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NUTRIENT VALUE OF LANDFILL LEACHATE ON THE GROWTH OF *Brassica rapa L.*

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ABSTRACT Leachate from Ampar Tenang landfill was characterized and then treated with ferric chloride. Treated leachate was used at different dilution levels as biofertilizer for the cultivation of *Brassica rapa* L. (leafy vegetable). A treatment with inorganic fertilizer at the same N-equivalent as the leachate, and a control (water) were also included. Physical growth parameters (leaf length, leaf width, stem height) and harvest parameters (total number of leaves, root length and dry weights of different plant parts) were determined. The dry-weights of leaf, root and stem in (both) treatments had significantly higher biomass over the control. *B. rapa* receiving 25%DTL had the highest specific growth rate for leaf length (0.53 mm/d) and leaf width (0.39 mm/d). Heavy metal accumulations in *B. rapa* grown with leachate and in *B. rapa* bought from the market were compared with the permissible concentration limit of FAO/WHO. Inorganic fertilizer did not give a better fertilizing effect in terms of plant yield and growth than the leachate treatments according to this study, but heavy metal accumulation makes the leachate unfit for fertilization of edible plants like *Brassica rapa* L.

(**Keywords:** Landfill leachate, irrigation, heavy metal, *Brassica rapa* L., Specific growth rate.)

INTRODUCTION

Waste generation is attracting much global attention in recent times due to increasing population, changing consumption patterns, economic development, changing income, urbanization and industrialization. Malaysia, like many other transitory nations, is confronted with solid waste generation and disposal problem; the production of municipal and commercial wastes has reached roughly 11.4 million metric tons/year [1].

In Malaysia, 95% of the waste collected is disposed off in 260 landfills. Various possible means of eliminating solid urban waste (e.g. by landfilling, composting, incineration, etc.) have shown that the cheapest, in terms of capital cost and exploitation, is landfilling, and it is estimated that the total volume of leachate generated from landfills in Malaysia is about 3.0 million liters per day [2]. This leachate is released into waterways after full or partial treatment. Treated leachate contains nutrients and minerals, and thus it is possible that it can be used for agro-irrigation with some pre-treatment.

Cheng and Chu [3] reported on both the positive and detrimental effects of landfill leachate on plant growth, depending on the plant species used and the concentration of the leachate. However, Menser and colleagues [4] explained that irrigation with leachate could lead to yield reduction, leaf damage, premature senescence and poor plant survival. In contrast, Liang and colleagues [5] suggested the use of landfill leachate as irrigation water in dry seasons to enhance the growth, survival and stomatal conductance of *Acacia confusa*, *Leucaena leuocephala* and *Eucalyptus torelliana*. Cureton and colleagues [6] reported significantly higher growth in *Phalaris arundinacea*, *Salix babylonica* and *Populus nigra* subjected to leachate application, but some phytotoxicity symptoms, such as brown leaves and necrotic spots, were observed in poplar leaves, while chlorophyll degradation or even complete chlorosis was found in willows.

Informal surveys [7] have indicated that in Harare alone, there are more than 100 hectares of land under horticultural production that utilize wastewater for irrigation of crops, such as maize (*Zea mays*) and leafy vegetables (*Brassica spp*.). As a number of factors influence plant vigour in field situation (i.e. soil type, plant species and variety, water quality and irrigation rates, climate, and interaction of two or more factors), predictions of plant growth in leachate irrigation systems are difficult to make.

Therefore, identification and recognition of plant stress in the field would be of great importance in assessing the short-term negative response that is likely to lead to more severe problems in the long run. Growth rates and biomass production are common indicators of imposed stress [8]. Leaf length, leaf width, shoot length, and leaf fluctuating asymmetry, which is a random non-directional deviation from anticipated symmetry, have been proposed as environmental stress indicators [9; 10]. Some consumers consider undamaged, dark green and big leaves as characteristics of good quality leafy vegetables. However, the external morphology of vegetables cannot guarantee safety from contamination. Heavy metals rank high amongst the chief contaminants of leafy vegetables [7; 11; 12].

