Pertanika J. Trop. Agric. Sci. 23(1): 15 - 22 (2000) ISSN: 1511-3701

Trace Element Concentration in Mango (*Mangifera indica L.*), Seedless Guava (*Psidium guajava L.*) and Papaya (*Carica papaya L.*) Grown on Agricultural and Ex-mining Lands of Bidor, Perak

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Keywords: trace element contamination, tin tailings, *Carica papaya, Mangifera indica, Psidium guajava*

ABSTRACT

Buah-buahan seperti mangga, betik dan jambu batu tanpa biji yang ditanam di atas tanah pertanian dan tanah bekas lombong di Bidor disampel untuk analisis pencemaran oleh logam berat. Kepekatan merkuri (Hg), plumbum (Pb), kuprum (Cu), zinkum (Zn), nikel (Ni), arsenik (As) dan kadmium (Cd) di dalam buah-buahan tersebut telah dianalisis. Keputusan menunjukkan bahawa buah-buahan yang ditanam di atas tanah pertanian mempunyai tahap logam berat yang lebih tinggi berbanding dengan buah-buahan yang ditanam di atas tanah bekas lombong, kecuali Hg dalam mangga dan Pb dalam jambu batu. Kepetakan logam berat dalam kesemua buah-buahan bagi kedua-dua jenis tanah mempunyai julat daripada 0.06 hingga 0.55 mg kg^{-1} untuk Pb, 5.20 hingga12.22 mg kg^{-1} untuk Zn dan 2.01 hingga 5.74 mg kg^{-1} untuk Cu. Kedua-dua kromium (Cr) dan Ni tidak dapat dikesan dalam betik yang ditanam di atas tanah bekas lombong manakala As tidak dapat dikesan dalam kesemua buah-buahan yang ditanam di atas kedua-dua jenis tanah. Keputusan ini mencadangkan bahawa kesemua buah-buahan mengandungi tahap Hg dan Pb yang sangat tinggi. Faktor-faktor yang mungkin menyebabkan pencemaran akan dibincangkan. Kajian lanjutan diperlukan untuk menentukan punca pencemaran oleh logam berat dalam kesemua buah-buahan tersebut.

ABSTRACT

Fruits namely mango, papaya, and seedless guava grown on agricultural and ex-mining lands in Bidor were sampled for analyse of heavy metal contamination. The concentration of mercury (Hg), lead (Pb), copper (Cu), zinc (Zn), nickel (Ni), arsenic (As) and cadmium (Cd) in the fruits were analysed. The results showed that, with the exception of Hg in mango and Pb in guava, fruits grown on agricultural land have higher levels of heavy metals than those grown on ex-mining land. The concentration of heavy metal in all fruits of both soil types ranged from 0.06 to 0.55 mg kg^{1} for Cd, 0.02 to 0.78 mg kg^{1} for Hg, 0.63 to 8.71 mg kg^{1} for Pb, 5.20 to 12.22 mg kg^{1} for Zn, and 2.01 to 5.74 mg kg^{1} for Cu. Both Cr and Ni were not detected in papaya grown on mine spoils, whilst As was not detected in all fruits grown on both types of soils. The findings indicate that all fruits contained unacceptably high levels of Hg and Pb. The probable causes of contamination are discussed. Further studies are required to investigate the cause of heavy metal contamination in these fruits.

INTRODUCTION

Heavy metals are components of normal soils, and they are absorbed by plants only in ionic forms. In some disturbed sites such as ex-mining land; it has been reported that some areas have a large amount of heavy metals (Malm *et. al.*, 1995). The formation of heavy metal ions can be due to the lowering of soil pH, and/or, an excessive introduction of free heavy metal ions from contaminated sources such as sewage, polluted water and fertiliser (Davis 1984; Smith 1996).

Heavy metal contamination in agricultural products is known to cause health hazards. The uncontrolled uses of fertilisers and agro-chemicals which are environmentally unsound and health unfriendly have raised public concerns over the contamination of food and fruits with heavy metal residues. Of the numerous trace elements that are present in contaminated soils, Cd, Pb, Hg, As, Se, Zn, Cu and Ni have been identified as elements of primary concern because of their potential hazard to man (Chaney 1983).

