Research Article

Survey Methodology for Heavy Metals Toxicity Assessment

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Abstract

In the present study, a comprehensive survey was conducted at five selected locations (Alipur, Shahdara, Kanjhawala, Mehrauli, and Najafgarh) in Delhi. Six vegetables selected of different categories such as root, leafy and fruit vegetables (potato, carrot, tomato, spinach, mustard, and okra) from cultivated areas. A questionnaire survey was conducted to grab the information of consumption pattern. Vegetables consumption information and data were collected at each location from 25 families. Several data, i.e. daily vegetable consumption, number of family members, body weight, male: female ratio and types of vegetables consume were collected from each family for the calculation of toxicity assessment indices. Results indicated that the gross per capita per day vegetable consumption was highest at Shahdara (0.314 kg/capita/day), followed by Najafgarh (0.307 kg/capita/day). It was also observed that the per capita per day consumption of vegetables was highest mostly in the case of potato followed by tomato. During the present study, face to face and online survey methodology used with designed format.

Keywords: Survey, Vegetables, Index, Assessment, Toxicity

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Introduction

Vegetables are mostly cultivated in the peri-urban areas to fulfil the growing demand in cities. The sufficient supply of irrigation water to these vegetables is a challenging task in the present time around the cities. Therefore, this ever-increasing demand compensated by applying sewage wastewater. The wastewater discharged from industries, and commercial activities are laden with heavy metals [1]. Vegetables being the carrier of metals, when used up by human beings, get ingested into the human body. Toxic metals can be unusually threatening to the human body, even at low levels, as there is no compelling excretion mechanism [2, 3]. Balanced nutrition is a primary human necessity for a healthy lifestyle. A well-balanced diet is a prerequisite for proper growth, development, and to remain active. The nutritional status of consumable products depends on their production system, which decides the health of consumers.

The recommended dietary allowances (RDA) guidelines are nutrient-centred and have technical aspects. Vegetables are eaten more due to the presence of nutritionally essential elements that are vital for human survival and are often known protective foods because they may prevent diseases in humans. Apart from providing nutrients, vegetable offers a host of essential nutrients which have a positive influence on health [4, 5]. Regulations on food quality provide the standards that decreased the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk of metals [6]. Globally, there are many organizations which are responsible for developing regulations for heavy metals in food items, i.e. United States Environmental Protection Agency (EPA), National Institute for Occupational Safety and Health (NIOSH), Bureau of Indian Standards (BIS), Occupational Safety and Health Administration (OSHA), and Food and Drug Administration (FDA) [7].

The Expert Committee (EC) of the Indian Council of Medical Research (ICMR), taking into attention the nutrient requirements, has recommended that each individual per day should consume at least 300 g of vegetables (including green leafy vegetables: 50 g; other vegetables: 200 g; Roots & Tubers: 50 g). Total Production of vegetables is about 30% less than the demand of 100 million tones [8]. The amount of vegetables enter into the human body mainly depends on the quantity and types of vegetables consumed per day, type of irrigation source, area of production, and age group of consumers [4]. In US, children and youths consume 1 serving of fruit and 1.3 servings of vegetables per day [9]. In Germany, the average consumption in children (ages of 3 to 17 years) is below the recommended standards. Only 12.2% of girls and 9.4% of boys consume the recommended 5 servings of fruits and vegetables per day [10]. Only 9% of children (11 to 18 age) are consuming the recommended quantities of fruits and vegetables every day in UK [11].

Researchers are using several methods of survey designed as per their ease to work and requirement. There are various types of surveys can be used for study and broadly classified into two categorized (i) according to

instrumentation and (ii) according to the period involved. The types of surveys, according to instrumentation, include the questionnaire and the interview. On the other hand, surveys according to the period used to conduct the study are comprised of cross-sectional surveys and longitudinal surveys (https://explorable.com/types-of-survey). In this study, the survey was based on the questionnaire and the interview (both telephonic and face to face contact). The collection of information's from field is an important step in toxicity assessment. Assessment of toxicity was done through several toxicity indices that required basic consumption and socioeconomic parameters of consumers for a particular site. All the analysis works carried out to study the factors linked with toxicity assessment due to the consumption of vegetables. The novelty in the present work was that survey methodology, and questionnaires were deal and redesign in the simplest manner with toxicity assessment.

