

Effect of Municipal Solid Waste Open Dumping on Soil, Water, Crop, Human Health and Its Prospectives

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Authors' contributions

This work was carried out in collaboration among all authors. Author SCK designed the study, wrote the protocol and first draft of the manuscript. Author PCR performed the statistical analysis. Authors CN and MMM managed the analyses of the study. All the authors read and approved the final manuscript.

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ABSTRACT

Characterization of heavy metals in 5 Km² range of dumping yard in relation to soil, water and crop has been studied. The concentration of Cd (4.05 mg/kg) in soil was higher than the permissible limit of WHO (3 mg/kg) and in descending order of metals in soil was found to be Fe>Cr>Cd>Ni>Zn>Cu>Pb and in bore well water it was Cr, Fe, Pb, Cd, Zn and Cu (23.20, 0.63, 0.31, 1.19 and 0.69 mg/l respectively) than the permissible limit (0.54, 0.40, 0.068, 0.03, 0.22, 0.018 mg/l) and their respective concentration ordered as Fe>Zn>Cu>Pb>Cd>Ni>Cr. Further the vegetables grown nearby dumping yard was highly contaminated by Cr in range (2.78 to 12.78 mgkg⁻¹) in tomato, beans and cabbage and even in ragi and green gram Cr was high (1.78 to 14.96 mgkg⁻¹). i.e., in Tomato; Cd>Fe>Cr>Zn>Pb>Ni>Cu, Beans; Cr>Cd>Pb>Fe>Zn>Cu>Ni, Cabbage; Cr>Cd>Pb>Fe>Zn>Cu>Ni, Ragi; Fe and Zn were below permissible limit and Pb, Ni, Cu, Cd are BDL and Green gram; Cr>Fe>Zn>Pb>Cu > Ni>Cd. In support of results, primary survey was conducted in nearby 20 villages circumventing the dumping yard. A total of 150 respondents were randomly enquired to know their level of knowledge and health status as result of open dumping

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site. The results revealed that 43.33%, 36% and 20.67% as medium, high and low impact in relation to health and knowledge aspect of dumping site. Thus there is a considerable impact on environment and humans due to the presence of heavy metal in crop, soil and water.

Keywords: Heavy metal; vegetables; open dump site; ground water and human health.

1. INTRODUCTION

Increased population over the years has seen commensurate rise in waste generation raising concerns on safe disposal and environmental pollution. Indeed majority of waste generated in recent years mostly end up in dumping yards which are located near to the agriculture land and human habitations. These wastes with their different composition contain hazardous heavy metals that are evidenced to contaminate soil and water. In turn the heavy metals through various pathways entering food chain system [1] causing unprecedented impact on health of native individuals and affecting children's. Although the concentration of heavy metals is low but the cumulative health effect as a result of long term contamination may cause chronic illness amongst people living in adjacent areas [2]. In addition there is fair possibility of these heavy metals entering the crops grown in and around the dumping yards. Thus consumption of plant products may cause the disease which is beyond diagnosable and treatable. [3] argued that the nearness of overwhelming metals in the earth is of extraordinary environmental noteworthiness because of their harmfulness at specific fixations, translocation through evolved ways of life and non-biodegradability which is responsible for their accumulation in the biosphere. Bengaluru is concerned, past evidence and media reports vehemently suggest that there is lack of scientific management of municipal solid waste. As per Solid waste management overview [4] it cost 500 -1500 Rs per ton of solid waste i.e per year 16,42,50,000 rupees is involved in management and disposal of 60 percent of waste generated. In most of the cases legacy of dumping waste to outskirts (Mostly in open spaces) has followed Municipal Corporation, grossly ignoring the fact of contamination of heavy metals like As, Cd, Hg and Pb and are dangerous to plants, creatures and humans [5]. Further the Metropolitan waste also contains substantial metals like As, Cd, Cu, Fe, Hg, Mn, Pb, Ni and Zn which end up in the sink when they are drained out from the dumpsites leading to soil contamination. Crops grown nearby dumping sites has the fair chance to enter into the food chain. The ease of entering

