AN INVESTIGATION OF USE OF WASTE WATER IN AGRICULTURAL FIELDS AT SANGANER AND BIOACCUMULATION OF HEAVY METALS IN *VIGNA UNGUICULATA*

Jaishree*

T.I.Khan*

Abstract:

The present research study was conducted to analyze the impact of waste water on Vigna unguiculata quality with respect to heavy metals in Sanganer, Jaipur. Samples each of soil, water and vegetables leaves and edible portions were collected from different agricultural fields around Sanganer. The water and soil samples were analyzed for pH, EC ,Chloride, and heavy metals .Water and soil samples were collected and analyzed for physic-chemical parameters and heavy metal concentration. Plant samples were also collected from the agricultural field of the Sanganer. The fruits of the crop plants contained higher concentration of heavy metals. Such as Zinc, Copper, Nickel, Cadmium, Chromium, Lead and Cobalt concentration varied from 15.684mg/gm to 15.708mg/gm, 8.348mg/gm to 8.878mg/gm,6.098mg/gm to 6.186mg/gm, 5.264mg/gm to 5.446mg/gm, 7.475mg/gm to 7.505mg/gm , 6.575mg/gm to 6.595mg/gm and 5.538mg/gm to 5.858mg/gm respectively.

Key words

Textile waste water, Heavy metals, *Vigna unguiculata*, Sanganer town.

* **Indira Gandhi centre for Human Ecology, Environmental and Population Studies Centre University of Rajasthan, Jaipur -302004**

Introduction:

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 China (Wong et al., 2003) and India (Khillare et al., 2004; Marshall, 2004; Sharma et al., 2008a,b). Heavy metals are non-biodegradable and persistent environmental contaminants, which may be deposited on the surfaces and then absorbed into the tissues of vegetables. Plants take up heavy metals by absorbing them from deposits on the parts of the plants exposed to the air from polluted environments as well as from contaminated soils (Singh, 2006; Singh and Kumar, 2006; Sharma et al., 2008a,b). A number of studies have shown heavy metals as important contaminants of the vegetable (Sinha *et al*., 2006; Singh and Kumar, 2006; Sharma *et al*., 2006, 2007, 2008a,b). Heavy metal contamination of vegetables may also occur due to irrigation with contaminated water (Singh *et al*., 2004; Sharma *et al*., 2006, 2007; Singh and Kumar, 2006). In India, textile printing and dyeing industries have expanded rapidly in recent years. The application of such wastewaters to agricultural fields is quite common in India, which has led to biomagnifications of heavy metals in vegetables and cereals (Sharma et al. 2001). The main object of the present investigation was to assess the aim of the study the present study was to observe the adverse impact of textile waste water on soil and water used in agricultural fields and bioaccumulation of heavy metals in the edible portion of the crop plants.

Study Area:- Sanganer, Jaipur was selected as study area. It is famous for many thriving cottage industries like dyeing and printing ,waste paper recycling, and blue potteries. Sanganer lies between 26^{o} 49’ to 26^{o}51’N latitude and 75^{o}46’ to 75^{o}51’E longitude (Fig 1). Various industries discharge untreated waste water in Amanishah Nala in Sanganer. A large number of small, medium and large scale textile industrial units are located in Sanganer. The untreated waste water which conatins chemical like anelin, caustic soda, acids, bleaching powder and heavy metals are used for irrigating agricultural fields for growing vegetables and other crop plants.

Material and methods

For this study *Vigna unguiculata* var.RC-101 was selected as test plant. *Vigna unguiculata* (cow pea) belongs to family *Fabaceae*. Green pods used as a vegetables and seeds are used as a

pulses. The plant sample were collected from the different agricultural field in Sanganer. Water sample were collected from the study area where the waste water used in agricultural fields. Soil samples from the agricultural fields of *Vigna unguiculata* were also collected and analysed. 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 and total dry weight). For dry weight determination roots and shoots were separated and dried in hot air oven at 80ºC for 72 hr. Chlorophyll a, b and total chlorophyll content in leaves were estimated by employing the method suggested by Arnon (1949). Carbohydrate content was estimated by emplying the Anthrone method .Protein content was determined by employing the method of 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:

Samples were collected from the study area. The waste water from the textile industries used in the agricultural fields of Vigna unguiculata. The results of the analysis revealed that pH ranged from 7.49 to 9.95, E.C. from 0.749 to 1.821 mmhos/cm, T.D.S. from 739.25 to 1523.11 mg/L, Chloride from 292.2 to 538.21 mg/L, Total Hardness from 215.83 to 605.42 mg/L, Calcium Hardness from 173.6 to 548.3 mg/L and Magnesium Hardness from 42.23 to 98.32 mg/L in the waste water collected from the study area from different location and times.(Table 1a)Heavy metal concentration was also determined. Zinc concentration varies from 3.025 mg/L to 3.221 mg/l, Copper 0.258 to 0.292 mg/L, Nickel from 0.959 mg/L to 0.973 mg/L, Cadmium from 2.041 mg/L to 2.061 mg/L, Chromium from 2.576 mg/L to 2.640 mg/L, Lead from 1.132 mg/L to 1.178 mg/L and Cobalt from 0.434 mg/L to 0.465 mg/L in the waste water collected from various locations and different times.(Table 1b)