Leafy vegetables are expected to grow where there is adequate water supply and the soil is well drained, fertile and preferably alkaline. They prefer a pH of 5.5 to 7 but tolerate pH in the range of 4.3 to 7.5 [13]. Shallow cultivation is carried out for weed control. Leafy vegetables prefer a cool moist reasonably fertile soil. The plants being shallow-rooted are intolerant of drought; thus they need to be grown in a moist fertile soil for the best quality leaves [14]. *Brassicas* and mustards need adequate nitrogen and sulfur [15]. An N:S ratio from 4:1 to 8:1 works well for *Brassica* species in general. *Brassicas* are widely cultivated, especially in China.

However, the search of alternatives to reduce the hazard caused by landfill leachate to the environment, whilst improving soil fertility for sustainable plant/crop production has resulted in studying the recycling possibilities of leachate from landfills. It could be used as a source of water or plant nutrients and as a soil conditioner for crop production.

This study was to analyze the leachate characteristics from the Ampar Tenang landfill, and at the same time to evaluate the fertilizer value compared with conventional inorganic fertilizer. More so, the pollution impacts based on the heavy metal content in the soil and in the test plant, *Brassica rapa* L., were compared with The Ministry of Agriculture, Fisheries and Forest (MAFF) United Kingdom and FAO/WHO permissible concentration standard.

MATERIAL AND METHODS

Site, leachate collection and description

The Ampar Tenang landfill in Sepang, Selangor, Malaysia, was opened in the year 2000, and has been managed by Alam Flora Sdn Bhd, a waste management company in Malaysia. The 4-ha open landfill was for about 150 metric tons of domestic waste generated daily in Sepang; located in the southern part of the state of Selangor. Leachate from this landfill is discharged into the nearby environment and ponds.

Leachate analysis included: pH and conductivity, measured using a pH and conductivity probe (Hanna Model, No. 8033). Total suspended solids (TSS) and colour were determined using a spectrophotometer, HACH Model (DR/4000). BOD_5, COD and total N were analysed according to the standard methods of APHA, AWWA, and WEF [16] while heavy metals were determined using the digested leachate by inductively coupled plasma optical emission spectrometry (ICP-OES).

The chemical treatment of the leachate was done by using a Jar Test [a six-paddle flocculator, from Stuart Scientific (Flocculator SW1) equipped with 6 beakers of 500mL each]. Iron (III) chloride at 4g/L in solid state was used as effective coagulant dosage for raw leachate at pH 7 [17], and the filtrate was used as biofertilizer for fertigation.

Growth conditions, Experimental design and treatments

This experiment was conducted under a netted plant shelter with dimensions of 1.2m x 1.2m x 3.3m to protect the treatments from direct rain and sunlight. *Brassica rapa* L. was grown in free-draining 4-L plastic bags containing 5 kg of black soil per plastic bag. Seeds were first sown in germination pots which received daily irrigation from water sprinklers. At 6 days after germination, uniform seedlings were selected and transplanted at a rate of two plants per bag (0.2m x 0.2m), spaced 8cm apart to reduce inter-plant competition for nutrients. All plants were well-watered daily until leachate application began on the 19^{th} day after seed germination. At this time, the plants had on average 3.5cm expanded leaf length, 2.5cm leaf width, 2.8cm root length by destructive sampling and 1.0cm stem height.

Nine treatments containing two plants per bag with four replicates in a randomized complete block (RCB) design with stringent elimination of weeds were imposed. Both 100% raw and treated leachate had the same total nitrogen content (0.090% N), while the 75 to 12.5% diluted treated leachate (DTL) contained 0.068 to 0.012% N. The N content of 50%DTL and 100% Inorganic Fertilizer (IF) was standardized at 0.045% N. For each treatment, leachate application rate of 200mL was initially (applied) by dripping twice a day (before 8AM and after 5PM) until the plants were more expanded, at which time fertigation was increased- 250mL (twice a day) because of higher evapo-transpirattion. Total leachate treatment period took 36 days. No pesticide was applied to all the plants till the end of the experiment.

After the 56th day (which is equivalent to 36 consecutive days of leachate application), the plants were harvested by uprooting. Fresh weights of the separated leaves, stems and roots were determined as well as the total leaf number (TLN). The leaf length (LL), leaf width (LW) and stem height (SH) were measured prior to harvesting while the root length was measured after harvest.

