

Temporal changes in heavy metal concentrations in sediments from Melbourne's waterways.

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SUMMARY: A temporal comparison was conducted of heavy metal concentrations in fine sediments from waterways in the Melbourne region, using data collected during 1981 to 1983 and during 1993 to 1997. Some improvements occurred in the lower Merri Creek, probably as a result of reductions in industrial discharges. Metal concentrations generally declined in the Maribyrnong River, remained similar at three sites on Dandenong Creek, but significantly increased in Gardiners Creek, one site in Dandenong Creek and two sites in Kororoit Creek. Lead concentrations tended to be lower or remain similar to those present during the early 1980s, whereas there were general increases in zinc and mercury. Further information is required to enable waterway management agencies to make informed decisions about how to manage metal contamination, however, toxicant issues are likely to be a priority issue in established inner urban suburbs and industrialised areas.

THE MAIN POINTS OF THIS PAPER

- Significant changes in the concentration of metals in fine sediments from Melbourne's waterways have occurred between the early 1980s and mid 1990s.
- Lead concentrations generally declined, whereas zinc and mercury increased in the past decade.
- More urban sites had contaminated sediments in the mid 1990s than in the 1980s.
- There is a need to determine the activities influencing these changes and how they can be managed to reduce impacts on aquatic ecosystems.

1. INTRODUCTION

Stream sediments have an important role as a sink for dissolved contaminants and a source of bioavailable contaminants to benthic biota and potentially the entire food chain (ANZECC, 1998).

A recent survey of metal concentrations in stream sediments found that many of Melbourne's waterways had metal concentrations that may be of concern to stream health (Pettigrove, 1998). This study reviewed heavy metal concentrations in fine sediments from 171 sites on 64 waterways in the Greater Melbourne region, using data collected during the 1990s. The concentration of these metals varied substantially throughout the study area in relation to catchment geochemistry and land use. Pettigrove (1998) concluded that these metals often may adversely impact the health of waterways in the Melbourne region, particularly inner urban waterways. The major sources of these metals were not identified, nor was it possible to comment on how heavy metal contamination changes over time.

This paper compares two heavy metals data sets collected from the fine sediments of streams around Melbourne to determine whether any temporal trends are evident. The Environment Protection Authority (EPA) sampled metals from several waterways during 1981 to 1983, however, these data were not published. Melbourne Water Corporation (MW) resurveyed many of these sites between 1993 and 1997, using the same

field sampling and usually the same analytical methods employed in the EPA study.

The data presented in this paper is also compared against draft interim sediment quality guidelines (ISQGs) proposed for Australian waterways (ANZECC, 1998). Metal concentrations that are below the ISQG-low have a low probability of impacting the benthic biota; those exceeding the ISQG-high have a high probability that there will be toxic effects; and values falling between these values will have an intermediate probability of effects (ANZECC, 1998). The implications of these results for waterway management agencies are also discussed.

2. STUDY AREA

The location of the 16 sites surveyed are illustrated in Figure 1. A list of the waterway reaches and the number of times they were surveyed by the EPA and MW is presented in Table 1. Another 13 sites were also surveyed by the EPA, but were not repeated in the MW study. MW sites were located as near as possible to the EPA sites, however, the exact location of the earlier collection is often not known, only the locality. Up to five replicates were collected per trip from some sites during the EPA study. These replicates varied little from each other, therefore, only the median values were used for comparison to the MW data. Most sites were located in urban waterways, only Merri Creek at Merriang and Kororoit Creek at Rockbank are in rural areas. Jacksons Creek, a major tributary of the Maribyrnong River, is in a

