ASCERTAINING THE EFFECTS OF HEAVY METAL IN WASTE WATER ON VARIOUS PARAMETERS BLACK GRAM (*PHASEOLUS MUNGO* VAR. T-9): A POT EXPERIMENT

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Abstract

This paper contains the result of a pot experiment using Phaseolus mungo as a test species and waste water in different proportion. Study recorded the effects of textile waste water on standard growth parameter and physiological parameters. The edible plant part (pods/pulse) contained Zinc, Copper, Nickel, Cadmium, Chromium, Lead and Cobalt concentration was 5.223mg/gm, 2.496 mg/gm, 1.229 mg/gm, 1.746mg/gm, 4.853 mg/gm, 1.874 mg/gm and 1.802mg/gm respectively.

Key words: *Phaseolus mungo*, Pot experiment and Heavy metals.

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Introdution

Heavy metal contamination of vegetables cannot be underestimated as these foodstuffs are important components of human diet. Vegetables are rich sources of vitamins, minerals, and fibers, and also have beneficial antioxidative effects(Ali and Al-Qahtani 2012). However, intake of heavy metal-contaminated vegetables may pose a risk to the human health. Heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Marshall, 2004; Radwan and Salama, 2006; Khan et al., 2008). Rapid and unorganized urban and industrial developments have contributed to the elevated levels of heavy metals in the urban environment of developing countries such as Egypt (Radwan and Salama, 2006), Iran (Maleki and Zarasvand, 2008), China (Wong et al., 2003) and India (Marshall, 2004; Sharma et al., 2008a,b). Recently,Sharma et al. (2008a,b)have reported that atmospheric deposition can significantly elevate the levels of heavy metals contamination in vegetables. In this paper results are given related to a pot experiment. In the outskirts of Jaipur, Specially in Sanganer, the waste water discharged from the small, medium and even large scale tie and Dye industries is used in agricultural fields. This waste water is used untreated. Hence the authors have collected this discharged effluent water and mixed with distilled water in different proportions and conducted a pot experiment. The objectives of conducting this experiment was to ascertain and estimate heavy metals in the vegetable *Phaseolus mungo* T-9 (black gram).

Materials and Methods

Experimental setup: For conducting a pot experimental study *Phaseolus mungo* Var. T-9 was selected as test plant. *Phaseolus* mango(black gram) belongs to family *Fabaceae*. It is a commonly used green pods as a vegetable and seeds as a pulses. The plants were grown in the earthen pots and the population of five plants per pot was maintained for experiment. Waste water was collected from Sanganer, Jaipur where large number of textile industries are located. These industries discharge huge quantity of untreated waste water in a dry river popularly known as Amanishah nala the erstwhile Drawyawati River. In this experiment six levels maintained containing different proportion of textile waste water and distilled water as follows:-

Level 1 - Controlled condition (Pure Double Distilled water)-(Control)

Level 2 - DW:WW:: 90:10

Level 3 - DW:WW:: 80:20

Level 4 - DW:WW:: 70:30

Level 5 - DW:WW:: 60:40

Level 6 - DW:WW:: 50:50

Growth parameters: The plants were harvested at pre-flowering, peak-flowering and post-flowering stages for studying different growth parameters (root and shoot length, dry weight of root and shoot). For dry weight determination roots and shoots were separated and dried in hot air oven at 80ºC for 72 hr before determining biomass in gms.

Biochemical analysis: Chlorophyll a, b and total chlorophyll content in leaves were estimated by employing method suggested by Arnon (1949). Carbohydrate content was estimated by employing the Anthrone method(Yemm and Willis, 1954) .Protein content was determined by employing the method suggested by Lowry *et al*. (1951) while nitrogen content was estimated by microkjeldhal's method (Allen, 1931). Heavy metals in the soil and crop plant samples were estimated using Atomic Absorption Spectrophotometer (AAS Model GBC 932 place).

RESULTS AND DISCUSSION

The plant of *Phaseolus* mango(black gram) was treated with waste water (Level -6) effluent showed a root length 12.96 (41.98%), shoot length 38.48cm (26.89%), Root dry weight was 0.200gm (58.76%) and shoot dry weight was 3.481 (21.20%) (Table 1a and 1b) at post flowering stage as compared to control condition. The amount of total chlorophyll was 0.761mg/gm at treatment level six with a reduction of 56.43 percent as compared to controlled conditions at post flowering stage .(Table 1c). while a maximum reduction in carbohydrate 35.1mg/gm (42.19%),phosphorous 3.11 (10.37%) nitrogen 0.861percent (58.24%) and protein 4.519percent (64.94%) content was found at treatment level six as compared to control condition at post flowering stage. (Table 1d and 1e).