The leaves, stems and roots were then dried at 70^{o}C in a forced draft oven (GO-251) for 3 days until constant weight. The dry matter yield was then determined. All data generated were subjected to statistical analysis using one-way ANOVA of the software **SPSS** version **17.0**. The specific growth rate (SGR) for leaf length, leaf width, root length and stem height was determined as follows [18; 19]:

$$\text{Specific growth rate, SGR} = \frac{\ln L_2 - \ln L_1}{t_2 - t_1} \quad \text{(mm/d)}$$

where L_1= the initial length at exponential phase, L_2 = the final length at exponential phase, t_1 = the beginning of the selected time interval and t_2 = the end of the selected time interval.

Heavy Metal Analysis

After drying, the oven dry weights (DW) of plants and soil were recorded to the nearest gram, and then the samples were individually ground to pass a 2-mm screen in a laboratory mill (Serial no. 39017, Christy and Norris LTD, Chelmsford, England), then a 0.1g sample was accurately weighed into a 500-mL volumetric flask [20]. 10mL of 65% HNO_3 and 10mL distilled water were added into the 500-mL volumetric flask and refluxed for 10 min by mounting the flask on the digestion heater (EAM9203 heating mantle) at 105^{o}C. Another 5mL of 65% HNO_3 were added after 15 min and the mixture digested until the solution became transparent. For the soil samples, 3mL (30%) H_2O_2 and 10mL HCL were added while refluxing for 15 min. The resulting solution was cooled, filtered and diluted to 50mL using deionized water, and was analyzed for K, Ca, Mg, Na, Pb, Cd, Se, Al, Mn, Cu, Zn, Fe and As, using ICP-OES analysis.

RESULTS AND DISCUSSIONS

Leachate

The total N present in the raw leachate sample was 900mg/L. This high concentration of total nitrogen could be attributed to the breakdown of nitrogenous substances during the organic waste decomposition [21]. The Amper Tenang landfill leachate exhibited typical characteristics of an ageing methanogenic landfill (Table 1). The BOD_5/COD ratio was between 0.06 and 0.08, which according to Christensen and colleagues [22] is characteristic of an ageing landfill.

The presence of TSS and Total Solid (TS) in the leachate at high levels was mainly due to the organic and inorganic compounds that were present in the leachate [23]. Among the heavy metals analysed from the leachate, Cd showed lowest concentration whilst the others were above (Standard B) of the Environmental Quality Act (EQA) 1974.

Cd content was reduced by about 100%, Al by 64.4%, Fe by 51.9%, Pb by 82%, Cu by 56.8% and Zn by 96.6% after the leachate were treated with 4g/L of $FeCl_3$ at pH 7. Hamidi and colleagues [24] found that the reduction of all parameters was greater with an increased dosage of coagulant (200 mg/L of $FeCl_3$), such as the removal of colour, turbidity and suspended solids.

However, $FeCl_3$ was able to remove 85% of Pb, 88% of Cu, 90% of Al, and 92% of Zn at the optimum dosage of 4g/500 mL [25]. Jayabala [26] reported a reduction of Cd by 83.3% at 60 mg/L $FeCl_3$. The best removal capacities for TSS was up to 80% at 1.5 g/L (without pH adjustment) when coagulants were added to stabilize the leachate [27].

Plant physical growth assessment

The cultivated *Brassica rapa* survived till harvest, and common symptoms of soil salination, such as chlorosis and leaf burn, were not observed in the plants irrigated with different leachate concentrations. The plants receiving 25% diluted treated leachate (DTL) produced significantly longer leaves (23.17±0.577cm) than the other treatments (Table 2), at a high probability level of $p<0.05$.

The same treatment also gave wider leaves which were 1.36 and 3.23 times higher than those of the plants receiving inorganic fertilizer [100%IF (N_{15}:P_{15}:K_{15})] and the control at $p<0.05$. A possible explanation to this may be that 25%DTL was optimum in satisfying the nutrient requirement for leaf expansion [28; 19].

Specific growth rate was 0.53mm/day leaf length (Table 3).