Soil samples from the agricultural fields were collected and analyzed. The results revealed that pH ranged from 7.29 to 9.21, E.C. from 1.490 to 2.660 µmhos/cm, Chloride from 12.16 mg/100gm to 17.53 mg/100gm, Organic carbon from 3.686 percent to 4.708 percent, Organic matter from 6.356 percent to 8.117 percent and Nitrogen from 0.079 percent to 0.189 percent in the soil collected from the study area from different location and times.(Table 2a)Heavy metal concentration was also determined. Zinc concentration varies from 11.758 mg/g to 16.495mg/g,

Copper from 11.013 mg/g to 11.589 mg/g, Nickel from 4.623 mg/g to 5.121mg/g, Cadmium from4.586 mg/g to 5.234 mg/g, Chromium from 6.189 mg/g to 6.998mg/g, Lead from 5.286 mg/g to 5.896mg/g and Cobalt from 3.684mg/g to 3.912mg/g in the soil collected from various locations and different times.(Table 2b)

The plant samples of Vigna unguiculata (cow pea) collected from the different sites of Sanganer agricultural fields and analysed. The root length varied from 33.74 cm to 39.7 cm ,50.36cm to 54.04cm, and 52.2cm to 56.4cm and shoot length varied from 77.3cm to 81.62cm, 94.56cm to 103.2cm and 102.8cm to 106.76cm at pre ,peak and post flowering stage respectively. Root weight varied from 1.843gm to 1.998gm ,2.896gm to 3.11gm and 3.714gm to 3.92gm and shoot weight varied from 4.05gm to 4.992gm ,6.65gm to 7.325gm and 8.518gm to 9.362gm at pre , peak and post flowering stage respectively.(Table 3a and 3b)The amount of total chlorophyll varied from 1.700mg/gm to 2.265mg/gm,2.028mg/gm to 2.778mg/gm and 2.126g/gm to 2.871mg/gm and carbohydrate varied from 58.632mg/gm to 64.554mg/gm , 82.564mg/gm to 89.792mg/gm and 83.528mg/gm to 91.054mg/gm and plant phosphorous varied from 3.472mg/gm to 4.31mg/gm ,3.972mg/gm to 4.842mg/gm and 4.046mg/gm to 5.046mg/gm at pre, peak and post flowering stage respectively. The nitrogen content varied from 2.065 percent to 2.11percent ,2.806percent to 3.616percent and 4.127percent to 4.494percent at pre flowering respectively and protein content varied from 12.905percent to 13.197 percent ,17.543 percent to 18.624percent and 25.793percent to 28.08percent at pre, peak and post flowering stage respectively.(Table 3c,3d and 3e).

Heavy metals were estimated in different plant parts samples of Vigna unguiculata(cow pea) at pre-flowering, peak-flowering and post-flowering stages. The heavy metals were estimated in mg/gm dry weight. The plants accumulated Zn concentration varied from 5.245mg/gm to 6.718mg/gm,7.522mg/gm to 7.541mg/gm and 8.495mg/gm to 9.512mg/gm in root, stem and leaves respectively at pre flowering stage. Cu concentration varied from 4.049mg/gm to 4.645mg/gm,4.455mg/gm to 4.969mg/gm and 5.088m/gm to 5.78mg/gm, Ni was from 3.130mg/gm to 3.740mg/gm, 3.218mg/gm to 3.826mg/gm and 3.298mg/gm to 3.519mg/gm , Cd varied from 3.570mg/gm to 3.859mg/gm ,3.719mg/gm to 3.932mg/gm and 3.734mg/mg to 3.959mg/gm , Cr varied from 4.285mg/gm to 4.303mg/gm ,4.286mg/gm to 4.318mg/gm and 4.400mg/gm to 4.445mg/gm ,Pb varied from 4.396mg/gm to 4.708mg/gm, 4.250mg/gm to