Reports on the heavy metal levels found in the temperate fruits such as strawberries, raspberries, blackcurrant, and food crops namely asparagus, peanuts, tomatoes, paprika, cauliflower, cucumber, leek, Chinese cabbage, lettuces, potatoes, sweet corn, and wheat had been reported (Chlopecka 1995; Tahvonen and Kumpulainen 1995; Wojciechowska-Mazurek *et al.* 1995). A severe heavy-metal contamination of agricultural produces has also been noted in waste disposal sites (Brandt and Rickard 1996). However, little is known about the heavy metal content of tropical fruits such as mango, seedless guava and papaya which are amongst the favourite fruits consumed widely in the tropics. In Malaysia, these fruits are mainly produced locally. They are normally grown in good agricultural soils, while in some cases, they are also cultivated on ex-mining land. Fruit orchards are a classical example of intensive farming where fertilisers, herbicide, and insecticide applications are extensively employed by farmers. The application of these chemicals may result in undesirable heavy metal contamination of soils, plants and their produces (Smith 1996). In addition, mining spoils resulted from tin mining activities have also been reported to have heavy metal contamination (Ang and Ang 1997). The fruits produced from these orchards have not been assessed for their heavy metal concentrations. Hence, the objectives of this study were to examine and to compare the concentrations of heavy metals in mango, guava and papaya produced from the agricultural land and mining spoils respectively.

Study Site

Samples of mango, seedless guava and papaya were collected from orchards located in Bidor which is about 128 km north of Kuala Lumpur. Bidor is located at 4°06'N latitude and 101° 16'E longitude, and had been a famous mining town during the 1940's. Presently, Bidor is popular for fruit productions especially the mango and seedless guava. Fruit orchards established along the main access road from Bidor to Teluk Intan comprise agricultural land and mining spoils. The agricultural land under fruit production in Bidor, is mainly characterised by Orthic Ferralsols and Orthic Luvisols that originated from riverine alluvium (Panton 1995), mostly with an average fertility. Whereas, the type of ex-mining land where the fruit orchards are established belong to sandy tin tailings that comprises > 99% sand. Generally, it is very infertile and requires intensive nutrient inputs and a good watering system if required for agricultural production. The chemical and physical properties of sandy tin tailings were well documented (Ang 1994; Ang & Ang 1997) *e.g.* the concentration of trace elements of ex-mining land in Bidor is given in the following table:

Some potentially toxic trace elements of tin tailings at 0-20 cm soil depth (Adapted from Ang & Ang 1997)

Trace element	sample size (n)	sand (mg kg^{-1})	slime (mg kg^{-1})
As	4	0.02-4.48	0.03-3.18
Cd	9	0.02-0.36	0.03-0.58
Cu	9	3.36-9.47	3.96-17.01
Cr	9	0.09-4.66	0.30-17.01
Hg	4	0.03-0.07	0.08-0.64
Ni	9	0.29-8.78	3.64-29.31
Zn	9	2.85-55.0	0.1-30.43

Three fruit orchards established on agricultural land and three on mining spoils were selected as the sampling sites.

METHODS

Sampling

Fruits comprising of mango (*Mangifera indica L*), seedless guava (*Psidium guajava L.*), and papaya (*Carica papaya L.*) grown on agricultural land and mining spoils were selected for this study. Only ripe fruits were harvested for determination of their heavy metal concentration. About 10 to 15 fruits of each species grown on each soil type were randomly collected. The fruit samples were then properly labelled and kept separately in a plastic bag.

Sample Preparation

The fruits were processed on the same day after collection. They were rinsed with distilled water before peeling, and the edible portion of the fruits were then sliced and oven-dried at 65°C till constant weight. After drying, the slices of dried fruit were ground to powder using an electrical blender and stored in air-tight plastic bags until taken for analysis.

