Lead, Mercury, Cadmium and Arsenic in the Environment
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CHAPTER 14

A Review on Lead Contamination of Hong Kong's Environment

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ABSTRACT

With a population of 5.5 million and a limited amount of land (1046 km^2). Hong Kong is one of the most densely populated areas in the world. Due to the decentralization scheme to ease the densely populated centres, the rural area has been urbanized rapidly. The so-called 'satellite' cities in the New Territories have developed and expanded tremendously. As a result, housing estates are interspersed with agricultural and industrial areas.

The discharge of untreated industrial effluent and sewage is the cause of higher lead concentrations in the coastal waters and in marine sediment leading to the higher level of lead in aquatic organisms.

Combustion of leaded gasoline from automobiles is believed to be the major lead contamination in the environment. This is of concern for those who live next to traffic-congested streets. However, the airborne lead levels range from 0.6 to 3.7 $\mu g/m^3$ and the mean value of lead in human blood samples is 15μg/100 ml. These values are comparable to lead levels in other parts of the world.

The measurement of lead in dust has also been used to indicate the extent of lead contamination in several studies. In general, they all found that the level of lead in street dust (mean = 1627 μg/gm in one study) was of the same magnitude as values obtained in different cities throughout the world. As reported elsewhere, the lead content in soil samples fell off rapidly with increasing distance from highways.

Vegetables grown near roadways were found to contain higher lead concentrations than those growing at remote areas. Since many households and farms are close to traffic, and since vegetable growing for family consumption is traditional, a more detailed investigation of lead levels in food and drink consumed locally seems important.

Two reports showed that the aqueous extracts of roadside dust and soil inhibited root growth of crops. It has also been discovered that the roadside population of two grass species, *Eleusine indica* and *Cynodon dactylon* had a higher tolerance to lead than their normal counterparts. This suggests that the lead levels in roadside

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soils are sufficiently high as to act as a relative factor in determining the survival of plants.

There is a common practice in Hong Kong, Taiwan, China and other Asian countries of recycling waste materials such as night-soil (human excreta), sewage sludge and animal manure for land application and as fishpond fertilizer or supplementary feeds. In general, various investigations demonstrated an increase in productivity with the appropriate application rates of these wastes. Nevertheless, the rather high concentrations of various heavy metals, including lead in the treated crops or fish, especially those treated with sewage sludge, might impose a health hazard.

GENERAL BACKGROUND

Hong Kong is located south of Kwantung Province, China, and consists of Hong Kong Island with its surrounding 200 smaller islands, Kowloon Peninsula, and part of mainland China named the New Territories (Figure 14.1). Out of the total land area of 1046 km^2, about 82% consists mainly of hill slopes.