4.656mg/gm and 4.304mg/gm to 4.594mg/gm , Co concentration varied from 2.738mg/gm to 2.782mg/gm ,2.764mg/gm to 2.784mg/gm and 2.822mg/gm to 2.851mg/gm in root, stem and leaves respectively at pre flowering stage.(Table 3f). The Zn concentration was increased in peak-flowering stage. Zn concentration was accumulated and varied from 11.619mg/gm to 12.032mg/gm ,11502mg/gm to 11.567mg/gm, 12.528mg/gm to 12.549mg/gm ,Cu varied from 5.858mg/gm to 5.959mg/gm, 5.684mg/gm to 5.693mg/gm and 6.682mg/gm to 6.703mg/gm ,Ni varied from 4.137mg/gm to 4.947mg/gm, 5.163mg/gm to 5.876mg/gm, Cd concentration varied from 4.682mg/gm too 4.706mg/gm ,4.735mg/gm to 4.748mg/gm and 4.765mg/gm to 4.795mg/gm, Cr was from 6.329mg/gm to 6.339mg/gm ,6.376mg/gm to 6.387mg/gm and 6.573mg/gm to 6.589mg/gm , Pb varied from 5.220mg/gm to 5.627mg/gm ,5.195mg/gm to 5.788mg/gm and 5.461mg/gm to 5.526mg/gm and Co concentration varied from 3.790mg/gm to 3.995mg/gm ,3.799mg/gm to 3.893mg/gm and 3.915mg/gm to 3.996g/gm in root, stem and leaves respectively at peak-flowering stage.(Table 3g)

Similarly the heavy metals concentration was estimated at post flowering stage also. Zn concentration varied from 13.633mg/gm to 13.650mg/gm, 13.554mg/gm to 13.957mg/gm and 14.607mg/gm to 14.623mg/gm ,Cu varied from 7.098mg/gm to 7.253mg/gm, 7.739mg/gm to 7.837mg/gm and 7.624mg/gm to 7.854mg/gm , Ni varied from 5.158mg/gm to 5.177mg/gm ,5.303mg/gm to 5.327mg/gm and 5.407mg/gm to 5.431mg/gm, Cd varied from 5.124mg/gm to5.286mg/gm ,5.113mg/gm to 5.186mg/gm and 5.026mgg/gm to 5.126mg/gm, Cr varied from 7.049mg/gm to 7.157mg/gm, 7.019mg/gm to 7.122mg/gm and 7.110mg/gm to 7.259mg/gm, Pb varied from 6.238mg/gm to 6.264mg/gm, 6.298mg/gm to 6.327mg/gm and 6.538mg/gm to 6.558mg/gm and Co concentration varied from 4.721mg/gm to 4.899mg/gm, 4.878mg/gm to 4.972mg/gm and 4.001mg/gm to 4.997mg/gm in root, stem and leaves respectively at post flowering stage.(Table 3h)

The heavy metal concentration in the edible parts was recorded at post flowering stage. Zinc, Copper, Nickel, Cadmium, Chromium, Lead and Cobalt concentration varied from 15.684mg/gm to 15.708mg/gm, 8.348mg/gm to 8.878mg/gm,6.098mg/gm to 6.186mg/gm, 5.264mg/gm to 5.446mg/gm, 7.475mg/gm to 7.505mg/gm ,6.575mg/gm to 6.595mg/gm and 5.538mg/gm to 5.858mg/gm respectively.(Table 3h)

According to Sharma et al., (2007) Heavy metal contamination of soil resulting from wastewater irrigation is a cause of serious concern due to the potential health impacts of consuming

contaminated produce. In their study an assessment was made of the impact of wastewater irrigation on heavy metal contamination of Beta vulgaris (palak); this is a highly nutritious leafy vegetable that is widely cultivated and consumed in India.The study concludes that the use of treated and untreated wastewater for irrigation has increased the contamination of Cd, Pb, and Ni in edible portion of vegetables causing potential health risk in the long term from this practice. In the present study also heavy metals in the crop plants were estimated the edible portion of each crop plants was brought from the agricultural field and analysed for Pb, Cu, Cr, Zn, Ni, Cd and Co and their concentration were found to be higher. Earlier worker(Gupta *et al*.,2013and Perveen *et al*., 2012) has shown that when crop plants were grown in the agricultural fields using untreated waste water the vegetation biologically accumulated heavy metals. In the present study also it was observed that the edible part of the crop plants(Seeds in pod) contained high concentration of heavy metals such as , Zinc, Copper, Nickel, Cadmium, Chromium, Lead and Cobalt concentration varied from 15.684mg/gm to 15.708mg/gm, 8.348mg/gm to 8.878mg/gm,6.098mg/gm to 6.186mg/gm, 5.264mg/gm to 5.446mg/gm, 7.475mg/gm to 7.505mg/gm ,6.575mg/gm to 6.595mg/gm and 5.538mg/gm to 5.858mg/gm respectively. Since Vigna unguiculata is used as vegetable as well as pulse, the authors suggest that the untreated wastewater should be adequately treated specially for removal of heavy metals ,before using it in irrigating agricultural fields.

ACKNOWLEDGEMENT

The authors are thankful to the Director, Indira Gandhi Centre for Human Ecology, Environment and Population Studies and Dean Faculty of Science, University of Rajasthan for providing necessary facilities. One of the authors (Jaishree) is thankful to University Grant Commission New Delhi for providing financial assistance as Rajiv Gandhi Senior Research Fellowship.