Martials and methods

Survey and sampling locations

Delhi city is resided in Northern India, at 28.7041°N 77.1025°E with 216m elevation. It is surrounded by Uttar Pradesh (Gautam Budh Nagar, Ghaziabad, and Baghpat) and by Haryana (Gurugram, Faridabad, Jhajjar, and Sonipat) on three sides. The NCR Delhi covers an area of 1,484 km^2, of which 783 km^2 is a rural area and 700 km^2 urban area. The river Yamuna was the historical boundary between Punjab and UP, and its flood plains provide fertile alluvial soil suitable for agriculture but are prone to intermittent floods. Delhi has a dry-winter humid subtropical climate, including a hot semi-arid climate. Temperatures range from 2 to 47°C with average annual rainfall is around 886mm, which most of which falls during the monsoon season (July-August) [12]. In Delhi NCR, 5 sampling sites were selected for conducted present study as location given in **Figure 1**. All the information about the sites were given in **Table 1**.

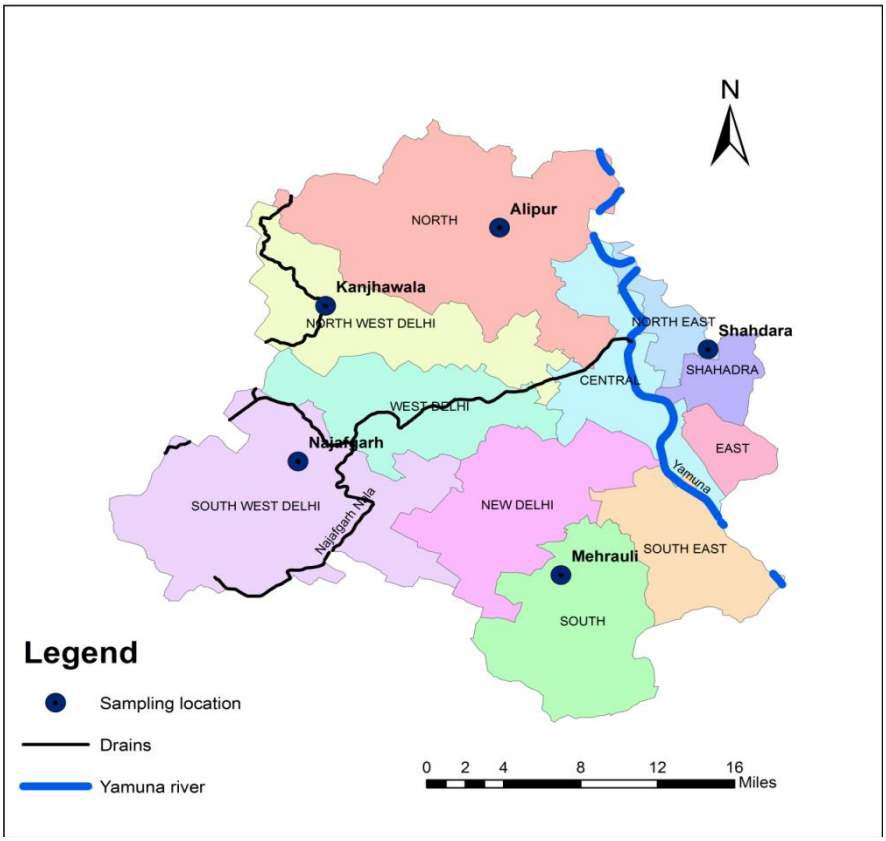

Figure 1 Location of selected sites in Delhi for survey

Table 1 Sampling sites with their latitude, longitude, and altitude

Site	District of Delhi	Latitude	Longitude	Altitude
Alipur	North West	28.797460	77.132991	214.4 m
Kanjhawala	North West	28.735456	77.002011	213.9 m
Najafgarh	South West	28.611856	76.981354	219.0 m
Mehrauli	South West	28.521586	77.179149	260.8 m
Shahdara	North East	28.700868	77.289846	207.0 m

Vegetables Selected

For the present study, information of 6 vegetables from different categories such as leafy, root, and fruit were collected (**Table 2**). The consumption pattern of these vegetables was surveyed and calculated per day per capita consumption pattern.

