BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL

SOUTHERN ZONE, CHENNAI

ORIGINAL APPLICATION NO.14 of 2024 (SZ)

[Earlier OA No. 685 of 2023 (PB)]

IN THE MATTER OF

In re: Suo-moto on News item appearing in One India dated 25.10.2023 titled "Vegetables Across Bengaluru Contaminated with Heavy Metals, Warns Study"

Vs

CPCB through its Member Secretary & Others

.....Respondents

INDEX

S. No	Particulars	Page No.
1.	STATUS REPORT ON THE ACTION TAKEN IN COMPLIANCE TO HON'BLE NGT ORDER DATED 21.11.2023 PASSED IN ORIGINAL APPLICATION NO. 685/2023 (PB) TITLED, "VEGETABLES ACROSS BENGALURU CONTAMINATED WITH HEAVY METALS WARNS STUDY	01-05
2.	**Annexure I:** Hon'ble NGT Order dated 21.11.2023	06-08
3.	**Annexure II:** Copy of the CPCB letter dated 04.12.2023 addressed to EMPRI	09-13
4.	**Annexure III:** Copy of the EMPRI Report entitled "Study of heavy metal concentrations in vegetables obtained from markets of Bengaluru City"	14- 78

COUNSEL FOR CPCB

18/03/2024

DEPONENT

J. Chandra Babu
REGIONAL DIRECTOR
CENTRAL POLLUTION CONTROL BOARD
REGIONAL DIRECTORATE - BENGALURU
(MIN.OF ENV,FOREST & CC, GOVT OF INDIA)
BENGALURU - 560 079. MOB: 9868278903

STATUS REPORT ON THE ACTION TAKEN IN COMPLIANCE TO HON'BLE NATIONAL GREEN TRIBUNAL (NGT) ORDER DATED 21.11.2023 PASSED IN ORIGINAL APPLICATION NO. 685/2023 (PB) and RENUMBERED AS ORIGINAL APPLICATION NO. 14/2024 (SZ) TITLED, "VEGETABLES ACROSS BENGALURU CONTAMINATED WITH HEAVY METALS WARNS STUDY"

1. **Background**

Hon'ble NGT (PB) registered the Original Application No. 685/2023 as *Suo motu* on the basis of the news item published in "One India" on 25.10.2023, titled "Vegetables Across Bengaluru Contaminated with Heavy Metals, Warns Study". The news item referred to the study conducted by Researchers from Environmental Management and Policy Research Institute (EMPRI), wherein 400 samples of 10 different vegetables were analysed and found the level of contamination by heavy metals exceeding the permissible limits set by the Food and Agricultural Organization (FAO). As per the news article, vegetables cultivated with wastewater have shown presence of heavy metals. The concentration of Iron and Cadmium in coriander and spinach, and Nickel in vegetables exceeded the permissible limits set by FAO.

In the aforesaid matter, the Hon'ble NGT vide order dated 21.11.2023 deemed it proper to implead the following organisations as respondents in the said OA:

1. Central Pollution Control Board (CPCB) through its Member Secretary.
2. Karnataka State Pollution Control Board (KSPCB) through its Member Secretary.
3. Environmental Management and Policy Research Institute (EMPRI) through its Director General.

Vide order dated 21.11.2023, Hon'ble NGT has given directions to Respondent No. 1 (CPCB) and relevant paragraph from the order is reproduced below:

> *"....8. Respondent No. 1 is directed to ascertain the correct ground situation and also duly examine the report of EMPRI and submit the factual status as also factual action taken report before the Southern Zone Bench of the Tribunal. Let the samples of vegetables be collected and analysed for the individual heavy metals and pesticides parameter in the Central Laboratory of CPCB, Delhi as per standard methods and let their report be furnished...."* A copy of the Hon'ble NGT order dated 21.11.2023 is annexed as **Annexure-1**

8/3/2024

J. Chandra Babu
REGIONAL DIRECTOR
CENTRAL POLLUTION CONTROL BOARD
REGIONAL DIRECTORATE - BENGALURU
(MIN.OF ENV,FOREST & CC, GOVT OF INDIA)
BENGALURU - 560 079. MOB: 9868278903

2. **Actions initiated by CPCB (Respondent No.1):**

In pursuant to the aforesaid Hon'ble NGT order dated 21.11.2023, CPCB, Regional Directorate, Bengaluru (RDB), sought a copy of the report from the EMPRI, Bengaluru vide letter dated 04.12.2023. A copy of the CPCB letter dated 4.12.2023 is given at **Annexure-2**.