References:

Abd El Rahim ,W.M.,W.K.B. Khali and G.E. Mariam (2008) Genotoxicity studies on the removal of a direct textile dye by a fungal strain, invivo, using micronucleus and RAPD-PCR techniques on male rats. *Journal of Applied Toxicology*.28: 484-490.

Allen, W. F.(1931).Accurate and adaptable microkjeldhal methods of nitrogen determination. *Ind. Eng. Chem. Anal.* 3:239-240.

Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts poly phenyloxidase in Beta vulgaris. *Plant physiology*.24(1):1-15.

Gupta, S., Jena, V., Jena, S., Davic, N., Matic, N., Radojevic, D. and Solanki, J.S.2013. Assessment of heavy metal contents of green leafy vegetables. *Food Science and Technology*. 5(2):53-60.

Jaishree and Khan,T.I. 2014. Monitoring of Heavy Metal in Textile Waste Water of Sanganer, Jaipur (Rajasthan). *International Journal of Scientific and Research Publications*.4(3):1-4.

Joshi V. J. and Santani D. D. 2012. Physicochemical Characterization and Heavy Metal Concentration in Effluent of Textile Industry. *Universal Journal of Environmental Research and Technology*. 2**(**2): 93-96.

Kaur, R., & Rani, R. (2006). Spatial characterization and prioritization of heavy metal contaminated soil—water resources in periurban areas of national capital territory (NCT), Delhi. *Environmental Monitoring and Assessment*.123:233–247.

Khillare, P.S., Balachandran, S., Meena, B.R., 2004. Spatial and temporal variation of heavy metals in atmospheric aerosols of Delhi. *Environ. Monit. Assess*. 90, 1–21.

Li Z, Zhang S, Zhang Y, Zhang Y, Wei L (2011) Evaluation of cleaner production audit in pharmaceutical production industry: case study of the pharmaceutical plant in Dalian, P. R. China. *Clean Techno Environ Policy* .13(1): 195–206.

Lowry, O.H., N.J. Rasebrogh, A.L. Farr and R.J. Ran dall(1951). Protein measurment with folin-phenol reagent. *J. Biol. Chem*.193: 265-275.

Pal, P.B. and Brijmohan (1990): Management of occupational environment in textile industry. *Indian J. Environ Prot*. 10(10): 767-772.

Perveen, S., Samad, A., Nazif, W. and Shah, S. 2012. Impact of sewage water on vegetables quality with respect to heavy metals in Peshawar Pakistan. *Journal of Botany. 44(6):1923-1931.*

Sharma, K, Chatuevedi, RK, Bhardwaj, SM and Sharma, KP. 2001. Heavy metals in the vegetables and cereals growing around Sanganer town, Jaipur. *Journal of Indian Botanical Society*. 80: 103–8.

Sharma,R.K ., Agarwal, M. and Marshall,F. 2007. Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. *Ecotoxicology and Environmental Safety* .66 (2):258–266.

Sharma, R.K., Agrawal, M., Marshall, F.M., 2008a. Heavy metals (Cu, Cd, Zn and Pb) contamination of vegetables in Urban India: a case Study in Varanasi. *Environ. Poll.* 154, 254–263.

Sharma, R.K., Agrawal, M., Marshall, F.M., 2008b. Atmospheric depositions of heavy metals (Cd, Pb, Zn, and Cu) in Varanasi city, India. *Environ. Monit. Assess.* 142 (1–3), 269–278.

Sinha, S., Gupta, A.K., Bhatt, K., Pandey, K., Rai, U.N., Singh, K.P., 2006. Distribution of metals in the edible plants grown at Jajmau, Kanpur (India) receiving treated tannery wastewater: relation with physiochemical properties of the soil. *Environ. Monit. Assess.* 115, 1–22.

Singh, S., Kumar, M., 2006. Heavy metal load of soil, water and vegetables in periurban Delhi. *Environ. Monitor. Assess*. 120, 71–79.

Tiwari P.K. 1994. An agenda for pollution control in dairy industry, Indian dairy man. 46 (10): 617-624.

Wong, C.S.C., Li, X.D., Zhang, G., Qi, S.H., Peng, X.Z., 2003. Atmospheric depositions of heavy metals in the Pearl River Delta, China. *Atmos. Environ*. 37, 767–776

Table 1a: **Physico-chemical analysis of Textile waste water collected from agricultural fields of Vigna unguiculata var. RC-101(cow pea) located in Amanishah nallah, Sanganer, at Pre, Peak and Post flowering stages.**