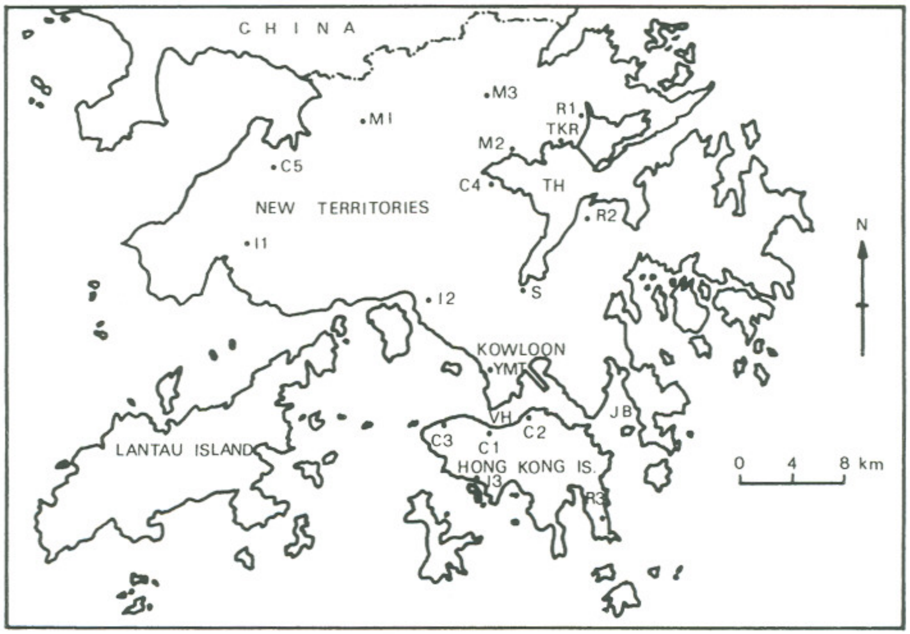

Figure 14.1 Map of Hong Kong showing various places mentioned in the text. JB: Junk Bay, VH: Victoria Harbour, TH: Tolo Harbour, TKR: Ting Kok Rd. S: Shatin, YMT: Yau Ma Tei. *Dust sampling sites*: Commercial and residential area C1: Central District, C2: North Point, C3: Kennedy Town, C4: Tai Po, C5: Yuen Long; *Minor agricultural area* M1: Mai Po, M2: Ha Hang, M3: Man Uk Pin; *Industrial area* I1: Tun Mun, I2: Tsuen Wan, I3: Aberdeen; *Recreational area* R1: Chung Pui, R2: Wu Kai Sha, R3: Shek O

A large portion of land in Hong Kong was reclaimed from the sea, for example, the commercial areas of the north coast of Hong Kong and the south of Kowloon Peninsula. Recently, a large scale land reclamation has been completed at Shatin New Town aiming to house over half a million people. Reclamations on a smaller scale have also been underway in other areas of the New Territories, e.g., Tai Po. This decentralization scheme of easing the densely populated areas led to rapid urbanization in the rural areas (the New Territories).

Although the number of registered vehicles had decreased to 327 803 by the end of 1983, a reduction of 3.5% compared with that at the end of 1982 after the introduction in May, 1982 of fiscal measures to restrain the growth in ownership of motor vehicles (Hong Kong Government, 1984), there is a high traffic density of over 200 vehicles per kilometre of road surface in Hong Kong with most of these vehicles concentrated in the small area of Hong Kong Island and also in 'metropolitan' Kowloon. Lower density traffic occurs in the New Territories.

LEAD FROM GASOLINE COMBUSTION

Hong Kong possesses some deposits of lead which have only been mined in small quantities. In addition, there is secondary lead production from recycled materials such as battery plates and lead pipes. The figures for recycled lead were 1887 tonnes for 1980, 2218 tonnes for 1981 and 2046 tonnes for 1982 (Hong Kong Environmental Protection Agency, 1984a). Secondary lead smelters have caused local neighbourhood health problems of lead in Europe and North America. Nevertheless, the emission of lead into the atmosphere from gasoline combustion is the greatest source of lead contamination although industrial emissions, for example, fossil fuel combustion from power plants, solid waste incineration, cement plants, etc., also emit a considerable amount of lead into the atmosphere. It has been estimated that the amount of lead emission from road transport was 123 tonnes/year (Kalma *et al.*, 1978).

Lead in Air

An earlier study using a computer model to predict atmospheric pollution in Hong Kong showed that the major source of lead emissions is the same as that for carbon dioxide and the estimated average lead concentrations at ground level ranged from 2 to 3 $\mu g/m^3$ under neutral atmospheric conditions. Maximum values at one of the most densely populated areas (Yau Ma Tei, Kowloon) were 8 $\mu g/m^3$, 3 $\mu g/m^3$ and 1 $\mu g/m^3$, respectively, for stable (where there is little turbulence and little wind), near-neutral (the most common condition of average wind speed and direction) and unstable conditions (where turbulence and wind speed are high) (Kalma *et al.*, 1978).

A subsequent survey indicated that the airborne lead levels ranged from 0.6 to 3.7 $\mu g/m^3$. It should be noted that the data were averages of seven consecutive twelve daylight-hour days while the International health standards are normally expressed as averages over three months to two years (Hong Kong Environmental Protection Agency 1982).

Lead in Dust and Soil

Lead in dust has also been used to indicate the levels of lead contamination derived from automobile exhaust. A significant correlation ($p < 0.005$) was found between lead in dust and average annual daily traffic. Table 14.1 lists the total concentration of lead in roadside dust and the values of the annual average daily traffic (AADT) in 14 sites throughout Hong Kong (Lau and Wong, 1982). The samples were tested by atomic absorption spectrophotometry after acid digestion (Allen *et al.*, 1974). The mean concentrations in these sites ranged from 132 to 3876 μg/gm which are of the same order of magnitude as an earlier report (Ho, 1979a). Clearly a major factor determining the lead content of dust and soil at roadsides is traffic density.