The results of heavy metal analyzed in different plant parts samples of *Phaseolus* mango(black gram) at pre-flowering, peak-flowering and post-flowering stages are given in table . The concentration of Zn increased with increase in waste water treatment. At six level treatment the plants accumulated Zn concentration 1.125mg/gm d.wt.,0.547mg/gm and 0.614mg/gm in root ,stem and leaves respectively at pre flowering stage. Cu concentration was 0.565mg/gm ,0.351mg/gm and 1.026 mg/gm ,Ni concentration was 0.185mg/gm,0.303mg/gm and

0.309mg/gm ,Cd was 0.188mg/gm,0.263mg/gm and 0.257 mg/gm, Cr was 0.215mg/gm ,0.191mg/gm and 0.422mg/gm, Pb was 0.409mg/gm, 0.204mg/gm and 0.202 mg/gm , and Co concentration was 0.308g/gm,0.209mg/gm and 0.303mg/gm in root ,stem and leaves respectively at pre-flowering stage. The Zn concentration was increased in peak flowering stage. At six treatment level the plants accumulated Zn concentration was 1.405mg/gm ,0.674mg/gm and 1.259 mg/gm , Cu was 0.736 mg/gm,0.586mg/gm and 1.427 mg/gm, Ni was 0.246mg/gm ,0.408mg/gm and 0.421mg/gm, Cd was 0.226mg/gm,0.323 mg/gm and 0.375mg/gm , Cr concentration was measured 0.319 mg/gm,0.358 mg/gm and 0.631 g/gm ,Pb was 0.476mg/gm, 0.339mg/gm and 0.267 mg/gm, Co was 0.416mg/gm, 0.357mg/gm and 0.462mg/gm in root ,stem and leaves respectively at peak flowering stage.

Similarly the heavy metals concentration was increased at post flowering stage at treatment level six effluent or waste water Zn concentration was 1.608mg/gm ,0.907 mg/gm and 1.865mg/gm , Cu was 0.802mg/gm,0.698mg/gm and 0.836 mg/gm ,Ni was 0.321mg/gm,0.574mg/gm and 0.585 mg/gm, Cd was 0.286mg/gm, 0.529mg/gm and 0.589 mg/gm, Cr concentration was 0.458 mg/gm,0.479 mg/gm and 0.928 mg/gm, Pb was 0.456 mg/gm, 0.469 mg/gm and 0.487 mg/gm, Co was 0.506 mg/gm, 0.519 mg/gm and 0.703mg/gm in root ,stem and leaves respectively at post flowering stage.

The heavy metal concentration in the edible parts was recorded at post flowering stage. Zinc, Copper, Nickel, Cadmium, Chromium, Lead and Cobalt concentration was 5.223mg/gm, 2.496 mg/gm, 1.229 mg/gm, 1.746mg/gm, 4.853 mg/gm, 1.874 mg/gm and 1.802mg/gm respectively.

Earlier studies by Khan and Marwari (2002, 2003) and Khan et al. (2003 a, b) reported high concentration of heavy metal in vegetables grown in agricultural fields receiving textile waste water. Metal accumulation in vegetables may pose a direct threat to human health (Türkdogan *et al*., 2003)Heavy metals may enter the human body through inhalation of dust, direct ingestion of soil, and consumption of food plants grown in metal-contaminated soil. Crop plants growing on heavy metal contaminated medium can accumulate high concentrations of trace elements to cause serious health risk to consumers. Long *et al*., (2003) studied the effects of excess zinc on plant growth of three selected vegetables i.e. Chinese cabbage, celery and pakchoi. They found that excess Zn in growth media caused toxicity to all three vegetable crops and showed symptoms like chlorosis in young leaves, browning of coralloid roots, and serious inhibitionon plant growth. Athar and Ahmad (2002) conducted a study by pot experiment to investigate the toxic effects of certain heavy metals on the plant growth and grain yield of wheat (*Triticum aestivum L*.). Present study was also conducted through a laboratory pot experiment to ascertain the bioaccumulation of heavy metals. Higher the amount of textile wastewater addition more was the bioaccumulation. The results revealed that heavy metals brought about significant reductions in both parameters, Cd being the most toxic metal followed by Cu,Ni, Zn, Pb , Cr and Co. There is also a reduction in plant protein and nitrogen content was recorded with the increasing concentration of heavy metals. Metal uptake by grains was directly related to the applied heavy metal with greater concentrations of metals found in cases where metals were added separately rather than in combinations.

The prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (WHO, 1992; Jarup, 2003). Some heavy metals such as Cu, Zn, Mn, Co and Mo act as micronutrients for the growth of animals and human beings when present in trace quantities, whereas others such as Cd, As, and Cr act as carcinogens (Feig et al., 1994; Trichopoulos, 1997). The contamination of vegetables with heavy metals due to soil and atmospheric contamination poses a threat to its quality and safety. Dietary intake of heavy metals also poses risk to animals and human health. Heavy metals such as Cd and Pb have been shown to have carcinogenic effects (Trichopoulos, 1997). High concentrations of heavy metals (Cu, Cd and Pb) in fruits and vegetables were related to high prevalence of upper gastrointestinal cancer (Turkdogan et al., 2002).

The authors conclude that higher the proportion of waste water more is the concentration of heavy metals in the plant parts including the edible part. The experiment suggest that untreated waste water should be discouraged to be used in agricultural fields in order to keep the edible part safe from heavy metlas.

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Table 1a: Effects of Textile Waste Water on Root and Shoot Lengths (cm) of Phaseolus mungo.var T-9 (black gram) through pot experiment.

Treatment Levels (DW:WW)	Pre-Flowering Stage		Peak-Flowering Stage		Post-Flowering Stage	
	Root Length (cm)	Shoot Length (cm)	Root Length (cm)	Shoot Length (cm)	Root Length (cm)	Shoot Length (cm)
Control (D.W)	15.72± 0.84	42.74±0.79	21.7± 0.90	49.46± 1.03	22.34±0.98	52.64±0.80
Level 1 (90:10)	14.76±0.74 (6.106)	41.28±0.87 (3.416)	18.6±0.90 (14.28)	46.46±1.10 (6.06)	19.7±0.902 (11.81)	50.04±1.158 (4.93)
Level 2 (80:20)	13.74±0.743 (12.59)	37.52±0.87 (12.213)	17.12±0.872 (21.05)	44.6±0.79 (9.826)	18.14±0.983 (18.800)	47.18±0.917 (10.372)
Level 3 (70:30)	12.1±0.886 (23.02)	35.12±0.952 (17.82)	15.12±0.87 (30.32)	41.66±0.918 (15.77)	16.52±1.044 (26.05)	43.66±0.918 (17.059)
Level 4 (60:40)	10.3±0.886 (34.47)	31.02±1.035 (27.42)	13.68±0.822 (36.95)	40.12±1.107 (18.88)	14.66±0.823 (34.37)	41.8±0.891 (20.592)
Level 5 (50:50)	8.78±0.589 (44.14)	28.54±0.92 (33.22)	11.42±0.92 (47.37)	36.34±0.887 (26.52)	12.96±0.702 (41.987)	38.48±0.936 (26.899)

Table 1b: Effects of Textile Waste Water on Root and Shoot Weight (gm) of Phaseolus mungo.var T-9 (black gram) through pot experiment.

Treatment Levels (DW:WW)	Pre-Flowering Stage		Peak-Flowering Stage		Post-Flowering Stage	
	Root Weight (gm)	Shoot Weight (gm)	Root Weight (gm)	Shoot Weight (gm)	Root Weight (gm)	Shoot Weight (gm)
Control (D.W)	0.367 ±0.011	2.312±0.008	0.438±0.009	4.106±0.016	0.485±0.009	4.418 ±0.012
Level 1 (90:10)	0.320 ±2.208 (12.80)	2.208 ±0.026 (4.49)	0.407 ±0.011 (7.07)	3.861 ±0.012 (5.96)	0.429 ±0.01 (11.54)	4.233 ±0.037 (4.18)
Level 2 (80:20)	0.233 ±0.015 (36.51)	1.967 ±0.012 (14.92)	0.338 ±0.011 (22.83)	3.561 ±0.014 (13.27)	0.360 ±0.011 (25.77)	4.152 ±0.015 (6.02)
Level 3 (70:30)	0.196 ±0.012 (46.59)	1.653 ±0.017 (28.50)	0.307 ±0.011 (29.90)	3.322 ±0.013 (19.09)	0.320 ±0.009 (34.02)	4.063 ±0.017 (8.03)
Level 4 (60:40)	0.155 ±0.014 (57.76)	1.319 ±0.019 (42.94)	0.230 ±0.19 (47.48)	3.016 ±0.137 (26.54)	0.241 ±0.011 (50.30)	3.810 ±0.017 (13.76)
Level 5 (50:50)	0.128 ±0.012 (65.12)	1.194 ±0.019 (48.35)	0.182 ±0.021 (58.44)	2.240 ±0.025 (45.44)	0.200 ±0.012 (58.76)	3.481 ±0.048 (21.20)

Table 1c: Effects of Textile Waste Water on Chlorophyll (mg/gm) in Phaseolus mungo.var T-9 (black gram) through pot experiment.