Stages	S. No.	Physico-chemical parameters						
	Samples	pH	E.C. m mhos / cm	Total solids mg/L	Chloride mg/L	Total Hardness mg/L	Calcium Hardness mg/L	Magnesium Hardness mg/L
Pre-flowering	Site 1	7.42 ± 0.352	1.935 ± 0.174	1345.21± 21.12	283.6 ± 25.41	333.22± 23.11	256.3 ±15.31	76.92 ±11.21
	Site 2	7.53 ± 0.331	1.962 ± 0.135	1471.5 ± 19.40	316.1 ±24.10	271.46±18.02	232.61 ±24.64	38.85 ±10.29
	Site 3	7.71 ± 0.338	0.996 ± 0.123	995.95 ± 21.49	382.2 ±26.31	550.53±21.32	459.3 ±12.66	91.23 ±15.36
	Site 4	8.25 ± 0.423	0.709 ± 0.134	756.81 ± 50.02	229.41±31.63	279.92±27.96	223.3 ±23.47	48.62±9.36
	Site 5	9.14 ± 0.418	0.689 ± 0.162	639.23 ± 42.45	314.2 ±61.62	302.53 ±22.36	249.2 ±19.28	53.33 ±8.89
Peak flowering	Site 1	9.23 ± 0.414	1.182 ± 0.150	785.39 ± 35.07	580.2 ±58.63	204.28 ±27.31	165.36 ±23.86	38.92 ±14.36
	Site 2	7.81 ± 0.384	1.042 ± 0.156	1186.21± 48.85	571.1 ±44.99	542.56 ±35.62	473.2 ±10.25	69.36 ±13.24
	Site 3	8.29 ± 0.398	0.932 ± 0.09	1079.50± 42.88	360.31±36.92	573.96 ±42.31	498.6 ±21.36	75.36 ±8.82
	Site 4	8.59 ± 0.394	0.917 ± 0.156	1486.26 ±32.13	376.61±18.75	566.61 ±38.92	494.3 ±29.82	72.31 ±16.22
	Site 5	8.33 ± 0.332	0.995 ± 0.09	1496.32± 21.23	445.3 ±35.23	632.15 ±45.62	539.52 ±25.6	92.63 ±17.62
Post flowering	Site 1	7.49 ± 0.335	1.821 ± 0.85	986.50 ± 19.20	538.21±51.23	215.83 ±12.36	173.6 ±19.61	42.23 ±19.21
	Site 2	9.95 ± 0.409	0.778 ± 0.131	739.23 ± 23.21	356.2 ±16.23	646.62 ±47.87	548.3 ±32.21	98.32 ±21.23
	Site 3	8.36 ± 0.411	0.964 ± 0.63	937.80 ± 36.32	391.1 ±35.62	498.53 ±25.23	436.3 ±13.69	62.23 ±13.96
	Site 4	8.19 ± 0.360	0.749 ± 0.08	1523.11± 49.63	360.34 ±36.1	605.42 ±25.36	509.81 ±25.36	95.61 ±7.83
	Site 5	7.86 ± 0.321	0.862 ± 0.170	1486.2 ± 25.23	292.2 ± 68.2	276.94 ±21.26	227.31 ±15.63	49.63 ±3.96

Table 1b: **Heavy metals analysis of Textile waste water collected from agricultural fields of Vigna unguiculata var. RC-101(cow pea) located in Amanishah nallah, Sanganer, at Pre, Peak and Post flowering stages.**

Stages	S. No.	HEAVY METALS						
	Samples	Zn	Cu	Ni	Cd	Cr	Pb	Co
Pre –flowering	Site 1	1.984	0.152	0.784	1.853	2.082	1.103	0.323
	Site 2	1.988	0.149	0.791	1.846	2.064	1.069	0.345
	Site 3	1.946	0.164	0.776	1.858	2.048	1.117	0.336
	Site 4	1.976	0.176	0.771	1.842	2.026	1.109	0.352
	Site 5	1.993	0.183	0.788	1.867	2.057	1.096	0.358
Peak flowering	Site 1	2.456	0.216	0.865	1.978	2.198	1.136	0.405
	Site 2	2.379	0.227	0.871	1.985	2.236	1.125	0.411
	Site 3	2.190	0.236	0.856	1.966	2.332	1.119	0.418
	Site 4	2.545	0.219	0.861	1.989	2.341	1.142	0.385
	Site 5	2.632	0.208	0.878	1.961	2.286	1.156	0.422
Post flowering	Site 1	3.023	0.289	0.962	2.061	2.586	1.132	0.456
	Site 2	3.128	0.263	0.968	2.051	2.640	1.154	0.434
	Site 3	3.114	0.271	0.956	2.058	2.576	1.168	0.421
	Site 4	3.136	0.258	0.959	2.046	2.596	1.171	0.461
	Site 5	3.221	0.292	0.973	2.041	2.604	1.178	0.465

Table 2a: **Physico-chemical analysis of soil from agricultural fields of Vigna unguiculata var.RC-101(Cow pea) at Pre Flowering stages.**