Fruit samples from both soil types were analysed for moisture and heavy metal contents based on AOAC Methods (1980). The wet extraction technique was employed for the digestion of the fruit samples. Total lead (Pb), copper (Cu), zinc (Zn), nikel (Ni), arsenic (As), and cadmium (Cd) were determined using an atomic absorption spectrophotometer. Total mercury (Hg) concentration was analysed using automated cold vapour, EPA stannous chloride method (Dorminski 1985). All samples were analysed in quadruplicate.

RESULTS AND DISCUSSION

Moisture Content

The moisture content of fruits varied from 83 to 90% (Table 1). Mango and seedless guava grown in mine spoils had significantly lower water content than those grown on agricultural soils. The lower moisture content of these fruits could be due to the interaction of environmental factors and their physiological characteristics. One of the possible reasons could be the harsh environment of mine spoils which are characterised by high air temperature and low water availability (Ang 1994), resulting in drier fruit tissues of the two woody species. However, the moisture content of papaya grown on ex-mining land was greater than those planted in agricultural land. This suggests that papaya, which has succulent property may have a different strategy to overcome drought through conserving tissue water, *e.g.* cactus.

TABLE 1
The moisture content (%) of fruits

Fruit	Sample size (n)	Mean moisture content of fresh fruit ± SEM (100 x g g-1)
Mango		
(a) Agricultural land	4	86.4 ± 0.5a
(b) Ex-mining land	4	82.6 ± 0.3b
Guava		
(a) Agricultural land	4	89.6± 0.2a
(b) Ex-mining land	4	82.6± 0.2b
Papaya		
(a) Agricultural land	4	88.1 ± 0.0a
(b) Ex-mining land	4	88.9 ± 0.1b

Note: For same species only, alphabetical letters indicate significant differences by SEM between two values in the same column.

Chemical Content

The heavy metal content of the edible portion of fruits are presented in Table 2. Generally, fruits grown on agricultural land have greater mean levels of heavy metals than those grown on mine spoils, except for Hg in mango, and Pb and Ni in guava.

Mango, papaya and guava grown on agricultural land contained a greater concentration of Cd, Cr, Cu and Zn than those planted on ex-mining land. The concentrations of Cd and Cu present in all fruits ranged from 0.06 to 0.55 mg kg^{-1} and 2.01 to 5.74 mg kg^{-1}, respectively. The concentration of Cd was below the permissible limit of 0.5 mg kg^{-1} independent of soil types *(Fig. 1a)*.

For fruits grown on ex-mining land, mango had a significantly higher level of Cu than guava and papaya (Table 2). The mean Cr level of all fruits was below 0.7 mg kg^{-1} and was below the level of concern (USFDA, 1993a), regardless of species and soil types. Interestingly, Cr was not detected in papaya grown on ex-mining land. The mean level of Zn in all fruits ranged from 5.20 to 12.22 mg kg^{-1}, and with the highest level was found in mango. The level of As was not detected in all fruits. Mango grown on ex-mining land had the highest mean concentration of Ni (Table 2).

The sources of contamination remain unclear in this study, however, the findings have indicated that several important heavy metals were found in the fruits grown in Bidor. Such metals can be easily absorbed into the human body through dietary intake. These potentially harmful elements can cause undesirable health problems such as kidney failure, cancer, liver failure and other illness (USEPA 1979; Logan & Chaney 1983; Smith 1996).

TABLE 2
Heavy metal concentration in dry weight basis of fruits grown on agricultural and ex-mining lands