food chain is fuelled by vegetable consumption as vegetables constitute the most important daily diets in many of the households globally [6]. Moreover urban areas become hot spot of contamination of heavy metals like Cu, Zn, Fe, Pb, Cd, Mn, Hg, and Cr resulting from urban farming [7]. The ingestion of heavy metal sullied vegetables may prompt different long haul waiting maladies; for example, persistent introduction of Cd can cause pneumonic effect like emphysema, bronchiolitis, and alveolitis [8]. Land contaminated nearby dumping site can ingest heavy metals and enters the food chain in the form of mobile ions present in the soil through their roots or through foliar absorption. These absorbed metals get bio cumulated in the roots, stems, fruits, grains and leaves of plants. Water contamination is most prevalent environmental issue all over the world [9] and among the pollutants the contaminants affecting water resources, heavy metals receive particular concern considering their high toxicity even at low concentrations [10]. On mere analysis it was found that there exists poor knowledge both at waste management and health effects of people residing nearby places. In the rainy season the soil and water condition worsen because of high rate of runoff or infiltration of leachate. Recent data reveals that the India alone generates 960 million tonnes of municipal solid waste per year in which 40-50 percent is managed unscientifically and creating an environmental hazard, harming the human health by entering into the food chain [11]. Therefore the study was undertaken to know effect of municipal solid waste on human health as well as knowledge of the community resides nearby dumping yards. Basic information related to health metrics were obtained from primary health centres (PHC) nearby villages of the dumping site. The respondents were selected randomly and were interviewed with predetermined questionnaire.

2. MATERIALS AND METHODS

The present study was carried out in Bangalore rural district, Doddaballapura, Gundalahalli (latlong: 13°31'N 77°37' E) where 25-30 percent of waste generated from the whole Bangalore is dumped and it is the second largest dumping site

after Mavallipuram site. The dumping site assumes the significance as it supply's most of the vegetables consumed in the areas circumventing Bangalore city. Assessment of heavy metal contamination was done in two ways, one by survey method and other by soil, water and plant sampling method.

2.1 Survey Method

Survey has been conducted in 20 villages which are situated around the dumping site within 5km range from the dumping yard by randomly selecting 150 villagers/ respondents. (Who were willing to provide the required information on knowledge of dumping yard and its impact on human health voluntarily).

2.2 Soil Sampling

A farmer's fields were selected on the basis of nearness of dumping site in the radius of 5 km. Soil samples were collected from the plots which uses bore well water for providing irrigation to vegetables (Tomato, Beans and Cabbage) crops (Ragi and Green gram). A total 20 soil samples i.e a samples per point were collected from 0-15 cm depth in 20 randomly selected plots using screw auger and were mixed thoroughly to get the representative samples. In order to establish fair process the location (latitude and longitude) of the sampling was recorded with the help of Global Positioning System (GPS). The soil samples were processed i.e. 0.05 g of 0.2 mm sieved soil samples were pre-digested with 8 ml HNO₃ (70%) and 2 ml H₂O₂ (30%). All the samples were replicated twice. Later, the samples were digested using a microwave digester (Milestone- START D) at 150°C with following steps: 1200 w for 15 minutes, 1200 w for 10 minutes and venting for 10 minutes. The digested sample was stored in clean plastic tubes of 50 ml capacity, after making up the volume using double distilled water and the heavy metals were analysed using ICP-OES (Thermofisher-model ICAP 7000 series) with the help of multi nutrient standard solution and also DTPA extractable elemental content in the soil samples were analysed by 0.005 M diethylene triamine penta acetic acid (DTPA) + 0.001 M CaCl₂.2H₂O + 0.1 N tri ethanol amine buffered at pH 7.3 [12] using the same ICP-OES.