The project report on "Study of heavy metal concentrations in vegetables obtained from markets of Bengaluru City" was received by the CPCB, RD Bengaluru, on 18.12.2023 from EMPRI vide letter dated 08.12.2023. A copy of the EMPRI study report is given as **Annexure-3**.

Subsequently, the report was examined and a meeting was convened by CPCB, Regional Directorate, Bengaluru on 26.12.2023 with the representatives from CPCB- Delhi, EMPRI, Karnataka State Pollution Control Board (KSPCB), and Food Safety and Standards Association of India (FSSAI), wherein the representative from EMPRI, Dr. Saritha Boya, Senior Consultant, made a brief presentation on the findings of the study before the participants.

3. **Comments on the project report submitted by EMPRI titled "Study of heavy metal concentrations in vegetables obtained from markets of Bengaluru City":**

The project report submitted by EMPRI was reviewed and clarifications were sought from the representative from EMPRI during the meeting held on 26.12.2023. The correct ground situation and comments on the said project report, based on the examination of the study report submitted by EMPRI and discussion held during the meeting held on 26.12.2023, are given below:

i. The sampling of vegetables was conducted during December-2021 to March-2022 from the retail, local, organic, and HOPCOMS in Bengaluru.

ii. The collected samples (one season samples) were analysed by following the tri-acid digestion method.

REGIONAL DIRECTORATE BENGALURU CENTRAL POLLUTION CONTROL BOARD MINISTRY OF ENVIRONMENT, FORESTS & CLIMATE CHANGE GOVT OF INDIA B'LURU-79 - 560079

18/3/2024

J. Chandra Babu
REGIONAL DIRECTOR
CENTRAL POLLUTION CONTROL BOARD
REGIONAL DIRECTORATE - BENGALURU
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iii. Draft Report on the study was finalised in November-2022 and placed in public domain on April-2023.

iv. The said research work was carried out only as a research based study on pilot plant scale using Atomic Absorption Spectroscopy.

v. Information regarding the sources of vegetable samples collected, water used for growing the vegetables and soil characteristics are not indicated in the report.

vi. Validation of the said project report is under process through a Committee constituted by EMPRI at present.

vii. The analysis results were compared with the standard prescribed by Food and Agricultural Organisation (FAO) and World Health Organization (WHO), but not with the standards prescribed by the Food Safety and Standards Association of India (FSSAI).

viii. As per the findings, amongst the 08 metals analysed in the study, 05 metals viz., Fe, Mn, Zn, Cu, and Ni were found to be within the permissible limits prescribed by FAO; whereas, the other 03 metals viz., Cr, Cd, and Pb exceeded the permissible limits prescribed by FAO as given in EMPRI study report.

ix. The methodology used for Heavy Metal analysis in the present study is not as per the FSSAI -Manual of Methods for Analysis of Foods –Metals published in 2016.

x. Also, during the course of the said research work at EMPRI, accreditation from the National Accreditation Board for Testing and Calibration Laboratories (NABL) was obtained only for water parameters (but not for the analysis of parameters related to food items).