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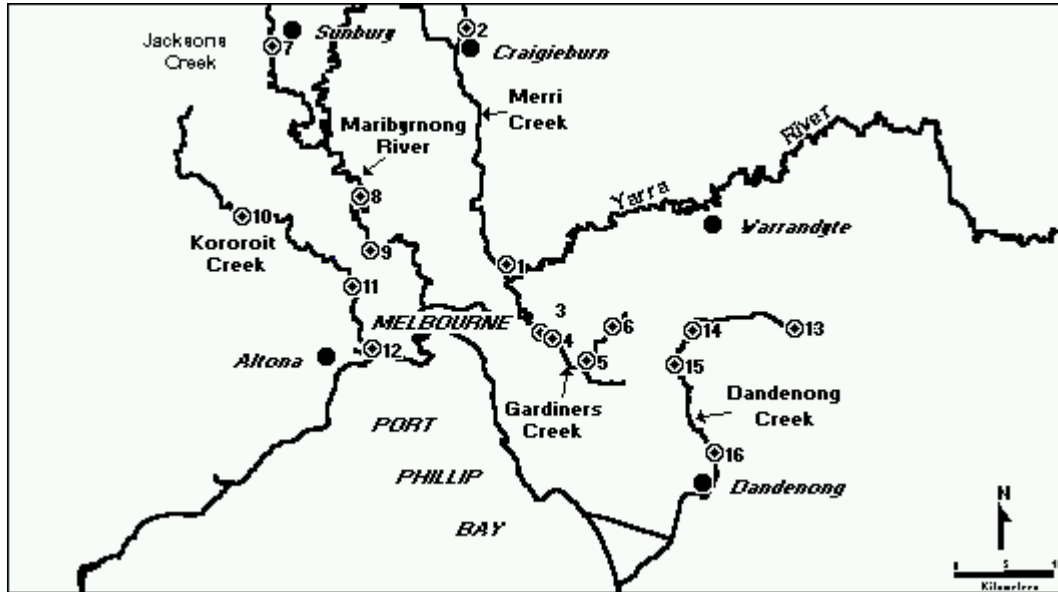


Figure 1: A location map of the sites surveyed in this study. The site corresponds to those used in Table 1.

Table 1: A list of the reaches surveyed by EPA and MW and the number of sampling events conducted. The site number corresponds to those used in Figure 1.

No	Waterway	Location	No. events	
			EPA	MW
1	Merri Ck.	Clifton Hill	27	7
2	Merri Ck.	Merriang	27	8
3	Gardiners Ck.	Malvern	13	4
4	Gardiners	Glen Iris	12	8
5	Gardiners Ck.	Chadstone	14	4
6	Gardiners Ck.	Burwood	12	4
7	Jacksons Ck.	Sunbury	4	5
8	Maribyrnong R.	Keilor	3	8
9	Maribyrnong R.	Avondale Heights	5	8
10	Kororoit Ck.	Rockbank	5	4
11	Kororoit Ck.	Deer Park	5	4
12	Kororoit Ck.	Altona	5	4
13	Dandenong Ck.	The Basin	5	8
14	Dandenong Ck.	Vermont	5	8
15	Dandenong Ck.	Glen Waverley	5	4
16	Dandenong Ck.	Dandenong North	5	8

predominantly rural catchment, but the site is immediately downstream of the township of Sunbury.

3. METHODS

Sediments were collected from depositional sections of each waterway by scooping sediment from a 10 m section of stream with a nylon net into a plastic bucket. The sediment was then sieved through a 64 µm nylon mesh net. Approximately 100 g of the sieved portion was retained for analysis in acid washed glass jars.

Samples were analysed for arsenic (As), mercury (Hg), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb) and zinc (Zn). Every attempt was made in the MW study to follow the analytical methods adopted by the EPA in order to improve data comparability between

both studies, although this did not occur on all occasions. Where differing methods were used, slight variations in the amount of metals that were extracted from the sediments may have resulted.

Cr, Cu, Pb and Zn were analysed in both studies using flame atomic absorption spectroscopy (AAS) with a detection limit (DL) of 1.0 mg/kg, except in one MW run, when all analyses were conducted using an inductively coupled plasma technique. Arsenic was analysed in both studies using a hydride generation technique (DL = 0.05 mg/kg). Hg was analysed in both studies using cold vapour AAS (DL = 0.005 mg/kg, except in a MW run when the DL was 0.10 mg/kg). Cd was analysed using graphite furnace AAS (DL = 0.01 mg/kg, except in autumn 1995 where a DL of 1.0 mg/kg applied). Most samples analysed for Cd by the EPA were below the DL of 1 mg/kg. Only a site on Merri Creek and another on Kororoit Creek exceeded the DL on all occasions, and are the only sites where EPA and MW Cd data are compared. The EPA and MW data were compared using the Mann-Whitney U test.