Harvest parameter assessment

Dry biomass weight

Dry leaf biomass of *B.rapa* receiving 50%DTL+50% inorganic fertilizer (IF) was highest at 2.25 and 1.60 times than the control and 100%IF. Statistical comparison showed that the difference in the means of leaf dry weight for the treatments 50%DTL+50%IF and 25%DTL were not significantly different at $p<0.05$. The dry root biomass of the treatment 25%DTL were 3.16 and 1.70 times higher than the control and 100%IF (Fig. 1). For dry stem biomass, the control plants were 5.47 times significantly lower than the plants with treatment 100%RL (1.37± 0.176g) at $p<0.05$. Applying 100% raw leachate and 100% treated leachate resulted in higher dry stem biomasses, and this might be from the effect of the organic content present in the raw leachate [7].

Heavy metals in soil and plants

The total concentration of the heavy metals present in the soil prior to irrigation with leachate or inorganic fertilizer was below the maximum permissible limits stipulated [29 and 30] (Table 5). The application of leachate generally led to changes in the physicochemical characteristics of the soil, and consequently the heavy metal uptake by vegetables [31]. Comparisons were made between [edible (upper) parts] 1cm above soil level of plants which received 50%DTL and 100%IF and a market sample of *B.rapa.* The concentrations of Cd in the edible parts of each of the specific treatments including the market control were zero and therefore below the permissible limits of 0.2mg/kg [32; 33] (Table 6 and 7).

Traces of Pb ranging from 0.07-0.09mg kg^{-1} were found in the edible parts of plants from treatments 50%DTL and 100%IF but there was zero Pb in the market sample. Nevertheless, the levels were still below the maximum permitted concentration (MPC) of 3mg kg^{-1} [33]. Arsenic was present at concentrations below the MPC of 1.0 mg kg^{-1} [33] proposed by the Food Quality and Standard Control Division, Ministry of Health Malaysia, for heavy metals under the Malaysia Standard *MS 894, conforming to [34, 32 and 33].

K, Ca, Mg, Na, Al and Fe showed higher accumulation in the edible parts of plants receiving the treatment 50%DTL than in the market sample. This result is in agreement with previous studies [35; 36] which showed elevated levels of metals in edible parts of food crops continuously irrigated with wastewater irrigation.

Previous studies [36; 37; 38] demonstrated that plants grown using leachate-irrigated soils were generally contaminated with heavy metals, which pose a major health concern. Our results reveal that roots of *B. rapa* receiving both the treatments 50%DTL and 100%IF accumulated more Pb than their corresponding edible parts. Also, several studies have shown that most of the absorbed Pb remains in the roots [39].

Generally, *B.rapa* has higher mineral accumulation tendencies in the leaf region. In this study, concentrations of K, Ca, Mg, Na, Al and Fe were the most dominant minerals present. Lead and cadmium were the most insignificant heavy metals found in the plant tissues according to our results.

General Statistics Information

The various treatments are statistically significant from the control and some are different from one another using the Least Significant Difference (LSD).

CONCLUSION

From the results of this study, it is confirmed that landfill leachate is as effective as inorganic fertilizers as a source of nutrients for *Brassica rapa*. However, the presence of heavy metals (which might be harmful to human health) in the leachate, which were accumulated by plants receiving leacheate-irrigation treatments, renders the leachate unfit for irrigating edible plants like *B. rapa*. The leachate can, however, be utilized as biofertilizer for non-edible plants, such as ornamentals and timber species. When compared with the FAO/WHO standard, the heavy metal accumulation in some of the leachate-grown plants was below the permissible concentration but still at levels generally higher than in the market sample control.

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Table 1: Characteristics of Ampar Tenang Landfill leachate compared with Standards A and B of Environmental Quality Act (EQA) 1974.