Stages	Sites	pH	E.C. m mhos / cm	Chlorides mg/100g	%Organic carbon	%Organic matter	% Nitrogen
Pre-Flowering	Site 1	7.31±0.06	0.98±0.07	5.76±0.45	2.617±0.011	4.512±0.006	0.082±0.009
	Site 2	7.49±0.04	1.06±0.08	6.93±0.45	2.217±0.009	3.823±0.007	0.099±0.01
	Site 3	7.11±0.05	0.84 ±0.06	8.16±0.351	2.312±0.009	3.986±0.008	0.069±0.012
	Site 4	8.06±0.05	1.35±0.06	9.63±0.300	2.682±0.009	4.624±0.011	0.118±0.007
	Site 5	8.19±0.06	1.56±0.05	10.43±0.503	3.106±0.011	5.356±0.011	0.134±0.008
Peak-Flowering	Site 1	8.62±0.06	2.45±0.07	13.52±0.45	3.145±0.011	5.422±0.006	0.159±0.009
	Site 2	7.97±0.04	1.76±0.08	11.93±0.45	3.957±0.009	6.823±0.007	0.099±0.01
	Site 3	7.19±0.05	1.54 ±0.06	10.16±0.351	3.472±0.009	5.986±0.008	0.079±0.012
	Site 4	9.06±0.05	2.76±0.06	14.63±0.300	4.132±0.009	7.124±0.011	0.177±0.007
	Site 5	8.49±0.06	2.56±0.05	16.22±0.503	4.034±0.011	6.956±0.011	0.144±0.008
Post-Flowering	Site 1	8.23±0.06	1.49±0.07	16.76±0.45	4.031±0.011	6.950±0.006	0.099±0.009
	Site 2	9.21±0.04	2.66±0.08	17.53±0.45	4.708±0.009	8.117±0.007	0.189±0.01
	Site 3	7.29±0.05	1.84 ±0.06	12.16±0.351	3.795±0.009	6.543±0.008	0.079±0.012
	Site 4	8.56±0.05	2.35±0.06	13.63±0.300	4.294±0.009	7.404±0.011	0.158±0.007
	Site 5	7.96±0.06	1.86±0.05	12.43±0.503	3.686±0.011	6.356±0.011	0.144±0.008

Table 2b: **Heavy Metal analysis (mg/gm) of soil from agricultural fields of Vigna unguiculata var. RC-101(Cow pea) at Pre Flowering stages collected.**

Stages	Sites	Heavy Metals (mg/gm)						
		Zn	Cu	Ni	Cd	Cr	Pb	Co
Pre-Flowering	Site 1	8.589	7.325	2.123	2.339	3.978	2.896	1.569
	Site 2	12.236	7.589	2.226	2.459	3.189	3.256	1.623
	Site 3	13.495	7.445	2.436	2.589	3.225	3.895	1.678
	Site 4	9.758	7.212	2.512	2.639	3.239	3.319	1.775
	Site 5	6.395	7.613	2.321	2.812	4.198	3.389	1.813
Peak-Flowering	Site 1	11.589	9.325	3.325	3.446	5.678	3.926	2.678
	Site 2	14.236	9.489	3.452	3.589	5.389	4.856	2.774
	Site 3	15.495	9.545	3.221	3.678	5.525	4.991	2.813
	Site 4	10.958	9.212	3.663	3.845	5.239	4.389	2.923
	Site 5	13.595	9.513	3.741	3.921	5.998	4.689	2.985
Post-Flowering	Site 1	13.289	11.125	5.011	4.586	6.378	5.896	3.684
	Site 2	15.236	11.589	4.789	4.865	6.189	5.286	3.712
	Site 3	16.495	11.445	4.623	4.912	6.245	5.895	3.776
	Site 4	11.758	11.512	5.121	5.019	6.539	5.319	3.845

	Site 5	14.698	11.013	4.948	5.234	6.998	5.489	3.912

Table 3a: Root and Shoot length (cm) in Vigna unguiculata var RC-101 (Cow pea) at Pre, Peak and Post-Flowering stages collected from agricultural fields.

Sites	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)
Site 1	36.58 ± 13.71	77.46 ± 4.21	51.2± 4.68	95.57 ± 3.94	52.2± 4.18	105.04 ± 3.09
Site 2	38.76 ± 15.04	81.62 ± 6.05	53.72 ± 9.22	101.56 ± 3.38	54.12 ± 7.22	106.76 ± 3.91
Site 3	35.02 ± 12.19	79.48 ± 5.56	54.04 ± 5.22	96.74 ± 3.95	56.4 ± 5.22	104.12 ± 4.5
Site 4	39.7 ± 8.87	80.38 ± 5.78	50.36 ± 5.86	103.28 ± 2.12	52.3 ± 5.86	103.54 ± 3.01
Site 5	33.74 ± 6.61	77.3 ± 1.62	52.78 ± 4.7	94.56 ± 1.37	53.8 ± 4.7	102.8 ± 2.11

Table 3b: Root and Shoot Weight (gm) in Vigna unguiculata var RC-101 (Cow pea) at Pre ,Peak and Post-Flowering stages collected from agricultural fields.