2.3 Plant Sampling and Processing

Edible parts of the crops (Ragi and Green gram) vegetables (Tomato, Beans and Cabbage)

grown common in the sites irrigated with bore well water were sampled. A total of 85 plant samples at maturity were collected during post monsoon of 2018 from the same plot where the soil samples were collected earlier. Crop plants were washed with running tap water followed by double distilled water to remove surface contaminants. The samples were dried in the hot air oven at 70°C for 72 hours, powdered and analyzed for their heavy metals content by following the same method as heavy metal analysis in soil.

2.4 Water Sampling

20 Bore well water samples were collected within the range of 5 Km² from the dumping yard, towards the slope using the Digital Elevation Model (DEM) and Bhuvan software. Water samples from bore wells are collected at the outlet few minutes after discharge. One litre bottle was used for the purpose of water sampling and the samples were labelled properly. The location (latitude and longitude) of the sampling was recorded with the help of Global Positioning System (GPS). The heavy metals were analysed using ICP-OES (Thermofisher-model ICAP 7000 series) with the help of multi nutrient standard solution and also DTPA extractable elemental [12].

2.5 Statistical Analysis and Interpretation of Data

The analyses and interpretation of the data was done using the Fisher's method of analysis and variance technique as given by [13] at 5% level of significance.

Ex post-facto research design was adopted for conducting the survey. This design was considered appropriate because the phenomenon has already occurred and the researcher does not have direct control over independent variables.

2.6 Attitude towards Dumping Yard

An attitude is a positive; negative or mixed evaluation of an object that is expressed at some level of intensity. It is the preparedness of people to respond in a certain way towards social objects or phenomena. Further, the variable was operationalized as the positive or negative mental predisposition of respondents towards unscientifically managed dumping yard [14].

The maximum allowable limits of heavy metals in soils, water and vegetables have been established by standard regulatory bodies such as Bureau of Indian Standards shown in Table 1.

Chart 1. Attitude towards dumping yard

Category	Criteria	Score
Low impact	$<(\text{Mean} - \frac{1}{2} \text{SD})$	Below 68.64
Medium impact	$(\text{Mean} \pm \frac{1}{2} \text{SD})$	68.64 to 72.10
High impact	$> (\text{Mean} + \frac{1}{2} \text{SD})$	Above 72.10