Table 2 Selected vegetables and their category

Vegetable	Botanical Name	Family	Category	Sampling season
Potato	*Solanum tuberosum* L.	Solanaceae	Root	Winter
Carrot	*Daucus carota* L.	Apiaceae	Root	Winter
Tomato	*Solanum lycopersicum* L.	Solanaceae	Fruit	Winter
Okra	*Abelmoschus esculentus* L.	Malvaceae	Fruit	Summer
Spinach	*Spinacia oleracea* L.	Chenopodiaceae	Leafy	Winter
Mustard	*Brassica juncea* L.	Brassicaceae	Leafy	Winter

Survey preparation

More than 300 samples of harvested fresh vegetables were collected from selected sites during 2018 and 2019. Samples were collected in triplicate for each vegetable form different silts. These samples were grouped into leafy (spinach and mustard), fruit (okra and tomato) and root vegetables (potato and carrot). All collected samples were stored in clean polythene bags, tagged according to their type and brought to the laboratory for further analyses [13]. A preliminary study with 125 families was carried out on the consumption of vegetables in adults (aged >12 years). Based on the information obtained, a survey was designed in 2 phases (summer and winter) to investigate the consumption pattern of different vegetables.

Both the online and offline/personal (face-to-face conversations) survey was conducted using a well-prepared format of questionnaires [14]. The online questionnaires have been tested and found to be useful because of the ability to collect information from persons of different locations, and because of the low cost compared with offline surveys. A questionnaire with a list of the six most-consumed vegetables (tomato, carrots, spinach, okra, mustard and potato) was prepared for the survey. Families were asked to provide the information about their consumption on per week basis of each vegetable listed in the questionnaire. There was no scale measurement pattern used, such as scale 1 to scale 7. The scale pattern used only to determine the quantity of vegetables consumed per week (from 1 to 6 scale). The weight of individuals was measured by weighing balance on the spot. In the end, the socioeconomic data of each family/member (age, sex, number of persons, male: female ratio, number of children, number of vegetable consumers and any specific problem concerning vegetable consumption) was collected [15].

Survey questionnaires and design

The survey questionnaire was prepared to discuss with the advisory committee and adapted the final approved version. To assess the heavy metal toxicity to consumers, several ground data, and basic information required. The questionnaires were prepared and collected during the study period from each site such as site name, latitude and longitude, name of family head, address and phone number, sex, number of persons, male: female ratio, number of children. no. of vegetable consumers, age of family members, weight of members, type of vegetable used daily, the quantity consumed per day per time, name of the market from vegetables purchased, any problem related to vegetables and vegetables quality issue.

Based on the data obtained in the preliminary inquiry, a survey was designed to investigate the toxicity assessment parameter in the consumers. All the data required to calculate a particular index used from survey forms. The questions are simple and deal with in a very easy way to collect all the necessary information without any loss [15]. The survey was conducted in their own home at each selected location, which probably develops an atmosphere of trust and friendliness. It was requested to the family member to answer by the lady who is dealing with household work such as purchasing and preparation of vegetables.

The data collection sheets were prepared by using standard parameters required for the assessment of the toxicity of metal. Families were randomly selected. The questionnaire requested self-reported information regarding sociodemographic characteristics and consumption pattern. Additionally, some other information also collected like male: female ratio in family and disease regarding information [16]. A total of 125 families were surveyed, 25 at each location including 455 members during 2017-18 and 2018-19.

Health risk assessment (HRA)

Health risk due to the consumption of heavy metals contaminated vegetables can be studied by using the several indices, i.e. Hazard Quotient (HQ), Hazard Index (HI), Daily Intake of Metals (DIM), Health Risk Index (HRI) and Metal Pollution Index (MPI)/ Pollution Load Index (PLI) (**Table 3**). A hazard quotient is the ratio of the potential exposure to a substance and the level at which no adverse effects are expected or ratio of determined dose to the reference dose (RfD). It is primarily used by US EPA to assess the health risks of toxics [17]. Another critical index related to HQ is the Hazard Index (HI). It is the sum of hazard quotients (HQs) for substances that affect the same target organ or organ system. Daily intake of vegetables in consumers was calculated by data obtained during the survey through a questionnaire [18].