Sites	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)
Site 1	1.843±0.189	4.992±0.28	2.896±0.228	7.325±0.251	3.714±0.224	9.362±0.23
Site 2	1.894 ±0.197	4.608±0.2	2.942±0.221	7.094±0.19	3.812±0.232	9.072±0.18
Site 3	1.944±0.19	4.372±0.19	2.986±0.22	6.942±0.19	3.87±0.22	8.824±0.16
Site 4	1.998±0.21	4.22±0.16	3.064±0.2	6.768±0.16	3.92±0.22	8.668±0.17
Site 5	2.098±0.20	4.05±0.13	3.11±0.21	6.65±0.17	3.81±0.23	8.518±0.16

Table 3c: Chlorophyll (mg/gm) in Vigna unguiculata var RC-101 (Cow pea) at Pre, Peak and Post-Flowering stages collected from agricultural fields.

Sites	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)
Site 1	1.457±0.55	0.808±0.426	2.265±0.324	1.796±0.351	0.982±0.131	2.778±0457	1.836±0.371	1.062±0.121	2.871±0.357
Site 2	1.257±0.612	0.698±0.315	1.955±0.461	1.66±0.231	0.905±0.127	2.565±0.356	1.692±0.231	0.985±0.127	2.621±0.316
Site 3	1.216±0.729	0.687±0.463	1.891±0.595	1.616±1.772	0.864±0.16	2.448±0.454	1.674±1.072	0.898±0.15	2.508±0.312
Site 4	1.106±0.302	0.603±0.165	1.848±0.467	1.479±0.197	0.806±0.108	2.285±0.306	1.529±0.197	0.841±0.108	2.347±0.306
Site 5	1.100±0.197	0.600±0.108	1.700±0.306	1.307±0.518	0.721±0.208	2.028±0.461	1.385±0.418	0.773±0.208	2.126±0.208

Table 3d: Carbohydrate and Phosphorous (mg/gm) in Vigna unguiculata var RC-101 (Cow pea) at Pre, Peak and Post-Flowering stages collected from agricultural fields.

Sites	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)
Site 1	61.748 ± 0.32	3.848 ± 0.14	84.548 ± 0.32	3.972 ± 0.11	85.23 ± 0.23	4.046 ± 0.16
Site 2	62.492 ± 0.32	4.006 ± 0.18	87.68 ± 0.21	4.152 ± 0.14	89.032 ± 0.14	4.17 ± 0.13
Site 3	63.494 ± 0.22	4.31 ± 0.21	88.536 ± 0.29	4.842 ± 0.11	89.598 ± 0.26	5.046 ± 0.14
Site 4	58.632 ± 0.29	3.472 ± 0.2	82.564 ± 0.27	4.058 ± 0.13	83.528 ± 0.25	4.498 ± 0.2
Site 5	64.554 ± 0.27	3.69 ± 0.18	89.792 ± 0.19	4.072 ± 0.18	91.054 ± 0.29	4.288 ± 0.19

Table 3e: Nitrogen and Protein in Vigna unguiculata var RC-101 (Cow pea) at Pre ,Peak and Post-Flowering stages collected from agricultural fields.

Sites	Pre-Flowering Stage		Peak-Flowering Stage		Post-Flowering Stage	
	% Nitrogen	% Protein	% Nitrogen	% Protein	% Nitrogen	% Protein
Site 1	2.065 ± 0.028	12.905 ± 0.18	2.926 ± 0.11	18.288 ± 0.7	4.289 ± 0.33	26.806 ± 2.17
Site 2	2.077 ± 0.028	12.988 ± 0.17	2.806 ± 0.098	17.543 ± 0.64	4.127 ± 0.61	25.793 ± 2.31
Site 3	2.083 ± 0.028	13.023 ± 0.18	2.98 ± 0.087	18.624 ± 0.59	4.408 ± 0.28	27.55 ± 1.92
Site 4	2.11 ± 0.028	13.197 ± 0.17	2.972 ± 0.108	18.581 ± 0.67	4.494 ± 0.33	28.08 ± 2.35
Site 5	2.108 ± 0.028	13.18 ± 0.17	3.616 ± 0.099	18.196 ± 0.66	4.238 ± 0.38	26.48± 2.48

Table 3f: Heavy Metal analysis (mg/gm) of Vigna unguiculata var RC-101 (Cow pea) at Pre Flowering stages collected from agricultural fields.