Element	Mango			Guava		Papaya	
	Permissible level (mg kg^{-1})	Agricultural land (mg kg^{-1})	Ex-mining land (mg kg^{-1})	Agricultural land (mg kg^{-1})	Ex-mining land (mg kg^{-1})	Agricultural land (mg kg^{-1})	Ex-mining land (mg kg^{-1})
Cadmium (Cd)	1.0	0.12 ± 0.07	0.06 ± 0.06	0.24 ± 0.00	0.12 ± 0.07	0.55 ± 0.32	0.34 ± 0.20
Mercury (Hg)	0.05	0.16 ± 0.15	0.26 ± 0.15	0.78 ± 0.75	0.02 ± 0.02	0.70 ± 0.44	0.08 ± 0.05
Lead (Pd)	0.5	1.64 ± 0.77	0.63 ± 0.44	2.44 ± 0.72	8.71 ± 0.71	1.38 ± 0.83	1.89 ± 0.67
Arsenic (As)	0.1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Zinc (Zn)	5	12.22 ± 3.20	7.63 ± 0.15	11.62 ± 1.22	8.74 ± 0.71	8.13 ± 0.93	5.20 ± 0.54
Copper (Cu)	10.0	5.74 ± 0.70	3.90 ± 0.17	4.61 ± 0.26	3.74 ± 0.36	3.48 ± 0.19	2.01 ± 0.49
+ Chromium (Cr)	4.86	0.66 ± 0.12	0.52 ± 0.52	0.58 ± 0.34	0.39 ± 0.39	0.58 ± 0.33	N.D.
+ Nickel	29.3	0.06 ± 0.06	1.07 ± 0.68	0.18 ± 0.18	0.55 ± 0.55	0.65 ± 0.49	N.D.

Notes: Permissible limit is after Food Act 1983 and Food Act Regulations 1985 (MDC, 1996) except for the contents of Cr and Ni which are calculated after USFDA (1993a, b) and known as levels of concern. N.D. denotes below detection limit and (denotes SEM.
+ denote level of concern of Cr and Ni in dry fruit :
- Average daily consumption rate of fruits per person (fresh weight) = 300 g
- Average daily consumption rate of fruits per person (dry weight) = 300 x 0.137 g =41.1 g
- Level of concern for Cr uptake through eating shellfish = 0.2 mg per person per day, if the Cr uptake comes only from fruits alone = (200 /41.1) = 4.86 mg kg^{-1}.
- Level of concern for Ni uptake through eating shellfish = 1.2 mg per person per day. If the Ni uptake comes only from fruits alone = (1200 /41.1) = 29.3 mg kg^{-1}

Mercury

Guava and papaya grown on agricultural land, were found to have a higher Hg content than those grown on ex-mining land (Table 2). With the exception of guava grown on ex-mining land, the mean Hg level of all fruits exceeded the acceptable limit of 0.05 mg kg^{-1} *(Fig. 1c)*. Several studies showed that high Hg concentration was found in sites of previous gold mining and smelting factories (Malm *et al.* 1995), farmland through the application of organomercurial fungicides (Smith 1996), and sludge-treated soil through sludge application as a fertiliser (Estes *et al.* 1973). Smelting of gold involving the use of pure mercury (Chan 1983; Malm *et al.* 1995). Release of Hg in the environment occurs basically in two ways: [a] sublimation of Hg from amalgam during melting and purification processes which involves burning, and [b] direct release to aquatic systems or to mine tailings. The record of gold mining and extraction in Bidor shows that the production of gold varied between 2.70 to 6.98 kg month^{-1}, with a maximum average of 56.50 kg month^{-1} for the period from June 1981 to May 1982 (Chan 1983). Hence it is not surprising to discover Hg content in the fruits grown in Bidor. The uptake of Hg in edible part of fruits may also come from the applications of agro-chemicals, organic fertiliser, fertiliser through foliar application, irrigation using contaminated water from the mining pond, and/or, from the contaminated soils. Interestingly, fruits grown on agricultural land contain a significantly higher mercury concentration than those grown in mine spoils *(Fig. 1c)*. A higher Hg uptake in plant is normally possible through direct aerial contact rather than from contaminated soils (Bache *et al.* 1973; Vigerut and Selmer Olsen 1986; Smith *et al.* 1992). However, aerial contact may also come from the volatilisation from soils and absorption by the aerial parts of plants, and could result in an increase of the Hg concentration in plant tissue (Lindberg *et al.* 1979). The soils of fruit orchards that are in the vicinity of a former gold smelting factory in Bidor may receive the Hg deposits from the contaminated source from the last decade. However, further analyses on the content of Hg of the agro-chemicals, water, fertilisers, and agricultural soils, are needed to further determine their roles in heavy metal contamination of fruits.