In the present research work, vegetables grown at the contaminated wastewater were collected from the study area, and their metal concentration was used to calculate the health risk index (HRI). The value of HRI depends upon the daily intake of metals (DIM) and oral reference dose (RfD). RfD is an estimated per day exposure of metal to the human body that has no hazardous effect during lifetime [20]. The metal pollution index (MPI) was computed to determine the overall heavy metal concentration in all vegetables analyzed. This index was obtained by calculating the geometrical mean of concentrations of all the metals in the vegetables [21].

Table 3 Parameters required for toxicity assessment

Sr. No.	Toxicity assessment index	Parameter required for calculation	Unit	Reference
1.	Hazard Quotient (HQ)	Dry weight of vegetables consumed	mg day^{-1}	17
		Metal concentration in vegetables	mg day^{-1}	
		Body weight of consumer	kg	
		Oral reference dose	mg kg^{-1} day^{-1}	
2.	Daily Intake of Metals (DIM)	Metal concentration in vegetables	mg day^{-1}	18
		Daily intake of vegetable	kg	
		Conversion factor	-	
3.	Health Risk Index (HRI)	Daily intake of vegetable	kg	19
		Oral reference dose	mg kg^{-1} day^{-1}	
4.	Metal Pollution Index (MPI)	Metal concentration in vegetables	mg day-1	20

Results and discussion

In this study, initially sites were selected for vegetable collection and then after families were chosen for survey. The survey was conducted at all the selected sites with almost 25 families per site. Initially face to face method was carried out for survey to buildup trust and reliability of data. The vegetable consumption data were collected from each site, i.e., Alipur, Shahdara, Mehrauli, Kanjhawala and Najafgarh through survey. From each site, 25 families were selected randomly to collect data (**Table 4** and **5**). In Alipur, Shahdara, Mehrauli, Kanjhawala and Najafgarh data of 103, 92, 99, 90 and 71 individuals were collected respectively regarding total vegetable consumption per week, total number of consumers, body weight and age. At all the sites, weight was measured but in calculation the average standard weight was used for male 55 kg and for female 45kg (**Table 6**). The oral reference doses of metals were already established by WHO, such as for As, Cd, Cr, Hg and Pb is 0.0003, 0.001, 0.003, 0.000035 and 0.0035 mg/kg bw/day respectively (**Table 7**) (USEPA IRIS, 2006). The moisture content in vegetables was 80, 95, 89, 91, 88 and 91% in potato, tomato, spinach, okra, carrot and mustard respectively. The conversion factor 0.085 was used to convert fresh weight of vegetables into dry weight.

Table 4 Number of families, family members and vegetable consumers at selected sites

Site	No. of family surveyed	Vegetable consumers
Alipur	25	92
Kanjhawala	25	82
Najafgarh	25	97
Mehrauli	25	85
Shahdara	25	70
Total	125	426

Table 5 Selected families and surveyed information

Site	Family surveyed	Total number of family member	Total number of non-vegetable consumer	Net vegetable consumer	Per capita/day consumption (kg)	Per capita consumption /day (kg/day)*
Alipur	25	103	Potato – 11, Okra – 22, Tomato – 0, Spinach – 20, Carrot – 11, Mustard - 30	Potato – 92, Okra – 81, Tomato – 103, Spinach – 83, Carrot – 92, Mustard - 73	Potato - 0.064, Okra - 0.039, Tomato - 0.053, Spinach - 0.039, Carrot – 0.045, Mustard – 0.039	0.279
Shahdara	25	92	Potato – 10, Okra – 2, Tomato – 0, Spinach – 3, Carrot – 0, Mustard -9	Potato – 82, Okra – 90, Tomato – 92, Spinach – 89, Carrot – 92, Mustard - 83	Potato – 0.057, Okra – 0.050, Tomato – 0.050, Spinach – 0.053, Carrot – 0.054, Mustard -0.048	0.314
Mehrauli	25	99	Potato – 2, Okra – 0, Tomato – 0, Spinach – 2, Carrot – 8, Mustard - 33	Potato – 97, Okra – 99, Tomato – 99, Spinach – 97, Carrot – 91, Mustard - 66	Potato – 0.053, Okra – 0.052, Tomato – 0.056, Spinach – 0.042, Carrot – 0.041, Mustard -0.048	0.291
Kanjhawala	25	90	Potato – 5, Okra – 3, Tomato – 0, Spinach – 2, Carrot – 6, Mustard - 15	Potato – 85, Okra – 87, Tomato – 90, Spinach – 88, Carrot – 84, Mustard - 75	Potato – 0.066, Okra – 0.058 Tomato – 0.050, Spinach – 0.042, Carrot – 0.048, Mustard -0.034	0.299
Najafgarh	25	71	Potato – 1, Okra – 5, Tomato – 4, Spinach – 3, Carrot – 2, Mustard - 49	Potato – 70, Okra – 66, Tomato – 67, Spinach – 68, Carrot – 69, Mustard - 22	Potato – 0.066, Okra – 0.051, Tomato – 0.053, Spinach – 0.044, Carrot – 0.061, Mustard -0.031	0.307