18/3/2024

J. Chandra Babu
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xi. During the course of the said research work, EMPRI was not recognized by FSSAI. ***However, the heavy metals and pesticide analysis of samples need to be carried out only at FSSAI approved laboratories and to be compared only with the FSSAI prescribed standards notified by Ministry of Health and Family Welfare vide notifications dated 01/08/2011 and 24/12/2018.***

4. Actions proposed for comprehensive study:

In order to ascertain the correct ground situation with regard to the heavy metals and pesticides in vegetables, further comprehensive study is required. Keeping in view the fact that the CPCB laboratories are not recognised by FSSAI for analysis of vegetables, following action is proposed for carrying out the ibid comprehensive study as detailed below:

a. A committee comprising a member from the following organizations may be constituted by CPCB
    1. Regional Director, Central Pollution Control Board, Bengaluru
    2. Member of Karnataka State Pollution Control Board
    3. Member of Central Licensing Authority, Food Safety and Standards Association of India, Chennai
    4. Member of Indian Institute of Soil Science, Bhopal
    5. Member of University of Agricultural Sciences, Bengaluru

b. EMPRI shall explore feasibility of analysis of vegetable samples preserved with EMPRI since March 2022 at FSSAI approved laboratory and results be shared with CPCB.

c. Survey, sampling locations, sampling size, laboratory to be chosen for analysis of collected samples (vegetables, water/ground water and soil) to be decided by the Committee to be constituted by CPCB.

15/3/2024

J. Chandra Babu
REGIONAL DIRECTOR
CENTRAL POLLUTION CONTROL BOARD
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d. Analysis of the collected vegetable samples from the selected locations through FSSAI approved laboratory to be carried out following the due procedures under the overall supervision of the Committee.

e. Collation of analysis results, preparation and finalisation of the report to be filed before Hon'ble NGT, shall be completed by CPCB within a period of four months.

It is humbly submitted that the above proposed action for ascertaining on ground facts with regard to the exceedance of heavy metals and pesticides in vegetables obtained from markets of Bengaluru City is submitted for kind perusal and for consideration.

COUNSEL for CPCB

19/3/2024

DEPONENT

J. Chandra Babu
REGIONAL DIRECTOR
CENTRAL POLLUTION CONTROL BOARD
REGIONAL DIRECTORATE - BENGALURU
(MIN.OF ENV.FOREST & CC, GOVT OF INDIA)
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Item No. 01 Court No. 1

BEFORE THE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI

Original Application No. 685/2023

In re: News item appearing in One India dated 25.10.2023 titled **"Vegetables Across Bengaluru Contaminated with Heavy Metals, Warns Study"**

Date of hearing: 21.11.2023

CORAM: HON'BLE MR. JUSTICE PRAKASH SHRIVASTAVA, CHAIRPERSON
HON'BLE DR. A. SENTHIL VEL, EXPERT MEMBER

Respondent: Mr. Mukesh Kumar, Adv. for KSPCB (Through VC)
Mr. Rajat Jonathan Shaw, Adv. for the State of Karnataka (Through VC)

ORDER

1. This Original Application is registered *suo motu* on the basis of the news item published in "One India" on 25.10.2023 titled **"Vegetables Across Bengaluru Contaminated with Heavy Metals, Warns Study"**. The news item refers to a study by Researchers from Environment Managemental and Policy Research Institute (EMPRI), who had analysed 400 samples of 10 different vegetables and had found the level of contamination exceeding the permissible limits set by the Food and Agricultural Organization (FAO). As per the news article, vegetables cultivated with wastewater have shown presence of heavy metals. The concentration of iron was almost two times and in coriander and spinach, Cadmium which is a toxic heavy metal was found to be 52.30 mg/kg as against 0.2 mg/kg. Nickel exceeded 67.9 mg/kg in vegetables. The consumption of such vegetables is highly toxic and hazardous and can lead to various health complications.

2. On advance notice, a brief report has been filed on behalf of the Karnataka State Pollution Control Board (KSPCB) referring to the study report of EMPRI and its findings.

3. The report by KSPCB mentions that to understand the extent of contamination in vegetables, a more comprehensive and in-depth investigation/study involving its sources is necessary at State level.

4. The OA involves a serious issue relating to environment and compliance of the provisions of the scheduled Act.

5. Power of the Tribunal to take up the matter in *suo-motu* exercise of power has been recognized by the Hon'ble Supreme Court in the matter of *"Municipal Corporation of Greater Mumbai vs. Ankita Sinha & Ors." reported in 2021 SCC Online SC 897*.

