Chapter 1

METAL CONTAMINATION IN SOIL AT AQUATIC PARK

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The San Francisco Bay ecosystem is highly vulnerable to the disturbances of human activity. With continued development and population growth, it is becoming increasingly so, to the extent that its inability to maintain life, functions and characteristics of an estuarine ecosystem may be impaired. Heavy metal contamination of soil in this system is but one of the many signs of human intrusion. Non-biodegradable metals can be accumulated by organisms existing within, on, or in proximity to soil. In this study I will assess the levels of heavy metals, including lead, cadmium, zinc and copper, in soils of Berkeley's Aquatic Park, in general and as a function of distance from roads. Such an analysis may be helpful in guiding future planning and uses for the Park, as well as the development of public areas around the Bay, so as to minimize or prevent harm from accruing to the flora, fauna and human activities within Aquatic Park.

Past Studies

Although there has been much research on heavy metals in San Francisco Bay sediments (e.g., Randolph, 1980; Peterson et al., 1972), their presence and impact on bay margins have received less attention. Yet the organisms and edaphic components of these margins are vital to the Bay's health and are sensitive to metal pollution. Soil and plants are viable indicators of metal contamination due to their structure and chemical make-up (Gailey and Lloyd, 1984). Several studies have found that metallic concentrations tend to decrease as distance of soil and plants from roads and industrial sites increases (Rolfe and Haney, 1975; Motto et al.,1969; Albasel and Cottenie, 1984). Metal accumulations in roadside mice are also related to road proximity (Welch and Dick, 1975). Though much work has focused on lead, distance from roads is also relevant in evaluating concentrations of zinc, cadmium and copper (OECD, 1975).

A recent study examined trace metals in marsh plants at two Bay Area sites and concluded that the concentrations were not potentially harmful, but the study did not evaluate them in the context of distance from roads (Kaplan, 1984). Another study examined metal content of water in Aquatic Park and found a low degree of hazard (Altamirano, 1983). Metal pollution levels in soil at the Brickyard, an area just west of the Park, were analyzed in relation to distance from roads but found low levels of toxicity (Bisio, this report).

Aquatic Park

Aquatic Park surrounds an 80-acre lagoon on the western edge of the city of Berkeley (Figure 1). In the late 1930s construction of the East Shore Highway and Bay Bridge over marsh and mudflats of the Bay

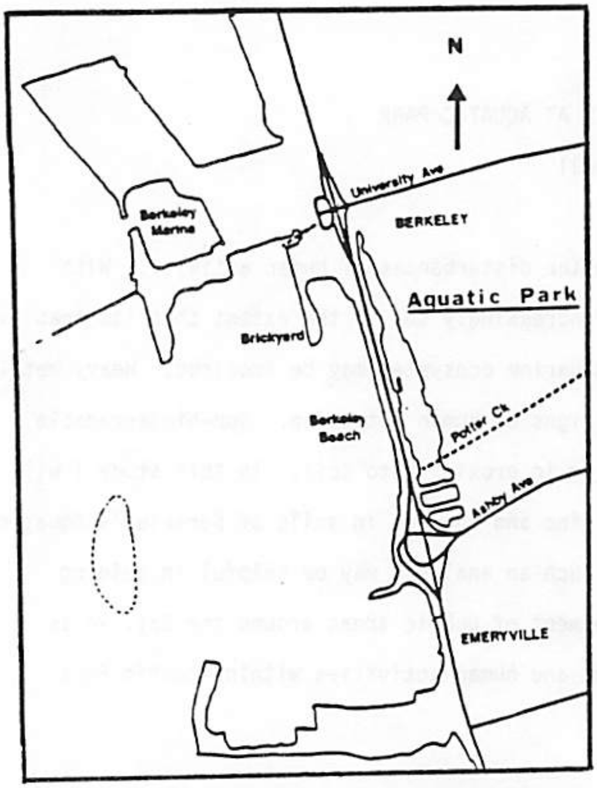

Figure 1a. East Bay Shoreline showing location of Aquatic Park.