Treatment Levels (DW:WW)	Pre-Flowering Stage			Peak-Flowering Stage			Post-Flowering Stage		
	Chl-a (mg/gm)	Chl-b (mg/gm)	Total Chl (a+b) (mg/gm)	Chl-a (mg/gm)	Chl-b (mg/gm)	Total Chl (a+b) (mg/gm)	Chl-a (mg/gm)	Chl-b (mg/gm)	Total Chl (a+b) (mg/gm)
Control (D.W)	0.774±0.507	0.453±0.15	1.227±0.456	1.178±1.101	0.677±0.131	1.855±0.13	1.157±1.54	0.613±0.166	1.747±0.354
Level 1 (90:10)	0.689±0.35 (10.98)	0.382±0.23 (15.67)	1.071±0.39 (12.71)	0.903±.0.725 (23.34)	0.511±0.183 (24.51)	1.415±0.718 (23.71)	0.894±0.299 (22.73)	0.487±0.163 (20.55)	1.382±0.462 (20.89)
Level 2 (80:20)	0.579±0.58 (25.19)	0.327±0.15 (27.81)	0.906±0.62 (26.16)	0.810±0.628 (31.23)	0.420±1.397 (37.96)	1.256±0.649 (32.10)	0.782±0.253 (32.41)	0.426±0.139 (30.50)	1.21±0.408 (30.73)
Level 3 (70:30)	0.504±0.39 (34.88)	0.280±0.11 (38.18)	0.784±0.43 (36.10)	0.692±0.459 (41.25)	0.384±0.208 (43.27)	1.071±0.355 (42.26)	0.670±0.37 (42.09)	0.365±0.201 (40.45)	0.962±0.571 (44.93)
Level 4 (60:40)	0.452±0.334 (41.60)	0.257±0.13 (43.26)	0.714±0.485 (41.80)	0.596±0.484 (49.40)	0.343±0.203 (49.33)	0.940±0.502 (49.32)	0.585±0.326 (49.43)	0.319±0.178 (47.96)	0.904±0.504 (48.25)
Level 5 (50:50)	0.400±0.30 (48.32)	0.218±0.16 (51.87)	0.617±0.47 (49.71)	0.501±0.217 (57.47)	0.298±0.126 (55.98)	0.799±0.338 (56.92)	0.494±0.414 (57.30)	0.267±0.171 (56.44)	0.761±0.571 (56.43)

Table 1d: Effects of Textile Waste Water on Carbohydrate and Phosphorous (mg/gm) in Phaseolus mungo var T-9 (Black gram) through pot experiment.

Treatment Levels (DW:WW)	Pre-Flowering Stage		Peak-Flowering Stage		Post-Flowering Stage	
	Carbohydrate (mg/gm)	Phosphorous (mg/gm)	Carbohydrate (mg/gm)	Phosphorous (mg/gm)	Carbohydrate (mg/gm)	Phosphorous (mg/gm)
Control (D.W)	39.58±0.822	3.282±0.09	58.8±1.01	3.346±0.18	60.72±0.871	3.476±0.09
Level 1 (90:10)	35.56±0.76 (10.15)	3.23±0.09 (1.52)	54.58±0.822 (7.17)	3.31±0.07 (0.89)	55.34±1.578 (8.86)	3.404±0.08 (1.90)
Level 2 (80:20)	31.2±0.839 (21.17)	3.18±0.088 (3.04)	49.4±0.935 (15.9)	3.24±0.99 (2.99)	50.64±0.838 (16.60)	3.308±0.09 (4.66)
Level 3 (70:30)	27.36±0.698 (30.87)	3.14±0.107 (4.26)	44.46±0.95 (24.38)	3.19±0.215 (4.49)	45.62±0.87 (24.86)	3.24±0.177 (6.62)
Level 4 (60:40)	24.1±0.935 (39.11)	3.058±0.112 (7.01)	40.0±1.106 (31.97)	3.136±0.151 (6.28)	41.1±0.967 (32.31)	3.19±0.12 (8.06)
Level 5 (50:50)	20.28±0.87 (48.96)	2.876±0.221 (12.5)	34.16±0.92 (41.90)	3.066±0.10 (8.20)	35.1±0.79 (42.19)	3.11±0.17 (10.37)

Table 1e: Effects of Textile Waste Water on Nitrogen and Protein Phaseolus mungo. var T-9 (black gram) through pot experiment.