Parameter	Unit	Ampar Tenang Landfill Leachate (untreated)	EQA 1974 STANDARD	
			A	B
Temperature	^{o}C	30	40	40
pH	-	6.12- 7.04	6.0-9.0	5.5- 9.0
BOD_5	mg/L	202- 216	20	50
COD	mg/L	2500- 3800	50	100
BOD_5 / COD ratio	mg/L	0.06- 0.08	N.A	N.A
Turbidity	FAU	950- 1570	N.A	N.A
Sulphate	mg/L	22- 420	N.A	N.A
Total N	mg/L	900	50	100
Total Solids	mg/L	1716- 1720	N.A	N.A
TSS	mg/L	12.5- 14.5	N.A	N.A
TDS	mg/L	332-330	N.A	N.A
Conductivity	ms/cm	8.10 – 16.10	N.A	N.A
Salinity	mg/L	0.2- 0.5	N.A	N.A
Colour	ADMI value	15310- 15390	N.A	N.A
K	mg/L	350-800	N.A	N.A
Ca	mg/L	20-150	N.A	N.A
Mg	mg/L	15-22	N.A	N.A
Na	mg/L	550-800	N.A	N.A
Pb	mg/L	0-0.50	0.01	0.5
Cd	mg/L	0.0001-0.01	0.01	0.02
Se	mg/L	1.30- 1.90	N.A	N.A
Al	mg/L	13.0- 25.0	N.A	N.A
Mn	mg/L	4.0- 9.5	0.2	1.0
Cu	mg/L	0.05-0.44	0.2	1.0
Zn	mg/L	1.20-3.5	1.0	1.0
Fe	mg/L	13.0- 17.10	1.0	5.0
As	mg/L	0-0.60	0.05	0.1

Table 2: Comparison of leaf length (LL), leaf width (LW), stem height (SH) and total leaf number (TLN) for *Brassica rapa L.*

Treatments	Av. Leaf length (LL) cm	Av. Leaf width (LW) cm	Av. Stem height (SH) cm	Av. Total leaf number (TLN)
100% RL	19.17 ± 0.58 **zcfg**	9.00 ± 0.87 **z**	2.43 ± 0.32 **z**	16.17 ± 1.89 **zdeh**
100% TL	19.50 ± 1.32 **zcfgh**	9.83 ± 1.16 **zh**	2.23 ± 0.32 **x**	18.67 ± 1.61 **zcdefh**
75% DTL	15.72 ± 1.11 **z**	8.33 ± 1.26 **z**	2.43 ± 0.42 **z**	14.33 ± 0.76 **z**
50% DTL	19.00 ± 1.80 **zcf**	9.00 ± 0.50 **z**	2.27 ± 0.31 **x**	12.00 ± 1.32 **z**
25% DTL	23.17±0.58 **zybcdfgh**	10.33± 0.29 **zch**	2.30 ± 0.36 **x**	12.33 ± 1.04 **z**
12.5% DTL	15.67 ± 1.04 **z**	9.33 ± 1.44 **z**	2.17 ± 0.38 **x**	15.17 ± 2.36 **zde**
50%DTL + 50%IF	16.83 ± 2.02 **z**	9.17 ± 1.16 **z**	2.50 ± 0.87 **x**	16.33 ± 1.61 **zdeh**
100% IF	17.00 ± 1.50 **z**	7.67 ± 0.76 **z**	2.50 ± 0.87 **x**	13.23 ± 1.66 **z**
dH_2O (Control)	7.17 ± 0.58	4.50 ± 1.80	1.50 ± 0.50	8.33 ± 0.76

Levels of significance $p>0.05$ at F= 35.256 $p>0.05$ at F= 7.035 $p>0.05$ at F= 1.03 $p>0.05$ at F= 11.

Table 3: Specific growth rate for *Brassica rapa L.* at harvest.

Treatments	**Leaf length LL (mm/d)**	**Leaf width LW(mm/d)**	**Root length RL (mm/d)**	**Stem height SH (mm/d)**
100% RL	0.47	0.35	0.30	0.22
100% TL	0.48	0.38	0.42	0.20
75% DTL	0.42	0.33	0.40	0.22
50% DTL	0.46	0.35	0.38	0.20
25% DTL	0.53	0.39	0.30	0.21
12.5% DTL	0.42	0.37	0.40	0.19
50% DTL + 50% IF	0.43	0.36	0.35	0.23
100% IF	0.44	0.31	0.42	0.23
dH_2O (Control)	0.20	0.16	0.21	0.09