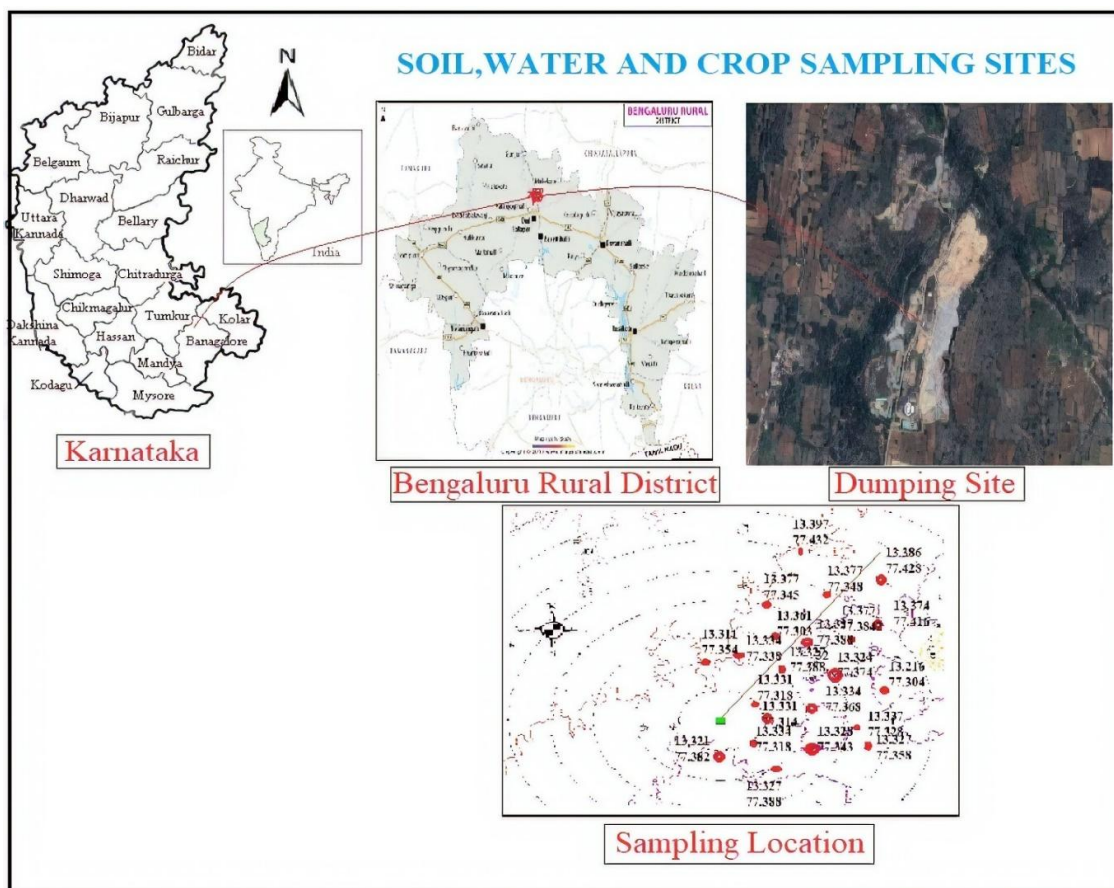


Fig. 1. Soil, ground water and crop sampling location irrigated with bore well water within the range of 5 km from dumping yard

Table 1. Maximum permissible limit of heavy metals in irrigation water, soil, vegetables and plants as per EUS and IS

Chemical element	Maximum permissible level in irrigation water (mg/l)	Maximum permissible level in soils (mg/kg)	Maximum permissible level in vegetables (mg/kg)
Cd	0.03	3	0.10
Cr	0.54	100	0.3
Cu	0.018	100	73.00
Fe	0.40	500	42.50
Ni	1.42	50	67.00
Pb	0.068	100	0.30
Zn	0.22	300	100

*BIS Indian Standards 2012 [15]

3. RESULTS AND DISCUSSION

The survey result (Table 2) reveals that the maximum variables were fall under high impact except some scientific proven and those in dilemma fall under the medium and less impact category. The awareness about harmful effects of presence of dumping yard was known to 74.67% i.e. 112 villagers out of 150. In fact the effects of pollution and health issues from dumping yard was to some extent but the knowledge of leachate infectious diseases, cancer causing agents through dumping yard and pre and post pregnancy issues were unknown (16%). The knowledge about harmful effect of dumping yard results were similarly in observed by [16,17,18] and concluded that the heavy metals has considered to be essential element for numerous bio-activities in the human body, its high level in the vegetables can affect consumer health negatively. Dumping yard will harm to that extent when the issue raised about cancer or questioned about cancer indicated an association between cadmium exposure and renal cancer. The respondent were not sure of any health check-up and maximum number of villagers won't believe that in future the continuous presence of unscientific dumping yard will cause cancer which has been confirmed in later studies of occupationally exposed workers [19] and [20]. With all this, the primary health centres data has been collected and analysed for the cross verification of primary collected data, knowingly the same pattern of curve has been observed with maximum number of case registered with Nausea, Vomiting, Headache, Gastric, dengue, Chikungunya and Malaria. [21] stated that the high concentrations of total dissolved solids from dumping yard leachate percolate to ground water will decrease the palatability and may cause gastro-intestinal irritation in human. Which are all one or the other way water borne diseases or polluted water effects. It is been well established that most heavy metals are required within the recommended limits for the smooth functioning of metabolic activities. Some of the beneficial health effects and negative consequences due to accumulation of heavy metals monitored in this study are compared with United States Environmental Protection Agency [22] and Agency for Toxic Substances and Disease Registry [23,24].

The overall impact of dumping yard on human health (Table 3) were also analysed with considering all the variables and their impact.