Table 14.1 The total concentration (μg/gm) of lead in the roadside dust and the values of annual average daily traffic (AADT) in the 14 selected sites in Hong Kong (from Lau and Wong, 1982).

	C1	C2	C3	C4	C5	M1	M2	M3
Mean	3 876	2 572	2 461	2 002	2 145	1 324	2 001	1 681
SD	1 439	1 431	1 234	1 016	913	491	967	735
AADT	37 180	21 140	18 710	23 730	17 970	9 220	7 180	1 550
	I1	I2	I3	R1	R2	R3		
Mean	748	617	1 415	386	132	423		
SD	657	538	343	606	91	406		
AADT	4 190	980	3 480	510	20	1 590		

Commercial and residential area C1: Central District, C2: North Point, C3: Kennedy Town, C4: Tai Po, C5: Yuen Long. Minor agricultural area M1: Mai Po, M2: Ha Hang, M3: Man Uk Pin. Industrial area I1: Tun Mun, I2: Tsuen Wan, I3: Aberdeen. Recreational area R1: Chung Pui, R2: Wu Kai Sha, R3: Shek O.

Table 14.2 further compares the mean lead concentrations in the street dust and soil samples in different cities throughout the world. It indicates that the lead level of roadside dust (1627 μg/gm) in Hong Kong is not as high as Leeds (UK) (4400 μg/gm), or Urbana, Illinois (3600 μg/gm), but is comparable to that found in Birmingham, UK (1800 μg/gm), Lancaster, UK (1890 μg/gm), and some of the cities in the United States (1500 μg/gm).

However, comments on the causes of the differences between lead levels are unjustified due to the absence of knowledge regarding industrial activities in the various locations, as well as information related to the population density of each region.

Table 14.2 Comparison of mean Pb concentrations (μg/gm) in the street dust and soil samples in different cities (from Lau and Wong, 1982)

Location	Dust	Soil	Reference*
Hong Kong	1627	88	Lau and Wong (1982)
Hong Kong	2006	—	Ho (1979a)
Rio de Janeiro, Brazil	700	—	Branquinho (1973)
Birmingham, UK	1800	—	Environ. Prot. Unit. Bir. (1975)
Birmingham, UK	1700	—	Stephen, in Day *et al.* (1975)
Lancaster, UK	1890	—	Harrison (1979)
Leeds, UK	4400	—	Dunn and Bloxam (1933)
Liverpool UK	—	96	Roberts and Johnson (1978)
Manchester, UK	970	—	Day *et al.* (1975)
Detroit, USA	—	65	Tel Haar (1970)
Urbana, Ill., USA	3600	—	Solomon and Artford (1976)
USA (average of 77 cities)	240—1500	—	Hunt *et al.* (1971)

* Refer to Lau and Wong, 1982 for details of references.

A subsequent survey carried out by the Hong Kong Environmental Protection Agency obtained a lower level with an overall mean of 337 μg/gm (Hong Kong Environmental Protection Agency, 1984b). The reduction of lead in petrol from 0.84 to 0.6 gm/litre on 1 July 1981 might have contributed to this reduction. It is envisaged that there will be further reduction of lead in dust when the content of lead is limited to 0.25 gm/litre on 1 January 1985 and with a reduction in the number of cars. However, it seems likely that the lower values obtained by the latest survey might be misleading, or at least more impressive than warranted, due to the fact that samples were collected at an average distance of 10 metres from the curbside rather than along the curbside of the earlier studies. Furthermore, the study was also conducted largely in parks and gardens. In addition, a different sample preparation and analysis also resulted in a discrepancy, for example, the sieve pore size employed in this study was 500 μm compared with 750 μm (Ho, 1979a) and 106 μm (Lau and Wong, 1982) of the earlier studies. It was noted that dust particles with a size smaller than 125 μm belonged to a homogeneous group and did not have significant differences in metal content, including lead (Lau and Wong, 1983).

It is interesting to note that the soil next to a minor agricultural area contained an even higher concentration of trace elements, including lead, than a commercial–residential area (Lau and Wong, 1982). Figure 14.2 further illustrates the lead contents in different depths along the soil profile at three different sampling sites (Wong unpublished data). In general, there is a trend towards a decrease in lead content with increasing depth, with the highest concentrations being found at the soil surface. The lowest concentrations were found at the grassland site, followed by the commercial–residential area, while the highest lead levels occurred in the agricultural area. The latter is an abandoned piece of agricultural land next to an intensive vegetable-farming area. Besides the increased traffic volume, fertilizers, pesticides, animal manure and even night-soil have been suspected of causing heavy metal contamination of agricultural soils located near highways.