4. RESULTS

Comparisons of median heavy metal concentrations between the early 1980s and mid 1990s are presented in Table 2. Those values with a grey background indicate a significant difference in concentrations between sampling periods for that metal.

4.1 Gardiners Creek

Zn concentrations significantly increased in the mid 1990s, compared to the early 1980s, at three sites and appeared to substantially increase at the fourth site (Table 2). The increases in median Zn concentrations between these periods ranged between 87 (Malvern) and 315% (Burwood). During the early 1980s, the median concentrations at three sites exceeded the ISQG-low of 200 mg/kg, and a fourth site had

concentrations below this guideline. In contrast, the median Zn concentrations during the mid 1990s exceeded the ISQG-high at all four sites.

Hg results followed a similar pattern to Zn, with three sites having significantly higher concentrations, and the remaining site at Malvern also being substantially higher in the mid 1990s. All median concentrations were below the ISQG-low of 0.15 mg/kg in the early 1980s, but Chadstone exceeded this guideline in the mid 1990s.

Significant increases in As occurred between the early 1980s and mid 1990s, at Malvern and Burwood, whereas As concentrations remained constant at Glen Iris and Chadstone. Although significant increases

occurred, median concentrations were still well below the ISQG-low of 20 mg/kg.

Significant increases of Cr, ranging between 56 and 92%, occurred at all four sites on Gardiners Creek. However, these concentrations are still well below the ISQG-low of 80 mg/kg.

Pb concentrations did not vary at three sites, but were significantly lower in the mid 1990s at Glen Iris. Median values at all four sites exceeded the ISQG-low of 50 mg/kg during both studies. The Glen Iris site has now dropped below the ISQG-high, whereas the lower site at Malvern exceeded the ISQG-high during both studies. Cu concentrations appear to be similar at each of the four sites in the mid 1990s, whereas elevated concentrations exceeding the ISQG-low of 65

Table 2: A comparison of median concentrations (mg/kg) collected during the early 1980s and mid 1990s from 16 sites on six waterways. Those values with a grey background are significantly different between the two sampling periods. Up to five replicates were collected from the EPA study conducted in the early 1980s. These replicates varied little from each other, therefore, only the mean values were used for comparison to the to the MW data.

Waterway	Location	Period	Zn	Hg	As	Cr	Pb	Cu	Cd	
Gardiners Ck.	Malvern	81-82	403	0.080	5	17	271	54		
		94-95	755	0.140	8.2	32	271	49		
	Glen Iris	81-82	265	0.080	5.7	14	239	52		
		94-97	515	0.130	5.3	26	123	48		
	Chadstone	81-82	298	0.070	3.7	14	196	116		
		94-95	780	0.240	4.9	27	175	62		
	Burwood	81-82	130	0.040	1.9	14	94	19		
		94-95	540	0.150	3.2	22	150	44		
	Dandenong Ck.	The Basin	81-82	57	0.031	2.4	24	17	15	
			94-97	52	0.045	2.3	25	18	12	
Vermont		81-82	180	0.130	2.1	20	86	24		
		94-97	439	0.157	4	21	96	39		
Glen Waverley		81-82	72	0.026	1.8	18	25	13		
		96-97	101	0.042	2	16	32	10		
Dandenong North	81-82	138	0.028	2.5	17	68	15			
	94-97	103	0.036	2.2	17	25	9			
Jacksons Ck.	Sunbury	81-82	100	0.021	3	33	31	33		
		94-97	126	0.032	7.2	47	40	47		
Maribyrnong R.	Keilor	81-82	222	0.054	4.3	35	172	35		
		94-97	121	0.041	6.1	56	35	56		
	Avondale Heights	81-82	207	0.099	5.2	49	35	49		
		94-97	129	0.074	4.8	63	56	63		
Kororoit Ck.	Rockbank	81-82	54	0.030	4.8	63	29	22		
		94-95	154	0.160	10.9	69	83	28		
	Deer Park	81-82	221	0.031	1.9	49	125	35		
		94-95	668	0.270	5	74	188	86		
	Altona	81-83	240	0.752	4	81	243	163		
		94-95	650	2.825	5	170	188	133		
Merri Ck.	Merriang	81-83	56	0.016	1.9	19	13	8	-	
		93-97	247	0.085	17.9	53	34	27	0.65	
	Clifton Hill	81-83	1875	0.308	17.4	79	830	183	3.63	
		93-97	1506	0.407	15.9	77	505	124	3.03	
ANZECC Guidelines	ISQG-low	200	0.150	20	80	50	65	1.5		
	ISQG-high	410	1.000	70	370	220	270	10		