Among the 150 respondents/ villagers the 54 were comes under the High impact category which directly implies that the 36% of population in and around the dumping yard were under severe health issues with all known facts and awareness. 43% i.e. 65 out of 150 respondents were under medium impact and while surveying the respondents were in state of dilemma that they are affected or not and was attributed to their large focus on livelihood activates.

3.1 Presence of Heavy Metals' Level in Water and Soil

Characteristics of the leachate depend primarily upon the waste composition and water content in total waste [25]. The heavy metals' levels in water were highest for Fe followed by Zn, Cu, Pb, Cd, Ni and Cr. The levels of heavy metals in water samples ranged from 20.50 to 25.80 mg/l, from 0.92 to 1.48 mg/l, from 0.48 to 0.92 mg/l, from 0.56 to 0.71 mg/l, from 0.016 to 0.036 mg/l, from 0.57 to 0.71 mg/l and from 0.29 to 0.37 mg/l for Fe, Zn, Cu, Pb, Cd, Ni and Cr, respectively. The concentrations of Fe, Pb, Cd, Zn, and Cu were higher than the permissible level, while those of Cr and Ni were lower (Table 4) thus the sequence: Fe>Zn>Cu>Pb>Cd>Ni>Cr. Further the findings indicate that the irrigating water nearby dumping yard is highly polluted mainly by Fe, Pb, Cd, Zn, and Cu. The presence of Fe is very high in an alarming rate nearby the dumping sites. The Cu (0.69 mg/l) content exceeds the standard level (0.017 mg/l). According to [26] the presence of Cu in the ground water indicates the disposal of chemicals used for photograph processing and steel pipes may have been disposed in the dumpsite. Although [27] recorded that the chemical composition of the landfill leachate in Italy with an important content of heavy metals can exhibit considerable temporal variation, their results are in contradiction with the findings of the current study where Fe has very higher concentration than the permissible limit. The present findings are consistent with DCC and JICA [28] where, it has been observed that higher concentration of metals than the standards. A similar result was also reported by [24] and agreed with the findings of [15] and [29]. In addition the research findings of [30] also indicated that the ground water nearby dumping yard are polluted to some extent raised concerns on impact on human health. It was also remarked that the formation of blue baby syndrome in babies and Goitre in adults are the results of consumption of water containing high amount of Nitrate above the specified quantity [31,15].

Table 2. Appraisal of dumping yard knowledge and its impact on human health

Sl. no	Component	Less impact		Medium impact		High impact	
		Numbers	Percent	Numbers	Percent	Numbers	Percent
1	Awareness of dumping yard	12	8.00	26	17.33	112	74.67
2	Air pollution	10	6.67	16	10.67	124	82.67
3	Soil quality	15	10.00	27	18.00	108	72.00
4	Water quality	4	2.67	9	6.00	137	91.33
5	Health Effect	1	0.67	30	20.00	119	79.33
6	Water infectious diseases	1	0.67	26	17.33	123	82.00
7	Leachate infections	10	6.67	78	52.00	62	41.33
8	Psychological disorders	10	6.67	37	24.67	103	68.67
9	Health issues	5	3.33	38	25.33	107	71.33
9a	Headache	1	0.67	8	5.33	141	94.00
9b	Gastrointestinal problems	3	2.00	17	11.33	130	86.67
9c	Cancer	92	61.33	35	23.33	23	15.33
9d	Dengue, Chikungunya and Malaria	1	0.67	4	2.67	144	96.00
9e	Nausea and vomiting	12	8.00	15	10.00	123	82.00
9f	Pre- and Post- pregnancy complications	24	16.00	70	46.67	56	37.33
9g	Low birth weight	3	2.00	35	23.33	112	74.67
10	Shift in crop cultivation practices	0	0.00	1	0.67	149	99.33
11	Shift in livestock rearing	26	17.33	58	38.67	66	44.00