Treatment Levels (DW:WW)	Pre-Flowering Stage		Peak-Flowering Stage		Post-Flowering Stage	
	% Nitrogen	% Protein	% Nitrogen	% Protein	% Nitrogen	% Protein
Control (D.W)	1.013±0.032	6.342±0.208	1.163±0.079	7.27±0.205	2.062±0.051	12.899±0.330

Level 1 (90:10)	0.905±0.039 (10.66)	5.434±0.276 (14.31)	1.056±0.036 (9.20)	6.602±0.231 (9.18)	1.895±0.059 (8.09)	11.857±0.356 (8.06)
Level 2 (80:20)	0.709±0.025 (30.00)	4.434±0.218 (30.08)	0.871±0.030 (25.10)	5.448±0.245 (25.06)	1.658±0.056 (19.59)	10.373±0.348 (19.52)
Level 3 (70:30)	0.604±0.034 (40.37)	3.781±0.220 (40.38)	0.715±0.042 (38.36)	4.472±0.219 (38.48)	1.359±0.054 (34.09)	8.497±0.330 (34.08)
Level 4 (60:40)	0.467±0.034 (53.89)	2.924±0.214 (53.89)	0.566±0.038 (51.33)	3.544±0.229 (51.25)	1.051±0.058 (48.98)	6.584±0.302 (48.95)
Level 5 (50:50)	0.407±0.031 (59.82)	2.549±0.201 (59.80)	0.490±0.035 (57.86)	3.070±0.222 (57.77)	0.861±0.051 (58.24)	4.519±0.291 (64.94)

Table 1f: Heavy metal analysis in Phaseolus mungo. var T-9 (black gram) through pot experiment at Pre-Flowering Stage.

Heavy Metals (mg/g)	**Plant Parts**	**Treatment Levels (DW:WW)**					
		100:00	**90:10**	**80:20**	**70:30**	**60:40**	**50:50**
Zn	**Root**	0.000	0.744	0.866	0.945	1.068	1.125
	Stem	0.000	0.242	0.269	0.393	0.494	0.547
	Leaves	0.000	0.279	0.348	0.455	0.564	0.614
Cu	**Root**	0.000	0.363	0.426	0.474	0.516	0.565
	Stem	0.000	0.118	0.156	0.226	0.304	0.351
	Leaves	0.000	0.346	0.438	0.562	0.737	1.026
Ni	**Root**	0.000	0.102	0.119	0.146	0.165	0.185
	Stem	0.000	0.102	0.137	0.215	0.264	0.303
	Leaves	0.000	0.082	0.138	0.186	0.243	0.309
Cd	**Root**	0.000	0.061	0.103	0.126	0.149	0.188
	Stem	0.000	0.059	0.107	0.166	0.205	0.263
	Leaves	0.000	0.086	0.136	0.168	0.204	0.257
Cr	**Root**	0.000	0.112	0.139	0.156	0.178	0.215
	Stem	0.000	0.000	0.063	0.127	0.159	0.191
	Leaves	0.000	0.045	0.129	0.232	0.305	0.422
Pb	**Root**	0.000	0.00	0.126	0.229	0.351	0.409
	Stem	0.000	0.026	0.095	0.138	0.169	0.204
	Leaves	0.000	0.000	0.053	0.128	0.157	0.202
Co	**Root**	0.000	0.082	0.164	0.207	0.259	0.308
	Stem	0.000	0.000	0.052	0.121	0.176	0.209
	Leaves	0.000	0.096	0.156	0.204	0.257	0.303

Table 1g: **Heavy metal analysis in Phaseolus mungo. var T-9 (black gram) through pot experiment at Peak-Flowering Stage.**