mg/kg, occurred at Chadstone and very low concentrations occurred at Burwood during the early 1980s.

Overall, Zn, Hg, As and Cr significantly increased in the highly urbanised Gardiners Creek between the early 1980s and mid 1990s. Increases in Hg and particularly Zn are of concern, as they now exceed the ISQG-high and therefore are likely to be impacting the aquatic ecosystem. Since 1983, a major freeway has been constructed along the lower section of the Gardiners Creek valley, which has probably led to increased traffic in the area and road runoff into the creek. Significant correlations have been found between Pb, Zn and Cu in waterways versus traffic and percent impervious catchment (Helsel et al., 1979), and may be a major factor influencing temporal trends in Gardiners Creek.

4.2 Dandenong Creek

Hg, Cr and Cu concentrations did not significantly vary between the EPA and MW studies (Table 2) and both were well below the ISQG-low guidelines of 0.15 mg/kg for Hg, 80 mg/kg for Cr and 65 mg/kg for Cu.

Arsenic concentrations significantly increased at Vermont in the mid 1990s, however these concentrations are still low when compared to other waterways in the Melbourne region (Pettigrove, 1998), and all sites are well below the ISQG-low of 20 mg/kg.

Pb concentrations were significantly less at Dandenong North, and did not substantially change at the remaining three sites. Median values exceeded the ISQG-low of 50 mg/kg at Vermont during the EPA study, but was below this guideline in the mid 1990s.

Zn concentrations significantly increased at Vermont, but not at the other three sites. During the early 1980s, Zn concentrations in Vermont were below the ISQG-low of 200 mg/kg, but by the mid 1990s had exceeded the ISQG-high of 410 mg/kg.

Overall, most sites in the Dandenong Creek have similar metal concentrations in both studies. Only the Vermont site, had significantly higher concentrations of Zn and As. These metal increases at Vermont probably reflect increased urbanisation in the catchment since the early 1980s. Metal concentrations in Dandenong Creek at Glen Waverley and Dandenong North may be diluted by clean sediment run-off from new local residential developments.

4.3 Maribyrnong River

Two trends emerge from the summary Maribyrnong data (Table 4). All metal concentrations remained steady in Jacksons Creek, Sunbury, except for a significant, albeit small increase in As. In contrast, the two Maribyrnong River sites had significantly lower concentrations of Zn. There was a large decrease in median Pb concentrations at Keilor from 172 mg/kg in

the early 1980s to 35 mg/kg in the mid 1990s. Furthermore, lower concentrations of Hg and no detectable change in As occurred at these sites. Cu was the only metal that significantly increased in the Maribyrnong River at Keilor and Avondale Heights.

All median metal concentrations in the mid 1990s were below the ISQG-low. This is a considerable improvement compared to the early 1980s, when Zn and Pb at Keilor and Avondale Heights were around the ISQG-high, and above the ISQG-low respectively.

Overall, there has been some improvements in the heavy metal contamination in the Maribyrnong River since the early 1980s. This improvement has occurred despite increased urbanisation in the local catchment, particularly at Keilor, Taylors Lakes, Sydenham and Sunbury. Reduced metals in Maribyrnong River sediments, may have occurred as a result of Keilor being connected to a wastewater treatment plant in 1980, which would have improved quality of urban run-off. Furthermore, metal concentrations may have been diluted by increased amounts of clean sediment run-off from local residential developments.

4.4 Kororoit Creek

The rural site at Rockbank had significantly higher Hg concentrations during the mid 1990s. Furthermore, median Zn and Pb concentrations were more than twice those in the early 1980s, but not were not significantly higher. All metals were below the ISQG-low during both surveys.