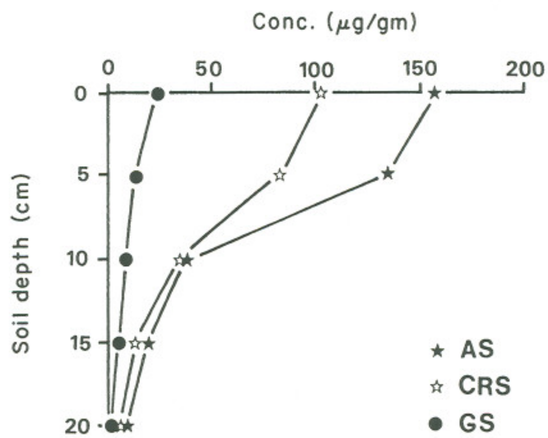

Figure 14.2 Concentrations of Pb at different depths in soil profiles at different sites. AS: agricultural soil. CRS: commercial-residential soil. GS: grassland

The adverse effects of higher concentrations of the various metals were reflected by the reduced root growth of *Brassica parachinensis* when grown on soil extracts of the agricultural soil as compared with soils of other origins (Wong and Lau, 1983).

When using *Brassica chinensis* and *B. parachinensis* to assess the phytotoxicity of the roadside dusts collected from different regions, it was also found that the higher concentrations of lead in water extracts of dust collected from Tai Po (AADT: 27 990) caused a greater reduction of root growth than at the other site (Ting Kok Road AADT: 16 040). Table 14.3 shows the higher concentrations of total and water-soluble lead, copper and zinc at the two sites (Wong *et al.*, 1984).

Table 14.3 The concentrations of Pb, Cu and Zn in dust samples from two different sites and the effects of dust extracts on root growth of *Brassica chinensis* and *B. parachinensis* (from Wong *et al.*, 1984)

Site		Pb	Cu (μg/gm)	Zn
Tai Po	Total content	1051*	100	124†
	Extractable content	777*	17	119‡
Ting Kok	Total content	258	75	83
	Extractable content	26	11	77

Comparisons are made between the two sites using Student's *t*-Test:
* $p < 0.001$,
† $p < 0.01$,
‡ $p < 0.05$

Lead in Vegetation

The lead content of soil samples fell off rapidly with the increase in distance from highways (Wong and Tam, 1978). Unfortunately for the Hong Kong residents, a high proportion live very close to the traffic-congested roads. Exposure may be especially high when there is extreme traffic congestion because of the high volume of traffic, magnified by the narrow canyon-type streets in Hong Kong Island and Kowloon. Furthermore, due to the establishment and expansion of new towns in the New Territories, agricultural areas are now interspersed with housing estates, recreational and industrial areas with highways linked to Kowloon. Vegetables (*Brassica alboglabra* and *B. parachinensis*) were noted to contain higher lead concentrations than those growing at remote areas although a portion of the lead remained as a topical coating on the foliage. Over 27% could be removed by repeated washing with detergent, while washing with distilled water alone reduced the content of lead to a lesser extent (2%) in leaves of *B. parachinensis* (Figure 14.3).

It has also been observed that lead deposition is facilitated on leaves with rough surfaces or hairs. Rain reduces lead tremendously and a drop of 70% in lead level was noted in *Alocasia odora* growing near highways after 13 mm of rain (Ho, 1979b).

Lead Tolerance in Plants

Populations of two grass species, *Eleusine indica* and *Cynodon dactylon*, collected from sites with high lead concentrations in soil and dust showed higher tolerance than those collected from sites with lower lead concentrations (Wong and Lau, 1985a). Table 14.4 shows the relative lead tolerance, as expressed by root elongation in the presence of lead, for three populations of the two grass species. The Tai Po population was the most