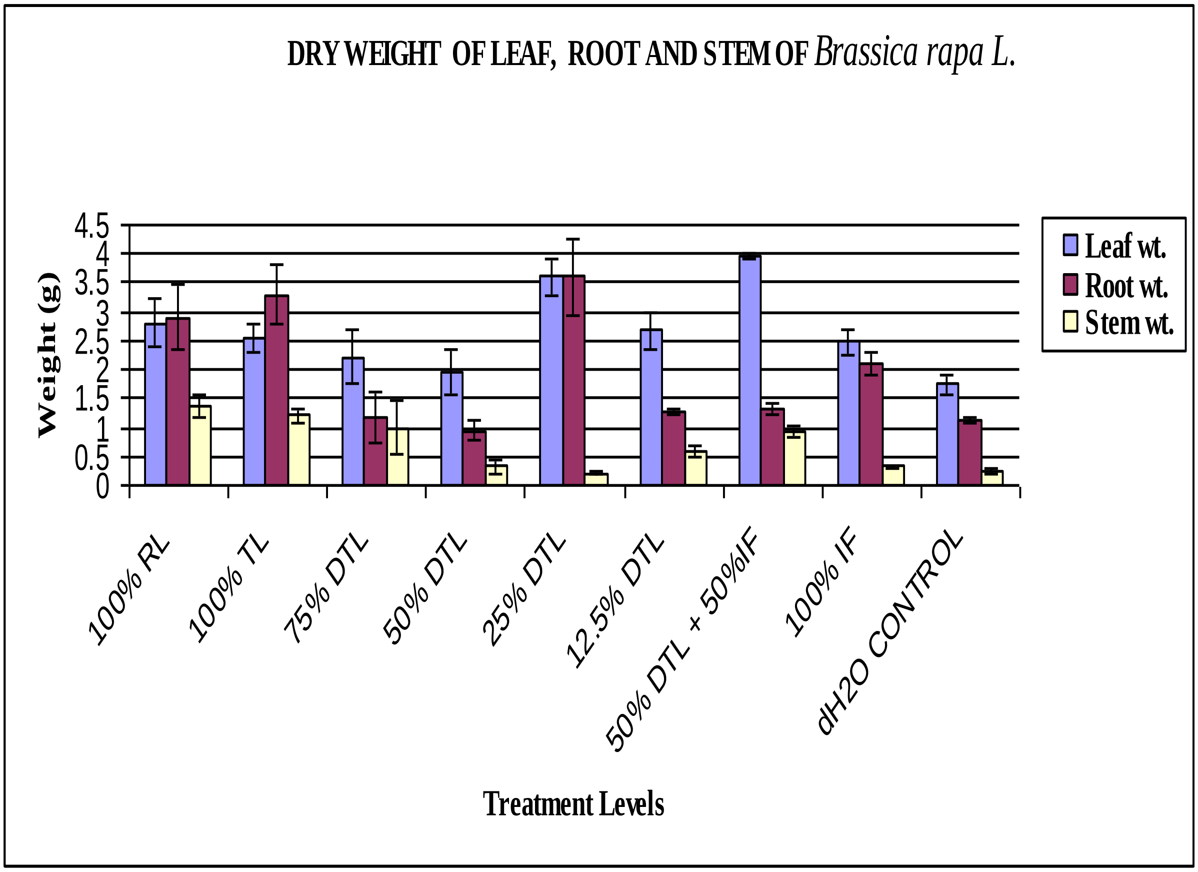

Figure 1: Dry weight of various plant parts at harvest under different treatments.

Table 4: Soil quality prior to leachate application compared to MAFF standard.

Heavy Metal	**Heavy metal in surface soil and MAFF standard**	
	Prior to leachate application (mg/kg)	MAFF Standard (mg/kg)
K	20.73	-
Ca	38.55	-
Mg	8.83	-
Na	6.68	-
Pb	>0.06	0.19
Cd	>0.01	0.07
Se	>0.05	-
Al	1.85	-
Mn	8.85	-
Cu	2.71	2.9
Zn	0.65	0.16
Fe	30.47	-
As	>0.01	0.16

Source: MAFF [29; 30]

Table 5: Heavy metal content comparisons for treatments 50%DTL and 100%IF with both controls for *Brassica rapa* L. (water and market sample)