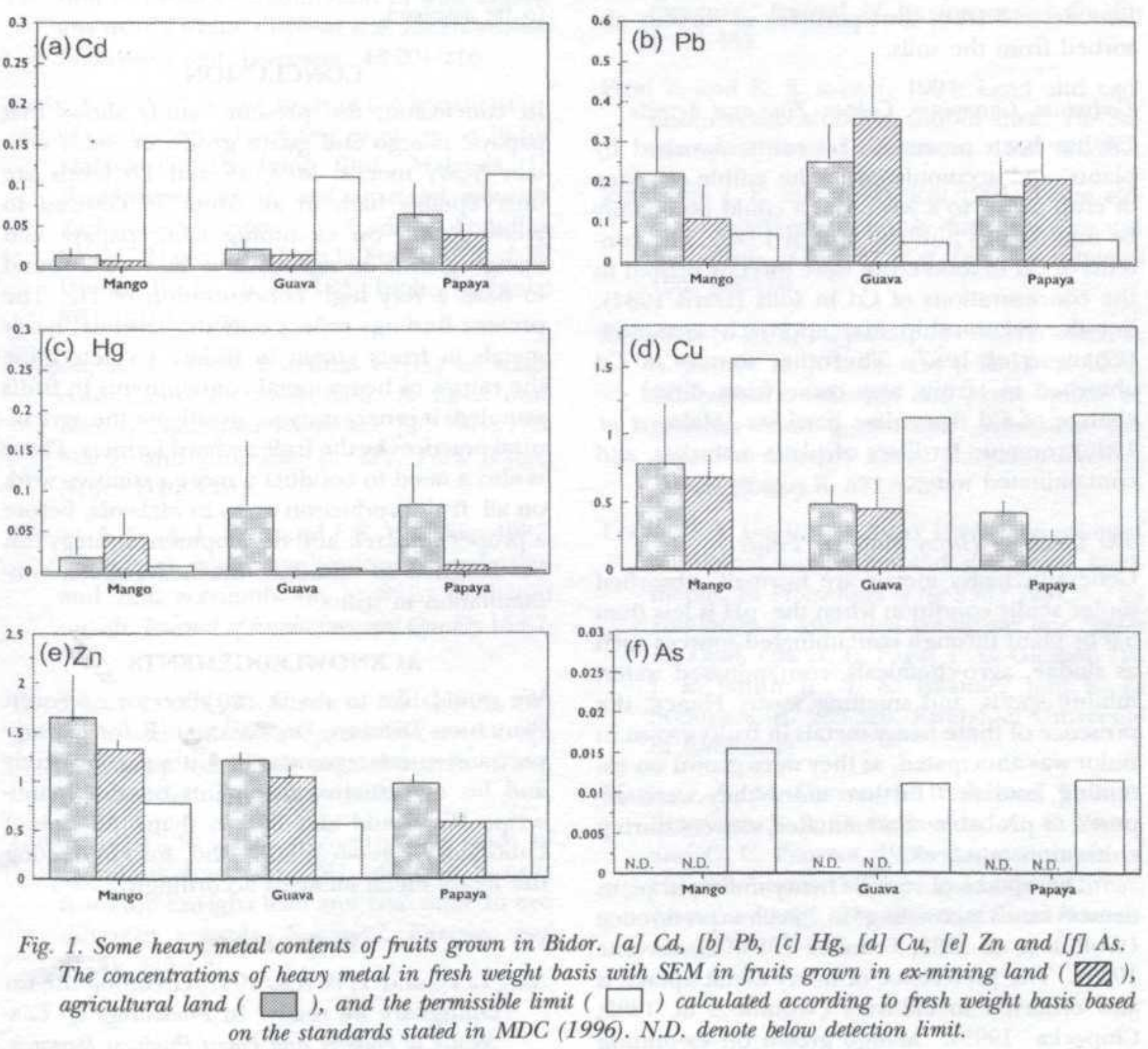

Fig. 1. Some heavy metal contents of fruits grown in Bidor. [a] Cd, [b] Pb, [c] Hg, [d] Cu, [e] Zn and [f] As. The concentrations of heavy metal in fresh weight basis with SEM in fruits grown in ex-mining land (▨), agricultural land (▦), and the permissible limit (□) calculated according to fresh weight basis based on the standards stated in MDC (1996). N.D. denote below detection limit.