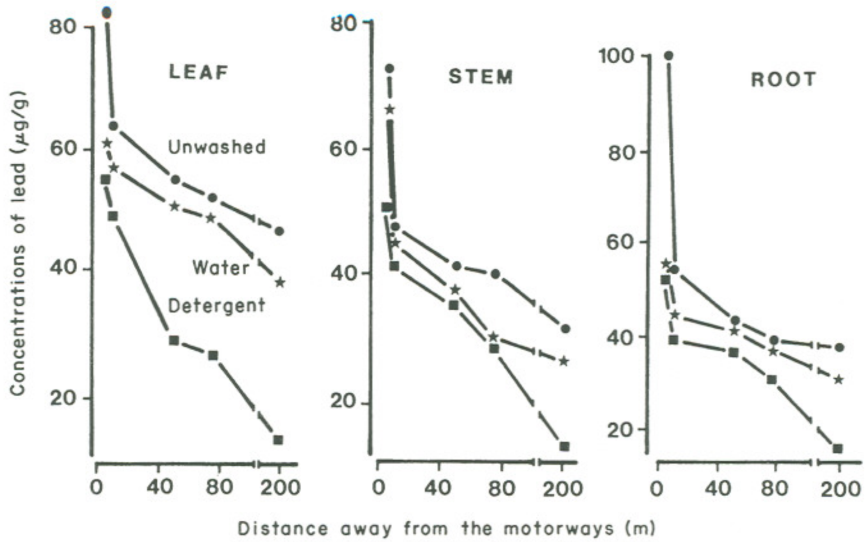

Figure 14.3 The concentrations of lead in different parts of *Brassica parachinensis* under different treatments (from Wong and Tam, 1978). 'Water' indicates that the plants were washed with distilled water and 'detergent' includes washing with detergent

tolerant. Lead tolerance in roadside populations of certain plant species has been reported by others (Wu and Antonovics, 1976; Artkins *et al.*, 1982). A genetic or physiological response to roadside lead appears to be evoked in some plant species suggesting that lead is acting as a selective factor, with advantages to those plant populations able to develop tolerance.

The special tolerance of vegetation growing on lead/zinc mines to these metals has been frequently reported (e.g. Jowett, 1964). At such sites lead levels are often very high. In the case of the Hong Kong grasses, it is interesting to note that these roadside grasses, growing at markedly lower concentrations of lead than vegetation of mine sites, can also evolve tolerance to lead.

While soils, dust and vegetation appear to have been influenced by the lead sources, a survey of lead levels in blood samples from the general human Hong Kong adult population indicates that the mean value of 15 μg/100 ml (Ng-Tan, 1980) is within the range found in other countries (WHO, 1977) and it is slightly lower than the figures reported for some cities in the US (United States Department of Health and Welfare, 1965; McLaughlin *et al.*, 1973). However, further studies are needed before a definite conclusion can be drawn. Human hair samples have also been used to indicate environmental exposure in Hong Kong (Chuang and Emery, 1978). However, lead was not included in this study.

Table 14.4 Index of tolerance of different populations of *Cynodon dactylon* and *Eleusine indica* at two different concentrations of Pb (Wong and Lau, in press a)

Conc. of Pb μg/gm	*Cynodon dactylon*		*Eleusine indica*	
	10	20	10	20
Tai Po	58.40c	35.80c	81.50c	13.10c
Shek O	34.60b	20.60b	73.30b	8.30b
Wu Kai Sha	10.50a	9.70a	25.60a	3.30a

$$\text{Index of tolerance} = \frac{\text{Mean length of longest root in solution with metal}}{\text{Mean length of longest root in solution without metal}} \times 100$$

Values followed by the same letter (a,b,c) under the same species and within the same Pb concentration are not significantly different at 5% level according to the results of Duncan's Multiple Range Test.

LEAD FROM OTHER SOURCES

Industrial Activities

The discharge of the relatively untreated effluent from the 20 000 factories in Hong Kong resulted in the lead concentration (0.66 μg/ml) of harbour waters being 160 times higher than those found in the open sea (Chan *et al.*, 1974). An analysis of 12 drain samples had lead concentrations on average 500 times higher and in one case 1000 times higher than those found in the open sea (Chan *et al.*, 1973).

Rather high concentrations of lead (20–77 μg/gm) were found in the sediments receiving runoff from several streams entering Tolo Harbour, an almost landlocked sea (Wong *et al.*, 1980).

Sewage Dumping

When analysing the marine sediments of Hong Kong for heavy metals it has been found that lead is one of the best indicators of human activities. The rather high values of lead in the sediments of Victoria Harbour are due to the fact that the harbour is one of the busiest in the world. The major source of pollution is due to the scraping off of the red lead-containing paints used in rust-proofing ships. This is emphasized as a source by the rather high concentrations of lead at Junk Bay where the shipbreaking industry is located (Yim and Fung, 1981). Furthermore, the discharge of 56 000 m^3 of sewage per day from the 18 sewage outfalls, which receive no pre-treatment apart from screening to remove large solid particles in the larger discharge, into Victoria Harbour also accounted for the elevated lead content in the sediment of the harbour (Watson and Watson, 1971).