	Treatment										
	50% DTL (mg/kg)			100% IF (mg/kg)			dH_2O Control (mg/kg)			Market Control (mg/kg)	
Heavy Metals	**Edible Parts**	**Roots**	**Soil**	**Edible Parts**	**Roots**	**Soil**	**Edible Parts**	**Roots**	**Soil**	**Edible Parts**	**Roots**
K	42.84 ± 4.07	31.6 ± 4.26	1.21 ± 0.01	62.89 ±3.84	3.27 ±2.01	1.31 ± 0.20	0.95 ±0.29	1.84 ±0.20	1.31 ±0.02	12.46 ±2.21	11.24 ±3.10
Ca	18.35 ± 2.90	14.06 ± 3.66	5.32 ± 0.08	41.99 ±3.97	2.56 ± 0.84	6.06 ±0.20	0.22 ±0.12	1.26 ±0.08	5.7 ±0.40	6.6 ±1.18	3.43 ±0.81
Mg	5.65 ± 0.03	4.85 ± 0.45	0.92 ±0.04	5.74 ±1.39	4.96 ± 1.22	1.83 ±0.11	3.06 ± 0.79	5.73 ±0.54	2.04 ±0.02	1.78 ±0.21	10.85 ±0.23
Na	41.02 ± 3.23	30.40 ± 4.38	5.29 ±0.13	15.53 ±1.39	2.93 ± 1.94	6.03 ±0.10	2.16 ±0.98	2.93 ±0.18	2.97 ±0.01	5.26 ±2.11	3.65 ±0.10
Pb	0.09 ± 0.12	0.41 ± 0.34	0.00 ±0.00	0.07 ±0.10	0.19 ± 0.07	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
Cd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Se	1.36 ± 0.10	1.97 ± 0.21	1.50 ±0.04	0.12 ± 1.2	1.23 ± 0.04	1.35 ±0.32	0.04 ±0.01	0.04 ±0.01	1.23 ±0.02	1.15 ±0.01	1.09 ±0.00
Al	20.05 ± 3.51	16.11 ± 2.66	3.12 ±0.03	0.83 ±2.33	3.49 ± 1.64	2.62 ±0.01	4.55 ± 0.69	4.80 ±0.84	5.69 ±0.15	4.47 ±0.15	3.64 ±0.00
Mn	0.43 ± 0.22	0.49 ± 0.09	0.07 ±0.01	0.18 ±0.41	0.43 ± 0.02	0.13 ±0.00	0.17 ±0.12	0.08 ±0.01	0.15 ±0.01	1.22 ±0.22	0.20 ±0.01
Cu	0.16 ± 0.02	0.25 ± 0.01	0.07 ±0.01	0.01 ±0.36	0.20 ±0.23	0.02 ±0.00	0.04 ±0.01	0.03 ±0.01	0.09 ±0.01	0.10 ±0.01	0.07 ±0.01
Zn	0.82 ± 0.47	1.16 ± 0.09	0.32 ±0.00	0.23 ±1.56	1.29 ± 0.39	0.40 ±0.00	0.40 ±0.08	0.33 ±0.14	1.00 ±0.00	0.90 ±0.13	0.34 ±0.08
Fe	8.82 ± 4.15	9.98 ± 0.43	0.37 ±0.00	0.91 ±2.55	2.51 ±2.77	0.28 ±0.00	4.34 ±0.39	4.00 ± 0.44	0.93 ±0.00	4.11 ±1.10	6.50 ±1.24
As	0.08 ± 0.03	0.08 ± 0.02	0.12 ±0.00	0.03 ±0.08	0.06 ±0.02	0.12 ±0.02	0.07 ±0.03	0.08 ±0.01	0.17 ±0.03	0.09 ±0.00	0.09 ±0.01

Table 6: FAO/WHO heavy metal permissible limits in vegetables.

Heavy metal	**K**	**Ca**	**Mg**	**Na**	**Pb**	**Cd**	**Se**	**Al**	**Mn**	**Cu**	**Zn**	**Fe**	**As**
FAO/WHO standard (mg/kg) dry wt.	N.A	75	N.A	N.A	>3	0.2	N.A	N.A	0.2	40	60	N.A	>1.0

Source: **FAO/WHO** [32, 33, 34].

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