6. Hence, at this stage, we deem it proper to implead the following as respondents in this OA:

i. Central Pollution Control Board through its Member Secretary.
ii. Karnataka State Pollution Control Board through its Member Secretary.
iii. Environmental Management and Policy Research Institute through is Director General.

7. Let the notice be served upon the Respondents No. 1 and 3 who are not represented today.

8. Respondent No. 1 is directed to ascertain the correct ground situation and also duly examine the report of EMPRI and submit the factual status as also factual action taken report before the Southern Zone Bench of the Tribunal. Let the samples of vegetables be collected and analysed for the individual heavy metals and pesticides parameters

in the Central Laboratory of CPCB, Delhi as per standard methods and let their report be furnished.

9. Since the matter relates to Southern Zone Bench, Chennai, therefore, the OA is transferred to the Southern Zone Bench, Chennai for further necessary action. Let the record of this OA be transferred to the Southern Zone Bench, Chennai.

10. List on 10.01.2024 before the Southern Zone Bench, Chennai.

Prakash Shrivastava, CP

Dr. A. Senthil Vel, EM

November 21, 2023
Original Application No. 685/2023
DV

केन्द्रीय प्रदूषण नियंत्रण बोर्ड
CENTRAL POLLUTION CONTROL BOARD
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय, भारत सरकार
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE, GOVT. OF INDIA

By Speed Post/E-mail

CM-13013/6/2023-TECH-RD-BENGALURU/726 4th December, 2023

To

The Director General
Environmental Management & Policy Research Institute (EMPRI)
Department of Forest, Ecology & Environment, Government of Karnataka
"Hasiru Bhavana", Doresanipalya Forest Campus
Vinayakanagara Circle, J.P. Nagar 5th Phase
Bengaluru 560 078, Karnataka

Sub: Hon'ble National Green Tribunal, Principal Bench, New Delhi order dated 21/11/2023 in case OA No. 685 of 2023 regarding " Vegetables Across Bengaluru Contaminated with Heavy Metals, Warns Study"

Sir,

The Hon'ble NGT, PB, New Delhi order dated 21/11/2023 in OA No. 685 of 2023 regarding " Vegetables Across Bengaluru Contaminated with Heavy Metals, Warns Study" passed following order:

".....Hence, at this stage, we deem it proper to implead the following as respondents in this OA:

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Contd...2/-

Since the matter relates to Southern Zone Bench, Chennai, therefore, the OA is transferred to the Southern Zone Bench, Chennai for further necessary action. Let the record of this OA be transferred to the Southern Zone Bench, Chennai. List on 10.01.2024 before the Southern Zone Bench, Chennai…" The copy of the order enclosed for information.

In view of above Hon'ble Tribunal order, it is kindly requested to arrange to provide a copy of the report of EMPRI (soft as well as hard copy) to examine and initiate further action from this office. A soft copy of the report shall be mailed to jcb.cpcb@nic.in and zobangalore.cpcb@nic.in , please .

Yours faithfully

(J. Chandra Babu)
Regional Director

Encl: As above

Item No. 01 Court No. 1

BEFORE THE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI

Original Application No. 685/2023

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Prakash Shrivastava, CP

Dr. A. Senthil Vel, EM

November 21, 2023
Original Application No. 685/2023
DV

STUDY OF HEAVY METAL CONCENTRATIONS IN VEGETABLES OBTAINED FROM MARKETS OF BENGALURU CITY

ENVIRONMENTAL MANAGEMENT & POLICY RESEARCH INSTITUTE (EMPRI)

Project Team

Dr.N.Hema, Aishwarya.P.B., Divya.D.R.

November, 2022

Acknowledgement

We would like to express our sincere gratitude to **Shri.R.K.Singh**, IFS, Former Director General, EMPRI and **Dr.Jagmohan Sharma,** IFS, Director General, EMPRI for providing us an opportunity to work on this project. We specially acknowledge his constant encouragement and kind support extended to us during the study.