Heavy Metals (mg/g)	Plant Parts	Sites				
		Site 1	Site 2	Site 3	Site 4	Site 5
Zn	Root	5.245	6.408	5.864	6.271	6.718
	Stem	7.525	7.531	7.532	7.541	7.522
	Leaves	8.504	9.512	8.495	8.506	8.814
Cu	Root	4.160	4.049	4.253	4.306	4.645
	Stem	4.455	4.461	4.649	4.864	4.969
	Leaves	5.177	5.295	5.389	5.678	5.088
Ni	Root	3.130	3.436	3.639	3.546	3.740
	Stem	3.218	3.323	3.416	3.525	3.826
	Leaves	3.314	3.519	3.409	3.298	3.308
Cd	Root	3.667	3.859	3.658	3.667	3.570
	Stem	3.719	3.824	3.725	3.932	3.853
	Leaves	3.734	3.759	3.953	3.959	3.740
Cr	Root	4.297	4.301	4.285	4.291	4.303
	Stem	4.298	4.286	4.294	4.311	4.318
	Leaves	4.439	4.445	4.400	4.417	4.421
Pb	Root	4.488	4.396	4.562	4.406	4.708
	Stem	4.259	4.250	4.345	4.465	4.656
	Leaves	4.320	4.525	4.329	4.304	4.594
Co	Root	2.747	2.764	2.782	2.759	2.738
	Stem	2.777	2.768	2.784	2.764	2.775
	Leaves	2.827	2.851	2.822	2.826	2.840

Table 3g: Heavy Metal analysis (mg/gm) of Vigna unguiculata var RC-101 (Cow pea) at Peak Flowering stages collected from agricultural fields.

Heavy Metals	Plant Parts	Sites				
		Site 1	Site 2	Site 3	Site 4	Site 5
Zn	Root	11.619	11.629	11.632	12.032	11.637
	Stem	11.560	11.556	11.502	11.567	11.555
	Leaves	12.528	12.538	12.546	12.549	12.539
Cu	Root	5.868	5.858	5.959	5.865	5.873
	Stem	5.690	5.691	5.682	5.684	5.693
	Leaves	6.697	6.703	6.688	6.696	6.682
Ni	Root	4.137	4.144	4.642	4.748	4.947
	Stem	4.545	4.550	4.646	4.253	4.758
	Leaves	5.163	5.371	5.358	5.362	5.876
Cd	Root	4.696	4.706	4.682	4.700	4.689
	Stem	4.735	4.740	4.741	4.745	4.748
	Leaves	4.786	4.795	4.782	4.790	4.765
Cr	Root	6.334	6.339	6.329	6.344	6.338
	Stem	6.376	6.383	6.380	6.385	6.387
	Leaves	6.586	6.589	6.580	6.578	6.573
Pb	Root	5.220	5.627	5.528	5.531	5.237
	Stem	5.279	5.483	5.686	5.788	5.195
	Leaves	5.461	5.468	5.475	5.459	5.526
Co	Root	3.799	3.804	3.805	3.790	3.995
	Stem	3.812	3.805	3.799	3.893	3.807
	Leaves	3.915	3.969	3.931	3.986	3.996

Table 3h: Heavy Metal analysis (mg/gm) of Vigna unguiculata var RC-101 (Cow pea) at Post Flowering stages collected from agricultural fields.

Heavy Metals	Plant Parts	Sites				
		Site 1	Site 2	Site 3	Site 4	Site 5
Zn	Root	13.637	13.650	13.639	13.633	13.642
	Stem	13.557	13.866	13.957	13.568	13.554
	Leaves	14.607	14.623	14.622	14.620	14.621
	Fruit	15.708	15.690	15.684	15.696	15.689
Cu	Root	7.098	7.112	7.105	7.197	7.253
	Stem	7.739	7.746	7.837	7.780	7.754
	Leaves	7.797	7.823	7.811	7.854	7.624
	Fruit	8.742	8.348	8.568	8.796	8.878
Ni	Root	5.158	5.165	5.160	5.175	5.177
	Stem	5.316	5.319	5.307	5.327	5.303
	Leaves	5.407	5.414	5.423	5.424	5.431
	Fruit	6.109	6.123	6.098	6.142	6.186
Cd	Root	5.124	5.136	5.248	5.259	5.286
	Stem	5.113	5.144	5.158	5.169	5.186
	Leaves	5.026	5.045	5.089	5.113	5.126
	Fruit	5.264	5.289	5.312	5.348	5.446
Cr	Root	7.049	7.114	7.056	7.100	7.157
	Stem	7.019	7.122	7.026	7.039	7.056
	Leaves	7.110	7.128	7.118	7.149	7.259
	Fruit	7.475	7.487	7.490	7.501	7.505
Pb	Root	6.238	6.244	6.248	6.257	6.264
	Stem	6.312	6.320	6.303	6.327	6.298
	Leaves	6.538	6.546	6.548	6.553	6.558
	Fruit	6.575	6.579	6.567	6.583	6.595
Co	Root	4.721	4.818	4.753	4.834	4.899
	Stem	4.878	4.887	4.896	4.991	4.972
	Leaves	4.979	4.985	4.988	4.997	4.001
	Fruit	5.538	5.546	5.548	5.553	5.858

Fig 1, Shows the sites in the study area for collection of soil, water and crop plant samples at Sanganer, Jaipur

Fig 2a

Fig 2b

Fig 2a and 2b shows pumping of waste water into Agricultural fields of *Vigna unguiculata* at Sanganer, Jaipur.