Higher concentrations of various heavy metals including lead were also obtained in marine organisms such as the seaweed *Ulva lactuca* (green alga) sampled along the coastal areas within Tolo Harbour, than those collected from remote areas south of Hong Kong Island (Wong *et al.*, 1982b). In addition, the rather high concentrations of various heavy metals in the tissue of the Pacific oyster (*Crassostrea gigas*), cultured at Deep Bay, which receives water from rural areas where industries are interspersed with agricultural activities, have received much attention (Wong *et al.*, 1981). Another report indicated that although cadmium and arsenic were enriched in the Pacific oysters purchased from retail markets in Hong Kong, lead, zinc, and copper concentrations were within the range reported elsewhere (Phillips *et al.*, 1982a). Significantly elevated concentrations of cadmium and arsenic in Hong Kong seafood (fish, molluscs, lobsters, prawns, shrimps and crabs) were also noted (Phillips *et al.*, 1982b). However, the present limit for lead in Hong Kong seafood of 6 μg/gm wet weight was not exceeded by the various seafoods (including oysters) analysed in these reports. An attempt has been made to use the rock oysters (*Saccostrea glomerata*) as an indicator of trace metals in Hong Kong (Phillips, 1979). Unfortunately, the detection of lead was omitted.

Agricultural Wastes

Agricultural wastes are the most serious cause of pollution in Hong Kong. Pig effluents and poultry droppings contribute more than two-thirds of the total quantity of readily putrescible matter entering streams. Some of this is used by fish farmers and vegetable growers, some is used to feed back to the chickens after being passed through a drum-drier, some is dumped on land, and more than 50% is dumped into streams (Issac and Revell, 1977). It has been revealed that waste materials also possess a substantial amount of lead (total lead of chicken manure 20 μg/gm, pig manure 8.3 μg/gm), copper, zinc and manganese (Cheung and Wong, 1981) which might hinder their usage.

Iron Ore Tailings

The environmental impact of the iron ore tailings deposited along the coastal area of Tolo Harbour has been extensively studied. It is generally found that the comparatively higher level of various metals, including lead in seawater and sediment, results in higher concentrations of these metals in living organisms (Wong and Li, 1977, Wong *et al.*, 1979, etc.).

RECYCLING OF WASTE MATERIALS

Attempts have been made to recycle waste materials such as sewage sludge, animal manure and refuse compost to enhance biological production. It has been noted that the properties of sewage sludge from one sewage treatment plant fluctuated at different times of the year (Wong and Yip, 1980). The concentrations of lead in the activated and digested sludge from two separate treatment plants (the campus of the Chinese University of Hong Kong and the pilot sewage treatment plant at Shek Wu Hui, respectively) also exhibited a similar phenomenon (Wong and Yip, unpublished data).

Recycling of waste materials in a densely populated area such as Hong Kong is most important, especially as some of the streams in the New Territories of Hong Kong are grossly polluted by pig and chicken manure (Bine and Partners, 1974) and contamination of marine sediment is caused by the discharge of sewage.

Growing Vegetables

The addition of sewage sludge at an appropriate rate resulted in much higher productivities of vegetables when compared with the control without any addition of sludge (Wong and Yip, 1978; Wong and Lai, 1982). When activated sludge, digested sludge, chicken manure and pig manure were applied to soils used for growing *Brassica parachinensis*, it was revealed that there was no significant difference in the contents of total lead in the treated soil between the types of waste or as a result of the different concentrations of wastes applied. However, significant differences ($p > 0.05$) were found, among different wastes and different concentrations of wastes applied, in the contents of exchangeable lead, for example, ammonium acetate or dilute HCl extractable.

Sewage sludge, especially activated sludge-amended soil, had a lower pH and organic matter content than animal manure-amended soils. This led to the accumulation of lead and other heavy metals in the crops, although the total and exchangeable lead contents in the waste materials were in the same order of magnitude (Figure 14.4, Cheung and Wong, 1981; 1983).

Refuse compost from the refuse composting plant at Chai Wan, Hong Kong, has a lead level about four times as great as that in the activated sludge but resulted in a lower concentration of lead in the treated crops than those grown in sludge-amended soils. This may be due to the higher pH and organic matter content of the composted material.