Source: The East Bay Shoreline, 1981

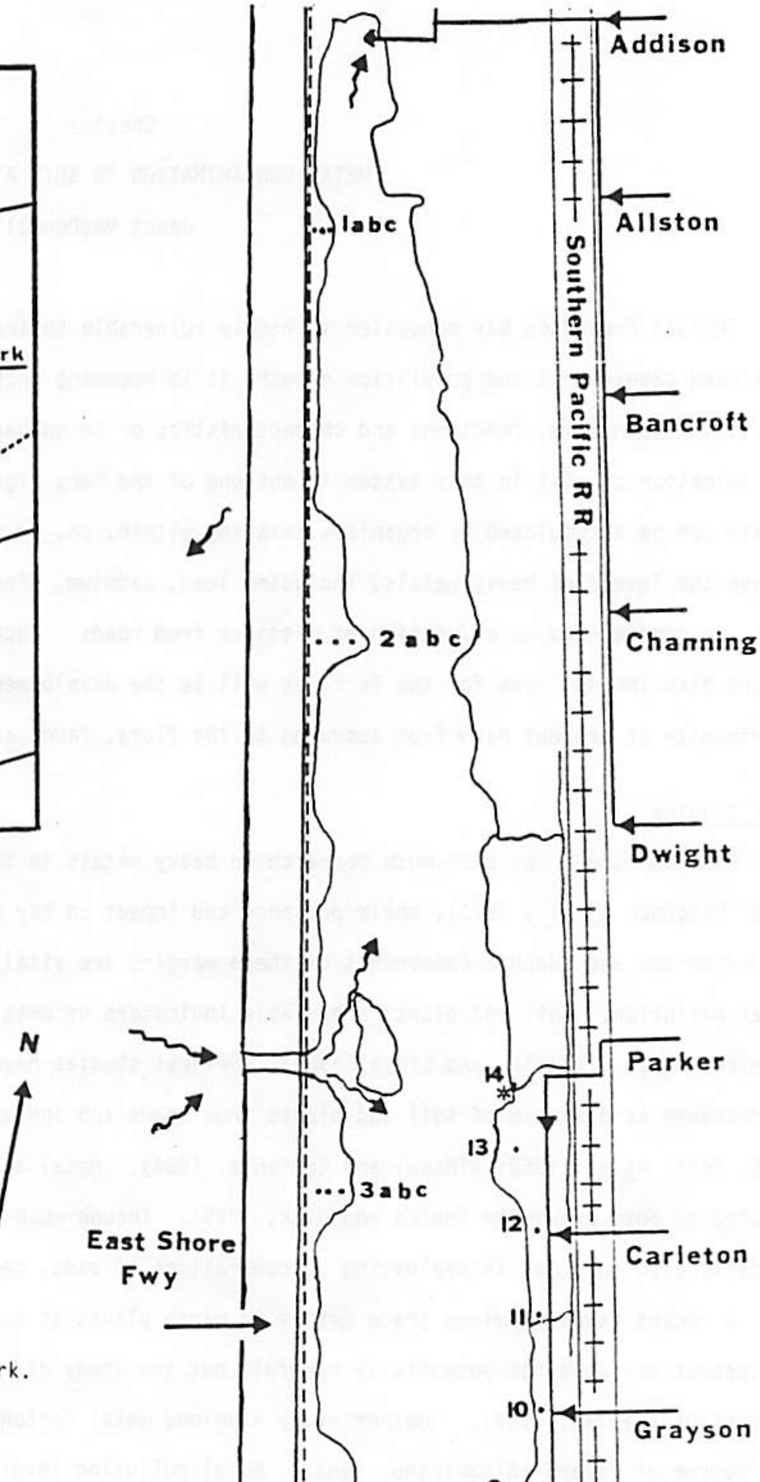

Figure 1b. Sample sites at Auqatic Park.

- storm drain line.
- approximate creek location
- current direction
- . site
- * water sampling site

Source: Adapted from Altamirano, C., 1983

Scale: 100m

created the lagoon (White, 1974). A two-lane access road borders all but the eastern side. A series of manually-regulated tide gates and internal pipes provide continuous circulation between Park and Bay water (Altamirano, 1983). Several storm drains and creeks empty into the water, carrying drainage from nearly 100 acres of residential and light industrial areas (Berkeley, 1970). Because the Park is along the East Bay shoreline, due east of the entrance to San Francisco Bay, it receives marine winds averaging seven miles per hour from the west, southwest and south (CDPR, 1982).

The Park has both recreational and ecological value. Water activities include boating, kayaking, waterskiing and fishing. There is a trail for walking and hiking, lawn and picnic areas, and parcourse and playground structures. Many species of plants grow along the water's edge, and it has been estimated that approximately 100 bird species spend time resting or feeding in the Park (GGAS, 1951). The south end of the Park is an important shorebird roost and houses the International Bird Rescue Center. Birds in the Park include ducks, sandpipers, gulls and egrets, just to name a few (White, 1974). In early November I spotted four egrets and one Canadian goose at one of my collection sites (4, Figure 1b). Rodents, fish, invertebrates and microorganisms also inhabit the Park. Such an assemblage of activity and wildlife could be threatened by high metal concentrations.