We are ever grateful for the insights, comments and suggestions provided by **Dr.K.H.Vinayakumar**, IFS (R), EMPRI Fellow (Environment) for reviewing the project report. Special thanks to **Shri.Mahesh.T**, Technical Officer, EMPRI for his timely inputs and guidance during the project tenure.

We express our heartfelt thanks to **Dr.O.K.Remadevi**, Senior Consultant and Head, Department of Climate Change, EMPRI for her support during the execution and completion of the project.

We would also like to thank **Dr.Kalaivannan**, Principal Scientist, Indian Institute of Horticultural Research (IIHR), Bangalore for providing technical advice during the project.

We would like to thank **Ms.Ashwini.G** GIS Scientist and **Mr.Shivaraj.S,** Project Associate, GIS Division, EMPRI Bengaluru for mapping the study area of the project

Lastly, we would like to thank all the administrative, accounts, technical and non-technical staff of EMPRI for their timely help during the study.

List of Figures

List of Tables

EXECUTIVE SUMMARY

Industrialization and population growth has led to an increase in demand for food especially in urban areas. Farmers are under pressure to produce more crops to cater to an ever-increasing population in cities. The vegetable vendors prefer vegetables and especially greens, to be fresh and try to source them from farms located close to the cities and peripheries and usually in polluted areas. Owing to scarcity of water resources, farmers are resorting to irrigate their crops with untreated sewage and effluent. This unethical practice has increased the threat of toxic metal entry into the human bodies through a process called bioaccumulation in crops as well as humans leading to biomagnification.

The present study was conceptualized to estimate the concentration of heavy metals in vegetables obtained from various markets/stores in Bengaluru city. Samples of vegetables were collected randomly in duplicates from five different Retail Markets (Big Bazar - BTM Layout, Metro Cash & Carry - Kanakapura Road, Spar Vega City Mall - Bannerghatta Road, More Mega Mart - Bannerghatta Road and Reliance Fresh, Jayanagar), Local Markets (Malleshwaram, Yeshwantpur, Banashankari, Gandhi Bazar and K.R.Market), Organic Stores (Organic World -Vasanthanagar, Village Naturals - ISRO layout, Grameena Angadi - Rajajinagar, Namdhari's Fresh – Indiranagar and Desi Organics and Naturals - Vajrahalli, HOPCOMS (Lalbagh, Yelahanka, Shanthinagar, Hebbal and Raja Rajeshwarinagar). A total of ten vegetables namely Brinjal, Tomato, Capsicum, Bean, Carrot, Green Chilly, Onion, Potato, Spinach and Coriander were collected in pairs from each of these markets. Hundred samples were analyzed from each type of store/market (10 vegetables in duplicates = 20 x 5 stores/markets = 100 samples). A total of 400 vegetable samples were collected, processed and digested using pre-automated program in NuWav-Ultra Microwave Digestion Extraction System and analysed for heavy metals content (Cd, CO, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) using Shimadzu Atomic Absorption Spectrophotometer 6300 model. The results are represented as mg/kg dry weight.

The permissible limits of heavy metals (mg/kg) in vegetables as prescribed by FAO/WHO are; Cadmium - 0.2, Lead - 0.3, Nickel - 67.9, Iron - 425.5, Copper - 73.3, Zinc - 99.4, Chromium - 2.30, Manganese - 500. The concentration of heavy metals in vegetables varied in different stores. Among the Retail markets samples, Coriander was found to have highest concentration of Manganese (499.60 mg/kg) as against the permissible limit of 500 mg/kg and Iron (514.05 mg/kg) as against the permissible limit of 424.5 mg/kg in samples obtained from Big Bazar and Metro Cash and Carry. Spinach (256.20 mg/kg) and Potato (239.70 mg/kg) had higher concentration of Iron from samples obtained from Malleshwaram market. Beans obtained from Organic world had Iron concentration as high as 810.20 mg/kg. The Iron concentration in Coriander was 945.70 mg/kg and 554.58 mg/kg in Spinach obtained from Village Naturals. Among the HOPCOMS, Onion was found to have 592.18 mg/kg of Iron in samples obtained from Yelahanka and 448.45 mg/kg of Iron in Spinach obtained from Shanthinagar.