It was noted that refuse compost and pig manure, with their higher organic matter, could reduce lead uptake in *Brassica chinensis* and *Raphanus sativus* by five-and seven-fold on average when compared with the control (without any application of waste materials). Na_4-pyrophosphate and $CaCO_3$ had similar effects in the reduction of lead uptake but the effectiveness was lower than with the two organic wastes (Wong and Lau, 1985b).

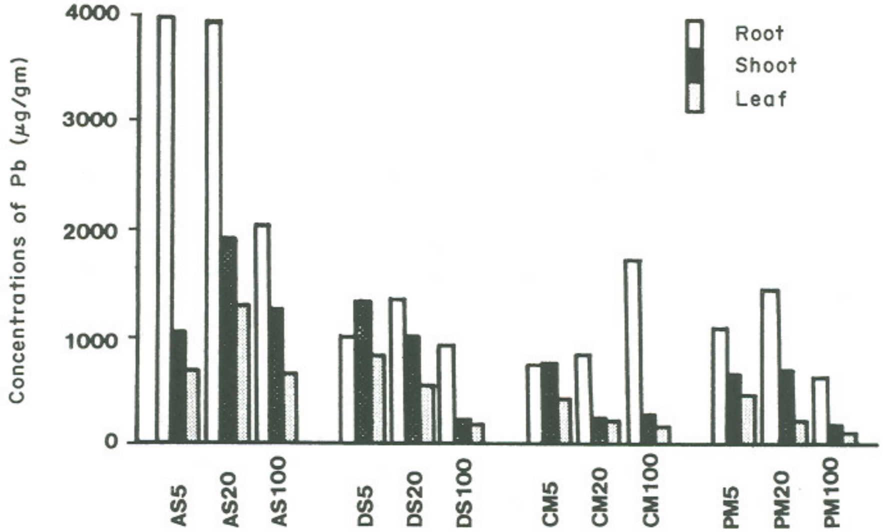

Figure 14.4 Concentrations of lead (μg/gm) in different parts of *Brassica parachinensis* harvested from soils treated with various concentrations of wastes (from Cheung and Wong, 1983). AS: activated sludge, DS: digested sludge, CM: chicken manure, PM: pig manure, rates of application: 5 = 0.1125 kg/m^2, 20 = 0.45 kg/m^2, 100 = 2.25 kg/m^2

Growing Algae

The aqueous extracts of sewage sludge and animal manure were found to be excellent culture media for growing *Chlorella pyrenoidosa, C. salina* and *Ulva lactuca* at suitable concentrations, even better than the artificially enriched media (Wong, 1977, 1981; Wong and Lau, 1979; etc.). However, the rather high levels of various heavy metals, including lead, in the sludge was believed to be the most important factor in inhibiting algal growth when the concentrations of sludge extracts exceeded 10% (v/v). Additions of 10^{-4} and 10^{-3} M EDTA greatly increased algal growth in activated sludge extract which possessed a rather high level of heavy metals (Figure 14.5, Wong *et al.*, 1984).

Since the public has reacted swiftly against food grown on wastes containing potentially objectionable inputs, such as those cultivated in sewage sludge, it is envisaged that algal products derived from food processing wastes would face less consumer resistance since these wastes, such as carrot, coconut, sugar-cane and soybean wastes, possess higher plant nutrients but a lower concentration of lead and other heavy metals (Wong *et al.*, 1985b).