Heavy Metals in Biological Systems

Of the heavy metals affecting ecological systems, some are valuable and necessary up to a certain level, beyond which they become toxic. This is true of zinc and copper (Kaplan, 1984). Lead and cadmium do not appear to have any beneficial contributions to biota at any concentration, Runoff, and wet or dry deposition from aerial transport of particulate metal emissions are significant mechanisms for metallic deposition onto soil, vegetation and organisms. Once present, these trace elements tend to be retained by ecosystems, especially within the surface horizon of the soil, an area crucial to ecosystem function (Gailey and Lloyd, 1984). Soil conditions such as pH, organic content, the presence of other metal ions, and the extent of soil dilution by precipitation affect the availability of trace elements to plants and organisms (Kaplan, 1984). Plants can take up metals in soil via their root systems and directly from atmospheric fallout (NRC, 1980). Animals may inhale metals and ingest them through the food chain. Some may even take in metals from grooming lead-exposed fur (NRC, 1980).

Lead

Lead in soils can affect the normal processes of plants, microbiota and larger organisms. In plants lead may reduce photosynthesis, inhibit growth by affecting the rate of mitosis, hinder uptake of necessary phosphates and cause chromosome and nuclear aberrations (Kaplan, 1984; Peterson, 1978). In rodents lead tends to concentrate in the bone, kidney and liver and may result in sterility, stunting and reduced longevity (Welch and Dick, 1975). Lead can also be responsible for depressing the intellectual development of humans, especially children (Lange et al., 1983).

Because the major pathways of lead into the ecosystem are by runoff and wet or dry deposition, it is important to assess atmospheric contamination. In California, motor vehicles contribute the largest volume of lead emissions to the atmosphere (Yaffe and Winkelstein, 1979). The Bay Area receives 19.5 percent of the state's total lead emissions. Ninety-seven percent of these emissions are from motor vehicles and three percent are from stationary industrial sources (Yaffe and Winkelstein, 1979). Roughly 54 percent of total emissions are deposited into terrestrial and aquatic ecosystems (Rolfe and Haney, 1973). Lead concentrations are highest near roadways, but return to near background levels within 40 meters from roads. This distance, as well as the steepness of the gradient, is influenced by wind direction and velocity (Peterson, 1977).

Other Metals

At high concentrations cadmium produces leaf chlorosis, a blanching of a plant's green parts, lowers the photosynthetic rate and destroys soil microflora (Lange et al., 1983; OECD, 1975). Cadmium is closely related to zinc and is often found where zinc is present. Both metals tend to be more easily mobilized within soils and plants than lead or copper (Fasset, 1980). An excess of zinc and copper, both plant nutrients in small amounts, can retard root growth and cell elongation and cause chlorosis (Kaplan, 1984). High copper levels also may reduce the normal absorption of other nutrients and may even inhibit enzyme activity in the soil (Ortloff and Raymore, 1962).

Methods

Samples were collected at 20 sites at Aquatic Park (Figure 1). At sites 1-3 soil was collected along transects to monitor changes in metal concentrations in relation to distance from roads. Three samples were taken per transect between 3.5 and 50 meters from the highway. Sites 4-6 were chosen to reflect a less detailed gradient of road distance (16-200m). Sites 7-14 were chosen to determine concentrations independent of distance from roads.

On January 13, 1986, approximately two pounds of soil was taken from each site. After rocks and organic material were removed, the soil was air-dried, ground and sieved through a 2-millimeter mesh. The residue was digested at $70^{o}C$ in 4N nitric acid (diluted from 16N or 70 percent HNO_3) and diluted. I am grateful to Dr. H.E. Doner of the Plant and Soil Biology Department for outlining this process. The metal concentrations were determined by a Perkin-Elmer 360 Atomic Absorption Spectrophotometer. Tom Morrison of the Chemistry Department was extremely helpful in assisting me with this analysis.

Results

Table 1 shows the concentrations of metals in the soil samples. Lead ranges from 51.0 to 1989ppm; cadmium, from 0.06 to 8.84ppm; copper, from 4.40 to 166 ppm; and zinc, from 51.3 to 635ppm.

The levels at sites farthest from the road (1c, 2c, 3c) all fall below the average concentrations of metals in urban soils as indicated in Table 2, except for cadmium at site 2c, which was slightly above. The levels at the intermediate sites (1b, 2b, 3b) were both above and below the average concentrations but none were excessive as defined by Linzon (Table 2), though the criteria used to set these excessive levels have not been well-documented. At sites closest to the road (1a, 2a, 3a), some excessive levels did occur: lead at sites 1a and 2a; zinc at sites 1a and 3a; and copper at all three sites.