Heavy Metals (mg/g)	Plant Parts	Treatment Levels (DW:WW)					
		100:00	90:10	80:20	70:30	60:40	50:50
Zn	Root	0.00	1.036	1.127	1.232	1.319	1.405
	Stem	0.00	0.409	0.486	0.559	0.606	0.674
	Leaves	0.00	0.609	0.746	0.867	0.963	1.259
Cu	Root	0.00	0.569	0.628	0.667	0.689	0.736
	Stem	0.00	0.225	0.293	0.365	0.429	0.586
	Leaves	0.00	0.634	0.789	1.063	1.253	1.427
Ni	Root	0.00	0.123	0.165	0.189	0.204	0.246
	Stem	0.00	0.110	0.204	0.298	0.353	0.408
	Leaves	0.00	0.136	0.202	0.274	0.358	0.421
Cd	Root	0.00	0.102	0.138	0.164	0.185	0.226
	Stem	0.00	0.128	0.165	0.223	0.283	0.323
	Leaves	0.00	0.142	0.203	0.254	0.318	0.375
Cr	Root	0.00	0.182	0.212	0.248	0.278	0.319
	Stem	0.00	0.103	0.185	0.228	0.292	0.358
	Leaves	0.00	0.154	0.252	0.328	0.439	0.631
Pb	Root	0.00	0.085	0.164	0.258	0.406	0.476
	Stem	0.00	0.118	0.149	0.251	0.281	0.339
	Leaves	0.00	0.047	0.119	0.154	0.204	0.267
Co	Root	0.00	0.124	0.203	0.289	0.373	0.416
	Stem	0.00	0.132	0.167	0.235	0.296	0.357
	Leaves	0.00	0.216	0.284	0.343	0.385	0.462

Table 9h: **Heavy metal analysis in Phaseolus mungo.var T-9 (black gram) through pot experiment at Post-Flowering Stage.**

Heavy Metals (mg/g)	Plant parts	Treatment Levels (DW:WW)					
		100:00	90:10	80:20	70:30	60:40	50:50
Zn	Root	0.00	1.236	1.324	1.464	1.525	1.608
	Stem	0.00	0.542	0.642	0.756	0.815	0.907
	Leaves	0.00	0.878	1.127	1.342	1.586	1.865
	Fruit	0.082	2.145	2.632	3.274	4.186	5.223
Cu	Root	0.00	0.541	0.601	0.652	0.709	0.802
	Stem	0.00	0.314	0.372	0.438	0.513	0.698

	Leaves	0.00	0.426	0.536	0.623	0.759	0.836
	Fruit	0.067	0.624	0.746	0.951	1.821	2.496
Ni	**Root**	0.00	0.182	0.208	0.251	0.298	0.321
	Stem	0.00	0.212	0.303	0.374	0.446	0.574
	Leaves	0.00	0.236	0.329	0.397	0.482	0.585
	Fruit	0.046	0.362	0.662	0.783	0.944	1.229
Cd	**Root**	0.00	0.143	0.175	0.208	0.236	0.286
	Stem	0.00	0.212	0.256	0.347	0.425	0.529
	Leaves	0.00	0.249	0.301	0.376	0.476	0.589
	Fruit	0.062	0.523	0.798	1.008	1.423	1.746
Cr	**Root**	0.00	0.146	0.216	0.329	0.396	0.458
	Stem	0.00	0.169	0.229	0.321	0.412	0.479
	Leaves	0.00	0.237	0.356	0.528	0.761	0.928
	Fruit	0.051	0.786	1.057	1.723	3.029	4.853
Pb	**Root**	0.00	0.181	0.229	0.302	0.379	0.456
	Stem	0.00	0.189	0.246	0.319	0.386	0.469
	Leaves	0.00	0.196	0.263	0.337	0.401	0.487
	Fruit	0.036	0.386	0.651	1.253	1.501	1.874
Co	**Root**	0.00	0.158	0.285	0.374	0.415	0.506
	Stem	0.00	0.221	0.302	0.376	0.439	0.519
	Leaves	0.00	0.331	0.435	0.508	0.596	0.703
	Fruit	0.041	0.623	0.873	1.142	1.518	1.802

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Safe limit of irrigation water for heavy metals

Heavy Metal	Concentration (mg/L)
Pb	0.5
Cu	0.2
Cr	0.1
Zn	5
Ni	0.2
Co	0.6
Cd	0.01

Source: Pescod, M.B. (1992)

Safe limit of heavy metals for human consumption in food stuff

Heavy Metal	Concentration (mg/L)
Pb	0.0025
Cu	0.03
Cr	0.02
Zn	0.05
Ni	0.07
Co	0.04
Cd	0.0015

Source: Awashthi, S. K. (2000).