Deer Park was the only site examined in this study that had significant increases in all six metals investigated. During 1981 to 1983, metal concentrations were below the ISQG-low for Hg, As, Cu and Cr, while Zn and Pb were above the ISQG-low. By the mid 1990s, Zn concentrations exceeded the ISQG-high, Hg exceeded the ISQG-low and Cr had increased to be just below the ISQG-low. These results indicate increased contamination at the site which may have a greater impact aquatic life than what occurred in the early 1980s.

Large residential areas have been developed in Deer Park and St. Albans immediately upstream of this site since 1983. It is likely that increased urbanisation of the catchment has contributed to increased metal run-off. Furthermore, some sediments in the local catchment, that may have been contaminated from past heavy industrial activities, are being mobilised as the urban sprawl moves into these areas.

There were significant increases in Zn and Hg in the lower Kororoit Creek at Altona during the mid 1990s compared to the early 1980s. Zn and Hg now exceed the ISQG-high, whereas previously they were below this level. Most metals have higher concentrations at this site, when compared to the other Kororoit Creek

sites or other waterways around Melbourne (Pettigrove, 1998).

Prior to 1990, petro-chemical industries discharged wastes directly into Kororoit Creek. These liquid wastes contained a variety of contaminants, including Hg, Cu, Cr and vinyl chloride monomer. These industrial discharges have now been diverted to the sewerage system (SER, 1988). However, the aquatic ecosystem is still stressed by elevated metal concentrations (Pettigrove, 1998), and it may take considerable time before these metals drop to levels that will enable the aquatic ecosystem to recover (SER, 1988).

4.5 Merri Creek

There were significant increases in Zn, Hg, As, Cr and Cu in the Merri Creek upstream of Craigieburn (Table 2). In addition, median Pb concentrations had increased from 13 mg/kg in the early 1980s to 34 mg/kg in the mid-1990s. All metals, except Zn, were still below the ISQG-low. Zn concentrations in the mid 1990s exceeded the ISQG-low of 200 mg/kg, whereas it was previously well below this figure.

The lower Merri Creek at Clifton Hill had significantly lower Pb and Cu concentrations during the mid 1990s than in the early 1980s. Many heavy metal concentrations were still high, and Zn and Pb concentrations still exceeded the ISQG-high of 410 and 220 mg/kg respectively. No significant change occurred in Zn, Hg, As, Cr, and Cd between the early 1980s and mid 1990s.

The urbanised lower section of Merri Creek, upstream of the Clifton Hill, has high metal concentrations in sediments that also are likely to impact the aquatic ecosystem (Pettigrove, 1998). These elevated concentrations are likely to be from poor waste disposal practises from local industries, prior to the establishment of the EPA and the development of stream pollution regulations (SER, 1988). Some reduction in metals has occurred in the lower Merri Creek since the early 1980s, but they are still high and are likely to be impacting the aquatic ecosystem.

5. OVERVIEW OF TEMPORAL TRENDS

Comparisons of the proportion of median metal concentrations to the ISQGs are presented in Figure 2. A smaller proportion of sites exceeded the ISQG-high for Pb during 1993 to 1997 compared to 1981 to 1983. This decline in Pb concentrations at many sites may be due to the introduction of unleaded petrol and catalytic converters in 1986 (EPA, 1996).

A larger proportion of sites exceed the ISQGs for Zn and Hg in the mid 1990s than in the early 1990s. There was no change in the proportion of sites that exceeded the ISQG levels for As, Cr and Cu.