Reliance Fresh, Jayanagar showed the least concentration of heavy metals (Fe, Zn, Mn, Pb, Cu and Ni) in vegetables compared to the other four Retail stores. Among the local market samples, Banashankari market showed the least concentration of heavy metals (Fe, Zn, Mn, Pb, Cu and Ni) compared to the other four local markets whereas Desi Organics & Naturals and Namdhari's Fresh showed the lowest

concentration heavy metals (Fe, Mn, Pb, Cu, Ni and Cd) compared to the other three organic stores. The vegetable samples from HOPCOMS - Lalbagh showed the least concentration of heavy metals (Fe, Zn, Mn, Pb, Cu and Ni) compared to the other four stores.

The final insights to the study revealed that, out of twenty stores/markets belonging to four different categories (Retail stores, local markets, Organic stores and HOPCOMS) sampled for different vegetables in Bengaluru city, Desi Organics & Naturals, Vajrahalli and Namdhari's Fresh, Indiranagar were found to have lower concentration of heavy metals as compared to all other stores. Further, to understand the source of vegetables and its contamination in different stores/markets, a detailed study may be proposed. This would help us to reduce the exposure of vegetables to heavy metal contamination at the source and thereby reduce the health risk to humans.

It is very clear from the present study that the edible portion of the vegetables are hyperaccumulators of heavy metals. So, taking into consideration the health risks associated with consumption of these vegetables, it is suggested that vegetable cultivation should not use waste water as a source. The farmers should be made aware of toxic metal accumulations in greens and vegetables and their imminent threat to consumers. For the farmers who grow food crops, testing of soils and water should be mandated by the concerned regional agricultural department or pollution control board. More particularly, farmers, who grow these crops on either side of highways, must go for soil testing. Farmers should not resort to unethical farming practices such as irrigating the crops with drainage and effluent waters. It is advised to avoid eating spinach bought from the vegetable markets of the Bangalore. Instead, these greens can be grown organically at home in rooftop gardens, window gardens and balcony gardens. Farmers of the suburban areas should not be allowed by law to grow the greens and vegetables utilizing the drainage and effluent waters. A continuous monitoring is recommended to rule out toxic metal contamination in these greens and vegetables.

