	14.0	6.4	1.0	8.0	24.0	0.4	9.3	2.5
Mean	22.9	50.1	9.8	10.8	33.3	21.6	22.5	3.3
± Confidence interval	32.0	109.1	22.6	19.4	60.4	0.1	7.3	1.8
Standard deviation	27.7	94.5	19.6	16.8	52.3	0.1	6.4	1.6
Number of values	3	3	3	3	3	3	3	3

No guidelines available

Note: Sites not significantly different, P>0.05

4 CONCLUDING REMARKS

The preliminary findings of the monitoring programme indicate that the overall sediment quality of the Port River estuary is good to moderately contaminated for the following reasons:

1. One site (site 1) has copper concentrations that could cause frequent adverse effects in marine organisms exposed to the sediment, and concentrations of zinc, lead and cadmium that could occasionally cause adverse effects in marine organisms exposed to the sediment. Concentrations at all other sites are low.
2. One site (site 3) has mercury concentrations significantly above detection limits and high enough to cause frequent adverse effects in marine organisms exposed to the sediment. Concentrations at all other sites are low.
3. Tributyltin concentrations are at levels regarded as moderate at two sites but sediment quality is good at all other sites.
4. Chlordane was observed in concentrations above detection limits at site 1 in all replicates during November 1996.

Other OC, PCB and herbicide concentrations are encouraging with all measurements taken to date being less than detection levels.

The concentrations of heavy metals reported in this report are similar to results reported for the Barker Inlet by Harbison (1986a,b).

A number of initiatives in the Port River estuary should improve water and sediment quality over time. These include effluent reuse programmes for the sewage treatment works, environmental improvement programmes being established by industry in the area, and the development of extensive wetlands to treat stormwater. These initiatives should reduce metal and other toxicants from entering the estuary and prevent their accumulation in sediment.

5 FURTHER READING

ANZECC. 1992. *National Water Quality Management Strategy Guidelines for Fresh and Marine Waters*. Australia and New Zealand Environment and Conservation Council.

Batley, GE. 1995. Heavy metals and tributyltin in Australian coastal and estuarine waters. In Zann and Sutton (eds) *State of the Marine Environment Report for Australia: Technical annex: 2 – Pollution*, pp. 63–72.

Cugley, J. 1994. Ambient water quality monitoring for SA—Issues and requirements. EPA Draft Report.

Department of Environment Protection. 1996. Southern metropolitan coastal waters study (1991–94): Report 17. DEP, Perth.

Harbison, P. 1986a. Diurnal variations in the chemical environment of a shallow tidal inlet, Gulf St Vincent, South Australia: Implications for water quality and trace metal migration. *Marine Environmental Research*, 20: 161–195.

Harbison, P. 1986b. Mangrove muds—A sink and a source for trace metals. *Marine Pollution Bulletin*, 17 (6): 246–250.

Long, ER, MacDonald, DD, Smith, SL and Calder, FD. 1995. Incidence of adverse effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management*, 19 (1): 81–97.

Richardson, BJ. 1996. The problems of chlorinated compounds in Australia's marine environment. In Zann and Sutton (eds) *State of the Marine Environment Report for Australia: Technical annex: 2 – Pollution*, pp. 53–61.

Taylor, JK. 1987. *Quality assurance of chemical measurements*. Lewis Publishers, pp. 129–146.

Waite, ME, Waldock, MJ, Thain, JE, Smith, DJ and Milton, SM. 1991. Reductions in TBT concentrations in UK estuaries following legislation in 1986 and 1987. *Marine Environmental Research,* 32: 89-111.

Zann, LP and Sutton, D (eds). 1995. *State of the Marine Environment Report for Australia: Technical annex: 2 – Pollution*. Great Barrier Reef Marine Park Authority, for the Department of the Environment, Sport and Territories, Ocean Rescue 2000 Programme: Townsville.