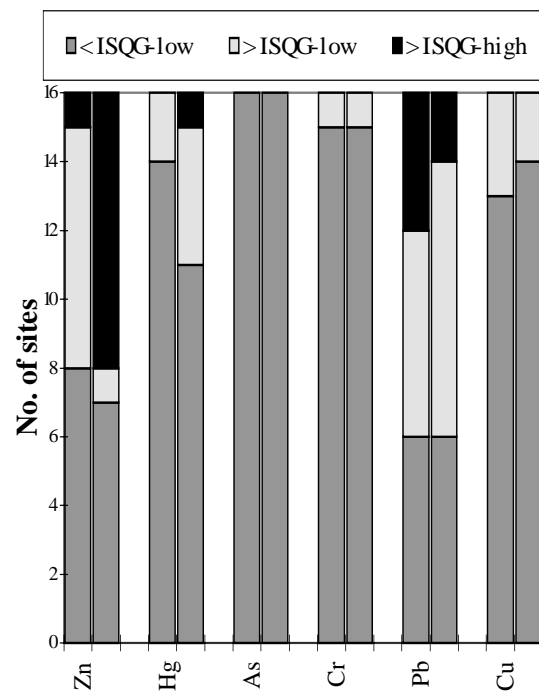


Figure 1: A comparison of median metal concentrations in fine sediments from 16 sites to ISQG low and high levels from the early 1980s (left bar) and mid 1990s (right bar).

The left column for each metal summarises the early 1980s data, whereas the right column summarises data from the mid 1990s.

Four of the 16 sites investigated (Merri Creek at Clifton Hill, Kororoit Creek at Altona and Gardiners Creek at Malvern and Glen Iris), had at least one median metal concentration exceeding the ISQG-high in the early 1980s. By the mid 1990s, these same four sites plus Kororoit Creek at Deer Park, Dandenong Creek at Vermont and Gardiners Creek at Burwood and Chadstone, had at least one median metal concentration exceeding the ISQG-high.

These trends indicate that Melbourne's urban waterways may be becoming more contaminated. Given that metal concentrations in stream sediments often exceed the ISQG-high, there is a high probability that these aquatic ecosystems are stressed by metals (ANZECC, 1998).

However, these trends in metal contamination vary between catchments. There have been improvements in the Maribyrnong River, little change in Dandenong Creek sites, except at Vermont, and a considerable deterioration throughout Gardiners Creek. The Gardiners Creek catchment is in an established inner Melbourne residential region. The concrete urban drainage system in this catchment would provide more efficient transport of contaminants to waterways. There has probably also been reduced sediment run-off into

Gardiners Creek, as major channels have been rock-lined and there are few urban developments.

Currently no direct data has been collected to identify the major sources of mercury and zinc entering Melbourne's waterways.

A major urban source of mercury contamination is the burning of fossil fuels (Berndt et al., 1998). Most mercury released into the atmosphere, is transported into waterways during wet deposition (Horkeby and Malmquist, 1977). Hg increases in the environment appear to be widespread. For example, Hg has been increasing in the atmosphere of the northern hemisphere at a rate of over 1% p.a. (Slemr and Langer, 1992) and that mercury inputs into lakes in much of central North America have increased as a result of atmospheric fallout (Swain et al., 1992).

Zn is often present in soils as a result of atmospheric deposition (WSDH, 1996) and as a contaminant from galvanised roofs and fittings (Duncan, 1995). Major sources of Zn dust and fumes into the air are refuse incineration, coal combustion, smelter operations, metal-working industries, iron and steel manufacturing, automobile emissions and soil erosion (WSDH, 1996). Discharges from waste water treatment plants are another potential major source of Zn (WSDH, 1996), but they do not occur in waterways in this study where Zn increases were observed.

6. CONCLUSIONS

It is suggested that many of the observed increases in Hg, Zn and some other metals in sediments from Melbourne's urban waterways, appear to be due to increased outputs of diffuse pollution from vehicles and residential areas. This would seem reasonable, as Melbourne's population has increased by 11.9% since June 1982 to be 3.25 million in June 1996 (ABS, 1998). Furthermore, vehicle usage has substantially increased, as indicated by a 27.6% increase in licensed drivers between 1981/82 and 1995/96 (ABS, 1998).

The significance of toxicants needs to be made on a catchment basis, but will generally be a high priority for waterway management agencies in established urban suburbs and industrialised areas. A considerable amount of basic information is still required to enable waterway management agencies to make informed decisions about how to manage heavy metal contamination. Further work is required to:

- monitor metal concentrations in stream sediments to determine how they vary over time in relation to changes in land use activities and water quality.
- isolate the major sources of contamination, so that actions can be taken to reduce contemporary sources.
- determine what impact observed changes in metal concentrations have on the health of Melbourne's aquatic ecosystems.

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