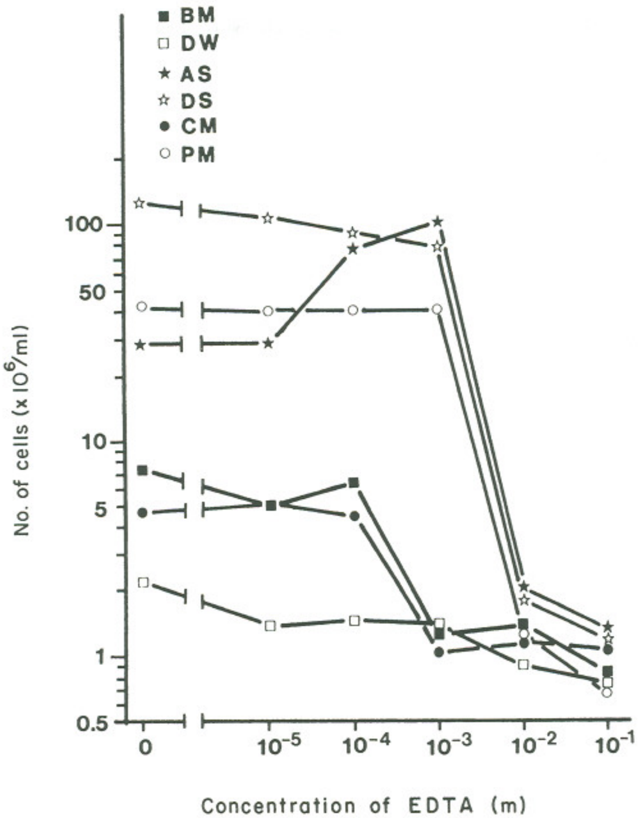

Figure 14.5 The effect on algal growth of adding EDTA to waste extracts (from Wong *et al.*, 1984). BM: Bristol medium, DW: distilled water, AS: activated sludge, DS: digested sludge, CM: chicken manure, PM: pig manure

Growing Fish

Chicken and pig manure have traditionally been added to freshwater fishponds to increase the productivity of fish mainly through the enrichment of the pond water, and used as supplementary feeds for fish to replace part of the expensive feedstuff in Hong Kong, Taiwan, China and other Asian countries.

Apart from the deoxygenation of the pond water due to organic matter utilization by microbes, accompanied by fish kills which are commonly observed in hot weather, the rather high concentrations of trace metals in the waste materials have also been of concern. A rather high concentration of lead was observed in the flesh of common carp (*Cyprinus carpio*) fed with the activated sludge supplementary diet, especially at the high ration (80%), as compared with those fed with carrot waste and chicken and pig manure which contained lower concentrations of lead (Wong and Cheung, 1980; Wong *et al.*, 1982a).

The bones of fish (common carp) feeding in ponds to which additions of 70% or 85% activated sludge were made and bones and heads of fish treated with 85% activated sludge had significantly higher concentrations of lead than those treated with a commercial diet (tubifex worm) alone (Table 14.5, Wong and Kwan, 1981). When examining the fish treated with sludge and manure, histological damages were observed in the gills and the hepatopancrease of fish (tilapia, *Sarotherdon mossambicus*) fed on diets supplemented with 60% pig manure, with 40 or 60% chicken manure (Wong *et al.*, 1985a).

Table 14.5 The concentrations of Pb, Cu and Zn (μg/gm dry weight basis) in different parts of carp (mean of three samples) (from Wong and Kwan, 1981)

Treatment	Part	Pb	Cu	Zn
Commercial feed alone (tubifex worms)	Head	106	18	932
	Bone	136	29	432
	Flesh	82	15	280
	Visceral organs	450	45	550
Activated sludge 70% plus commercial feed 30%	Head	98	16	859
	Bone	213*	31	432
	Flesh	81	16	400
	Visceral organs	446	133*	1166*
Activated sludge 85% plus commercial feed 15%	Head	188*	21	1008
	Bone	233*	43	601*
	Flesh	183	12	344
	Visceral organs	531	138*	1140*

* Significant difference between the control and treated fish ($p = 0.05$)

Higher concentrations of other heavy metals such as copper, zinc and manganese were also found in the waste materials and generally these elements were elevated in the treated fish.

GENERAL CONCLUSION

Although the data on the concentrations of lead in different ecological compartments of Hong Kong are fragmented, the preliminary studies indicated that lead contamination of air, soil, dust, marine sediment and living organisms are connected mainly to the combustion of leaded gasoline and the dumping of untreated sewage.

Knowledge of the sources of the environmental exposure and the pathways of this metal in the environment are urgently needed before any effective control strategy can be recommended. This is especially important in a densely populated area such as Hong Kong where a large portion of the population is exposed to the congested traffic as well as various industrial activities. Furthermore, surveys on lead emissions from industrial origins, for example, combustion of fossil fuel and incineration of municipal wastes, are required.

The common practice in the area of recycling waste materials such as night-soil (human excreta), animal manure, and sewage sludge which contain a substantial amount of heavy metals should not be ignored. Reports elsewhere have shown concern that continued use of sewage materials might lead to a hazardous accumulation of metals in soil and therefore restrictions on their uses are suggested. However, investigation on the usage of these waste materials as fishpond fertilizer and feed supplements should also be initiated in order to trace the fate of the various metals derived from the wastes.

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