Lead

The level of Pb in fruits ranged from 0.63 to 8.71 mg kg^{-1} (Table 2). This value was not significantly different between fruits *(Fig. 1b)*. The Pb content of guava collected from ex-mining land was shown to have about 17 folds greater than the permissible limit (Table 2). The unacceptable concentration of Pb in the fruits could have resulted from direct contacts with contaminated sources such as the dust particles (Fergusson & Kim 1991; Feng and Barrat 1994), and in an extreme acidic soil conditions with < pH 3.0 (Smith 1996). Certainly, the Pb contamination is unlikely to come from direct contacts with fruits during the sample preparation because the fruits were rinsed with distilled water, and the outer coat of the fruits were peeled off. Hence, the Pb contamination of fruits grown in Bidor is probably in the form of exchangeable ions derived from dust particles or directly absorbed from the soils.

Cadmium, Chromium, Copper, Zinc and Arsenic

Cd has been proven to be easily absorbed by plants, and accumulated in the edible portions of crop plants to a level which could potentially be injurious to humans (Smith 1996). The contents of Cd in food crops were directly related to the concentrations of Cd in soils (Davis 1984), but the relationship may approach asymptote (Chang *et al.* 1987). The other sources of Cd absorbed in fruits may come from direct exchange of Cd from dust particles (Malm *et al.* 1995), organic fertiliser of plant materials, and contaminated water.

The Uptake of Heavy Metals in Fruits

Generally, heavy metals are normally absorbed under acidic condition when the pH is less than 5.0 by plant through contaminated sources such as sludge, agro-chemicals, contaminated water, mining spoils, and smelting waste. Hence, the presence of these heavy metals in fruits grown in Bidor was anticipated, as they were grown on ex-mining land and further more they were exposed to probable contaminated sources during cultivation practices.

The uptake of various heavy metals in plant tissues varies according to species preference (Wolnik *et al.* 1983; Eriksson 1989; Chukwuma 1995). The preference of heavy metal uptake is also observed in cultivars (Wolnik *et al.* 1983; Clopecka 1995). Mango grown on ex-mining land accumulated a higher concentration of Hg than papaya and guava. This could be due to its predilection to the metal. Similarly, the preference of guava to Pb uptake was observed. Guava had a greater Pb content per kg fresh weight than mango and papaya irrespective of planting sites *(Fig. 1b)*.

The species preference of fruit trees for certain heavy metal uptake needs further confirmation in control environments. In addition, further investigations on site toxicity and cultivation practices of fruit tree orchards in Bidor are needed. The suitability of ex-mining land in Bidor for food production has to be ascertained due to the presence of heavy metals. In view of these findings, the chemical properties of the ex-mining land nation wide need to be systematically characterised and investigated. The site toxicity and suitability for food production need to be assessed.

CONCLUSION

In conclusion, the present study shows that papaya, mango and guava grown in Bidor contain heavy metals. Mercury and Pb levels are unacceptably high in all fruits. In contrast to guava grown on ex-mining land, papaya and mango grown on agricultural land were found to have a very high concentration of Hg. The present findings reflect only the level of heavy metals in fruits grown in Bidor. To determine the causes of heavy metal contaminants in fruits sampled, it is necessary to investigate the agricultural practices by the fruit orchard farmers. There is also a need to conduct a more extensive work on all fruit production areas in Malaysia, before a proper research and development strategy can be designed to minimise the heavy metal contamination in fruits.

ACKNOWLEDGEMENTS

We would like to thank the director of Forest Plantation Division, Dr. Baskaran K for his support and encouragement in initiating this study and his constructive comments on this manuscript. We would also like to thank AS Lee of Laboratory Chemical Sdn. Bhd. for conducting the heavy metal analyses accordingly.

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Received: 10 July 1998
Accepted: 3 Jan. 2000