*This is the total amount of 6 selected vegetables consumed per capita per day

Table 6 Basic information for toxicity assessment

Parameter	Unit	Value
Average body weight	kg	Male – 55, Female – 45
Conversion factor	-	0.085
Male: Female ratio*	-	Alipur – 64: 39 Shahdara – 53: 39 Mehrauli – 65: 34 Kanjhawala – 55: 35 Najafgarh – 47: 24

*It is the ratio of male and female in selected 25 families member at each location

Table 7 Oral reference dose of heavy metals [20]

Heavy metals studied	Oral reference dose (RfD) (mg/kg bw/day)
As	0.0003
Cd	0.001
Cr	0.003
Hg	0.000035
Pb	0.0035

In Alipur, the total vegetable consumption per week was 41kg, 22kg, 38.5kg, 22.5kg, 29kg, and 20kg of potato, okra, tomato, spinach, carrot, and mustard respectively. The per capita per day consumption of leafy vegetable (mustard) is lowest (39g/day) and of root vegetable (potato) is highest (64g) at this site. At Alipur, the male: Female ratio was observed 64: 39. In Shahdara, the total vegetable consumption per week was 33kg, 31.7kg, 32.5kg, 33.3kg, 35kg, and 27.8kg of potato, okra, tomato, spinach, carrot, and mustard respectively. The per capita per day consumption of leafy vegetable (mustard) is lowest (48g/day) and of root vegetable (potato) is highest (57g) at this site. At Shahdara, the male: Female ratio was observed 53: 39. In Mehrauli, the total vegetable consumption per week was 36kg, 36kg, 38.5kg, 28.5kg, 26.3kg, and 22kg of potato, okra, tomato, spinach, carrot, and mustard respectively. The lowest and highest per capita per day consumption was found in the case of root vegetable (carrot) 41g/day and in fruit vegetable (tomato) 57g, respectively at this site. At Mehrauli, the male: Female ratio was observed 65: 34. All the data regarding to quantity of vegetables consumed per week and vegetable consumption order are presented in **Table 8**.

Table 8 Selected sites, quantity of vegetables consumed per week and vegetable consumption order

Site	Vegetable selected for study	Quantity of vegetables consumed per week (kg/week/25 families)	Order of vegetable consumption (kg/capita/day basis)
Alipur	Potato, Tomato, Okra, Carrot, Mustard and Spinach	Potato – 41, Okra – 22, Tomato - 38.5, Spinach - 22.5, Carrot – 29, Mustard - 20	Potato > Tomato > Carrot > Okra ≈ Spinach ≈ Mustard
Shahdara	Potato, Tomato, Okra, Carrot, Mustard and Spinach	Potato – 33, Okra - 31.75, Tomato - 32.5, Spinach - 33.25, Carrot – 35, Mustard - 27.75	Potato > Carrot > Spinach > Okra ≈ Tomato > Mustard
Mehrauli	Potato, Tomato, Okra, Carrot, Mustard and Spinach	Potato – 36, Okra – 36, Tomato - 38.5, Spinach - 28.5, Carrot - 26.25, Mustard - 22	Tomato > Potato > Okra > Mustard > Spinach > Carrot
Kanjhawala	Potato, Tomato, Okra, Carrot, Mustard and Spinach	Potato – 39, Okra - 35.5, Tomato - 31.5, Spinach – 26, Carrot - 28.5, Mustard - 18	Potato > Okra > Tomato > Carrot > Spinach > Mustard
Najafgarh	Potato, Tomato, Okra, Carrot, Mustard and Spinach	Potato - 32.5, Okra – 23.75, Tomato – 25, Spinach - 20.75, Carrot - 29.50, Mustard - 4.75	Potato > Carrot > Tomato > Okra > Spinach > Mustard