Table 3. Overall impacts on human health due to dumping yard

Sl. no.	Impact level	Villagers/ Respondents	
		Number	Per cent
1	Low impact	31	20.67
2	Medium impact	65	43.33
3	High impact	54	36.00
	Total	150	100.00

Mean = 70.37 and 0.5 SD = 1.73

Heavy metal content of soils in and around the waste disposal sites is also presented in Table 4. The mean value of Cd (4.05 mg/kg) has higher the permissible limit when compared with WHO standards (3 mg/kg) and found highest amount when compared with following metals in an decreasing order Cd>Ni> Cr>Cu>Pb>Zn>Fe and the amount of Cd found very high at near disposal site. The levels of heavy metals in soil samples ranged from 3.22 to 4.72 mg/kg, from 1.54 to 2.81 mg/kg, from 3.42 to 4.87 mg/kg, from 1.17 to 2.13 mg/kg, from 0.82 to 1.31 mg/kg, from 1.36 to 2.73 mg/kg and from 36.5 to 46.7 mg/kg for Cd, Ni, Cr, Cu, Pb, Zn, Fe respectively. The concentration of Cd was higher than the permissible level, while the remaining metals were found lower than the permissible limit. There are many factors which control the mobility of heavy metals in soils profile e.g., soil p^H , soil texture, type of clay minerals, percentage of organic matter, cation and anion exchange capacity soil drainage and amount of rainfall. Many studies also have examined relationships among elements (major and trace) and other soil

properties (clay content, cation exchange capacity, pH, soil texture, carbonates) in non-contaminated soils [32]. The similar results i.e. amount of Cd was found above the threshold values were reported in the Canadian Council of Ministers of the Environment [33]. Heavy metals present in soils consist of serious environmental hazards from the point of view of polluting the soils [34].

3.2 Heavy Metals Content in Different Crops under Bore Well Water Irrigation in and around Dumping Yard

Concentration of Cr in vegetable crop samples ranged from 1.78-12.78 mg Kg⁻¹. The concentration in different vegetable plants viz., Tomato, Beans, Cabbage, Ragi, and Green gram was in the range of 6.32-8.10, 2.78-3.91, 4.86- 12.78, 4.72-14.96, and 1.78-3.45 mg kg⁻¹, respectively (Table 5) in soils irrigated with bore well water in and around dumping site and Cr has sever health effects as recorded by the survey and the similar results were observed by [35] and [36]. Chromium is a widely reported pollutant around tanning industries and known to cause allergic dermatitis. Out of 20 tomato plant samples collected randomly from the farmers' fields irrigated with bore well water surrounded by dumping site, we found Fe and Cd has significant difference with standards and these two metals have in range of polluting but the Cr has found high in concentration followed by

Cd> Fe>Zn>Pb> Ni>Cu. This trend was found to be in accordance with previous studies estimating heavy metals in vegetables [37]. The similar pattern of observations were recorded in 13 samples of beans i.e. higher concentration of Cr and Cd presence than the permissible limit [38] with the following metal concentration in an descending order Pb> Fe> Zn> Cu> Ni. These might be due to higher mobility of these heavy metals with a natural occurrence in soil [39] and the low retention of them in the soil than other toxic cations. Out of 20 samples in cabbage the heavy metals like Fe, Pb, Cr, Cd were above the permissible limit and in consideration of metal concentration in an descending order Cr>Cd>Pb>Fe>Zn>Cu>Ni were found. In many plants lead accumulation can exceed several hundred times the threshold of maximum level permissible for human [40]. On the other hand, the concentration of Pb in vegetables and fruits was significantly lower than that detected in India, Egypt, and Turkey [41,42]. Usage of toxic metals had produced a significant effect on biomass production and plant growth [43]. Ragi and green gram were the staple food in southern Karnataka but the accumulation of heavy metals like Cr was high in amount than the permissible limit and Metal uptake to phytotoxic concentrations has been demonstrated when soils were sufficiently contaminated [44]. Fe and Zn were in optimum range and the remaining heavy metals were below detectable level i.e. Pb,

Ni, Cu, Cd. The similar pattern was recorded in green gram as Ragi but Pb>Cu > Ni>Cd were in minimal quantity than permissible limit.