Along the transects at sites 1-3, all the metals display decreasing concentrations as distance from the interstate increases, except for lead at site 3 and cadmium at site 2. The results for sites 4-6 do not reflect a gradient related to road distance.

Site	Distance from road (m)	Metal Concentration (ppm)			
		Pb	Cd	Cu	Zn
1a	3.5	690	1.75	120	635
1b	23 3	452	1.21	37.0	159
1c	33	81.4	0.06	20.0	62.1
2a	3.5	1989	2.95	166	299
2b	33	560	0.76	46.7	133
2c	50	182	1.60	35.6	112
3a	16	224	2.55	139	609
3b	70	284	0.99	25.0	186
3c	210	100	0.49	17.0	84.2
4	--	152	0.89	23.7	91.8
5	--	203	0.79	25.5	122
6	--	87.0	1.15	14.7	96.8
7	--	51.0	0.65	21.0	73.7
8	--	100	1.75	10.3	109
9	--	12.0	0.89	4.40	51.3
10	--	68.0	0.76	16.9	108
11	--	110	1.28	27.5	156
12	--	74.0	0.81	17.0	112
13	--	63.0	8.84	20.0	166
14	--	130	1.20	50.0	289

Table 1. Concentrations of heavy metals in soils at Aquatic Park (ppm dry weight).

Metal	Average Concentration (ppm) 0-2.5cm	Excessive Concentration (ppm) 0-5cm
Cd	2.3	10
Cu	33.2	100
Pb	292	600
Zn	154	400

Table 2. Average and excessive concentrations of heavy metals in metropolitan soils (in top 2.5 and 5cm).

Source: Adapted from Linzon et al., 1976, Tables 2,3).

Discussion

The data in general support the inverse relationship between road distance and metal concentration in soil within 40 meters of the orad. Most of the sites at 3.3 meters from the roadside contain excess metal concentrations which may be deleterious to organisms along the road's edge.

Aquatic Park samples yielded both higher average concentrations and a more consistent relationship between increasing distance from roads and decreasing metal levels than the Brickyard study (see Debbie Bisio's paper, this report). This difference may be due to the fact that the Park is exposed to the westerly wind after it has passed over the freeway, and thus the air may contain more particulate metals prone to deposition than air over the Brickyard. Measuring concentrations along both sides of the road would be helpful in understanding better how wind affects metal deposition.

The only trend apparent for sites 4-6 is that site 5 has higher metal concentrations than sites 4 and 6, except for cadmium, for which it is lowest. However, it is hard to draw valid conclusions from the data of such few samples. A more comprehensive sampling may reveal more significant results.

Noticeably high levels of heavy metals at a number of sites may be due to various factors. The extremely high lead concentration at site 2a may stem from a local concentrated lead source, such as a battery. The high levels of copper and zinc at sites nearest the road might be caused by wires, motor oil from spillage, runoff or discarded containers, or other sources containing these elements. These sites may warrant further investigation.

Although the eastern sites all reflect near average concentrations, some levels stand out. The high cadmium level at site 13 and the high copper level at site 14 may be results of metallic sources other than atmospheric pollution. It is interesting to note that at sites 11 and 14, where creeks empty into the lagoon, the levels of all metals were higher than at other sites along the eastern edge. A previous study of Park water also found higher levels of lead and copper, on the average, at a site close to the creek near site 14 as compared to sites not proximate to a creek (Altamirano, 1984). These concentrations may be due to the presence of metals in surface runoff which other sites do not receive.

In addition to creek drainage and intense individual pollution sources, differences in metal concentrations may be results of natural soil variance, past human and industrial activity and testing errors, such as chemical processing of samples and a machine error of 5-10 percent (Morrison, pers. comm., 1986).

Conclusion

The results of this report are promising for the natural inhabitants and users of Aquatic Park, as the data indicate non-threatening levels of metal toxicity. However, more research into the interactions and pathways between soil, water, flora and fauna in the Park may be useful for assessing the effects of external influences such as pollution. Hopefully, such research would lead to the establishment of more rigorous standards for both tolerable and toxic levels of heavy metal pollution in soils.

Such a large open space and wildlife haven is a rare and valuable asset to citizens of an ever-expanding metropolitan center like the Bay Area. More attention should be invested in the usage, maintenance and monitoring of the Park so that it can remain a safe and attractive resource for all its human and non-human patrons.

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