In Kanjhawala, the total vegetable consumption per week was 39kg, 35.5kg, 31.5kg, 26kg, 28.5kg, and 18kg of potato, okra, tomato, spinach, carrot, and mustard respectively. The lowest and highest per capita per day consumption was found in the case of leafy vegetable (mustard) 34g/day and in root vegetable (potato) 66g, respectively, at this site. At Kanjhawala, the male: Female ratio was observed 55: 35. In Najafgarh, the total vegetable consumption per week was 32.5kg, 23.7kg, 25kg, 20.7kg, 29.5kg, and 4.75kg of potato, okra, tomato, spinach, carrot, and mustard respectively. The lowest and highest per capita per day consumption was found in the case of leafy vegetable (mustard) 31g/day and in root vegetable (potato) 66g, respectively at this site. At Najafgarh, the male: Female ratio was observed 47: 24

Per capita per day consumption rate of selected vegetables was observed highest in the case of potato at all the sites except Mehrauli, where the tomato was consumed in higher amount (**Figure 2**). Tomato was second highest consumed vegetable at most of the sites. Mustard was consumed lowest at most of the sites except Mehrauli. The consumption order of selected vegetables given in Table 9. In selected vegetables, we observed that consumption of root vegetables especially potato was higher as compared to other vegetables. The consumption pattern of vegetables determines the risk assessment in further studies of heavy metals analysis. The type of vegetables consumption pattern also determines the requirement or demands some specific vegetables in particular.

During this survey, mostly focused on the face to face interaction process to collected the data required. The selection of a family is a most important thing for this survey process. The accurate data and information required should be come with reliable person, who engaged with household work. We mainly focused on women to collect information regarding to vegetable consumption. The standard questionnaires format and ease to applicability also determine the progress and swiftness of study. There are lot of hurdles in survey study such as repo and trust building, level of education of key person, reachability to the areas, transport facility and the existence of problem. Besides these hurdles, we have to overcome and focus to survey methodology with association to experts and population among which survey was conduct.

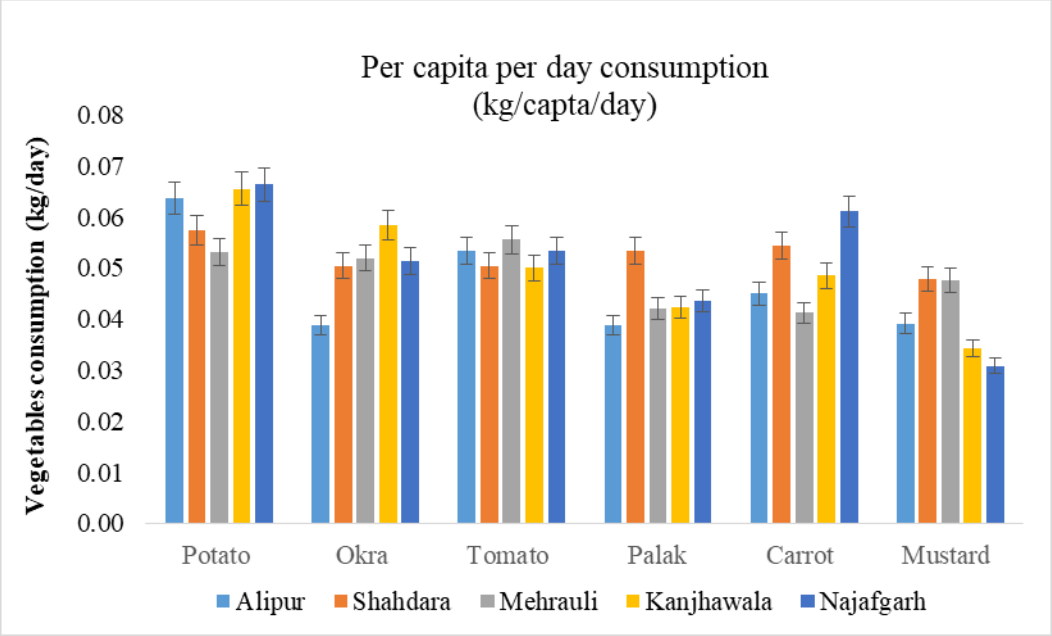

Figure 2 Per capita per day consumption rate of selected vegetables

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