Table 4. Effect of different heavy metals from open dumping yard on surrounding soil and water

Heavy metals ppm		Soil (20)	Bore well Water (20)
Fe	Mean	41.38	23.20
	Range	36.5 - 46.7	20.5 - 25.8
	SD	± 3.15	± 1.81
Pb	Mean	1.09	0.63
	Range	0.82 - 1.31	0.56 - 0.71
	SD	± 0.15	± 0.03
Cr	Mean	4.21	0.02
	Range	3.42 - 4.87	0.29 - 0.37
	SD	± 0.38	± 0.00
Cd	Mean	4.05	0.31
	Range	3.22 - 4.72	0.016 - 0.036
	SD	± 0.45	± 0.02
Zn	Mean	2.08	1.19
	Range	1.36 - 2.73	0.92 - 1.48
	SD	± 0.37	± 0.14
Ni	Mean	2.26	0.65
	Range	1.54 - 2.81	0.57 - 0.71
	SD	± 0.36	± 0.04
Cu	Mean	1.61	0.69
	Range	1.17 - 2.13	0.48 - 0.92
	SD	± 0.23	± 0.14

Parenthesis () indicate number of samples

Table 5. Effect of different heavy metals from open dumping yard on surrounding vegetables and crop

Sl. no			Fe	Pb	Cr	Cd	Zn	Ni	Cu
1	Tomato (20)	Mean	410.52	0.02	7.13	0.09	58.29	0.04	30.78
		Range	361.46 - 456.92	0.01 - 0.04	6.32 - 8.10	0.03 - 0.15	40.80 - 72.89	0.01 - 0.07	17.7 - 43.10
		SD	± 28.69	± 0.01	± 0.56	± 0.03	± 9.95	± 0.02	± 7.69
2	Beans (13)	Mean	150.24	0.04	3.36	0.20	35.09	0.02	BDL
		Range	138.08 - 173.62	0.02 - 0.05	2.78 - 3.91	0.11 - 0.28	28.16 - 41.39	0.01 - 0.03	BDL
		SD	±10.21	±0.01	±0.34	±0.05	±3.75	±0.01	±0.00
3	Cabbage (20)	Mean	558.31	1.40	8.81	1.81	81.49	0.95	18.19
		Range	538 - 578.64	0.50 - 2.46	4.86 - 12.78	1.16 - 2.48	70.13 - 94.60	0.67 - 124	1.82 - 2.64
		SD	±14.44	±0.53	±2.31	±0.34	±8.46	±0.14	±3.19
4	Ragi (20)	Mean	267.77	BDL	11.16	BDL	16.88	BDL	11.34
		Range	220 - 317	BDL	4.72 - 14.96	BDL	15.12 - 19.27	BDL	8.62 - 14.38
		SD	±26.76	BDL	±2.67	BDL	±1.15	BDL	±1.57
5	Greengram (12)	Mean	273.25	0.06	2.63	BDL	28.65	0.02	1.15
		Range	216.30 - 315.18	0.04 - 0.07	1.78 - 3.45	BDL	20.91 - 31.70	0.01 - 0.03	1.12 - 1.19
		SD	±30.13	±0.01	±0.48	BDL	±4.77	±0.01	±0.02

*Parenthesis () indicate number of samples

4. CONCLUSION

The focus of the study was on impact of Solid waste on human health due to unscientific way of disposal and its effect on soil, crop and water. It is found that the heavy metals concentration was bit higher in range than the permissible limit (WHO) within the range of 5 km from the dumping site, hence the maximum range for habitation of human and agriculture should be 5 km away from the dumping site for safer side or it should be managed scientifically. In support of the research findings the survey data also reveals that health issues within the range of 5km from the dumping site were high and 16% of population even now don't know form where and how the pollution is happening.

CONSENT

As per international standard informed and written participant consent has been collected and preserved by the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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