ಕಾರ್ಯನಿರ್ವಾಹಕ ಸಾರಾಂಶ

ಕೈಗಾರಿಕೀಕರಣ ಮತ್ತು ಜನಸಂಖ್ಯೆಯ ಬೆಳವಣಿಗೆಯು ವಿಶೇಷವಾಗಿ ನಗರ ಪ್ರದೇಶಗಳಲ್ಲಿ ಆಹಾರದ ಬೇಡಿಕೆಯಲ್ಲಿ ಹೆಚ್ಚಳಕ್ಕೆ ಕಾರಣವಾಗಿದೆ. ನಗರಗಳಲ್ಲಿ ಹೆಚ್ಚುತ್ತಿರುವ ಜನಸಂಖ್ಯೆಗೆ ಅನುಗುಣವಾಗಿ ಹೆಚ್ಚಿನ ಬೆಳೆಗಳನ್ನು ಉತ್ಪಾದಿಸುವ ಒತ್ತಡದಲ್ಲಿ ರೈತರು ಇದ್ದಾರೆ. ತರಕಾರಿ ಮಾರಾಟಗಾರರು ತಾಜಾವಾಗಿರಲು ತರಕಾರಿಗಳು ಮತ್ತು ವಿಶೇಷವಾಗಿ ಸೊಪ್ಪನ್ನು ಬಯಸುತ್ತಾರೆ ಮತ್ತು ಅವುಗಳನ್ನು ನಗರಗಳು ಮತ್ತು ಪರಿಧಿಗಳಿಗೆ ಸಮೀಪವಿರುವ ಮತ್ತು ಸಾಮಾನ್ಯವಾಗಿ ಕಲುಷಿತ ಪ್ರದೇಶಗಳಲ್ಲಿ ಇರುವ ಫಾರ್ಮ್‌ಗಳಿಂದ ಪಡೆಯಲು ಪ್ರಯತ್ನಿಸುತ್ತಾರೆ. ಜಲಸಂಪನ್ಮೂಲದ ಕೊರತೆಯಿಂದಾಗಿ ರೈತರು ತಮ್ಮ ಬೆಳೆಗಳಿಗೆ ಸಂಸ್ಕರಿಸದ ಕೊಳಚೆ ಮತ್ತು ಕೊಳಚೆನೀರಿನ ಮೂಲಕ ನೀರುಣಿಸಲು ಆಶ್ರಯಿಸುತ್ತಿದ್ದಾರೆ. ಈ ಅನೈತಿಕ ಅಭ್ಯಾಸವು ಬೆಳೆಗಳಲ್ಲಿ ಜೈವಿಕ ಸಂಚಯನ ಎಂಬ ಪ್ರಕ್ರಿಯೆಯ ಮೂಲಕ ಮಾನವ ದೇಹಕ್ಕೆ ವಿಷಕಾರಿ ಲೋಹದ ಪ್ರವೇಶದ ಬೆದರಿಕೆಯನ್ನು ಹೆಚ್ಚಿಸಿದೆ ಮತ್ತು ಮಾನವರಲ್ಲಿ ಜೈವಿಕ ವರ್ಧನೆಗೆ ಕಾರಣವಾಗುತ್ತದೆ.

ಪ್ರಸ್ತುತ ಅಧ್ಯಯನವು ಬೆಂಗಳೂರು ನಗರದ ವಿವಿಧ ಮಾರುಕಟ್ಟೆಗಳು/ಅಂಗಡಿಗಳಿಂದ ಪಡೆದ ತರಕಾರಿಗಳಲ್ಲಿ ಭಾರವಾದ ಲೋಹಗಳ ಸಾಂದ್ರತೆಯನ್ನು ಅಂದಾಜು ಮಾಡಲು ಪರಿಕಲ್ಪನೆಯಾಗಿದೆ. ತರಕಾರಿಗಳ ಮಾದರಿಗಳನ್ನು ಐದು ವಿಭಿನ್ನ ಚಿಲ್ಲರೆ ಮಾರುಕಟ್ಟೆಗಳಿಂದ (ಬಿಗ್ ಬಜಾರ್ - ಬಿಟಿಎಂ ಲೇಔಟ್, ಮೆಟ್ರೋ ಕ್ಯಾಶ್ ಮತ್ತು ಕ್ಯಾರಿ - ಕನಕಪುರ ರಸ್ತೆ, ಸ್ಪಾರ್ ವೇಗಾ ಸಿಟಿ ಮಾಲ್ - ಬನ್ನೇರುಘಟ್ಟ ರಸ್ತೆ, ಮೋರ್ ಮೆಗಾ ಮಾರ್ಟ್ - ಬನ್ನೇರುಘಟ್ಟ ರಸ್ತೆ ಮತ್ತು ರಿಲಯನ್ಸ್ ಫ್ರೆಶ್, ಜಯನಗರ) ನಕಲುಗಳಲ್ಲಿ ಯಾದೃಚ್ಛಿಕವಾಗಿ ಸಂಗ್ರಹಿಸಲಾಗಿದೆ. ಮಾರುಕಟ್ಟೆಗಳು (ಮಲ್ಲೇಶ್ವರಂ, ಯಶವಂತಪುರ, ಬನಶಂಕರಿ, ಗಾಂಧಿ ಬಜಾರ್ ಮತ್ತು ಕೆಆರ್‌ಮಾರ್ಕೆಟ್), ಸಾವಯವ ಮಳಿಗೆಗಳು (ಸಾವಯವ ಪ್ರಪಂಚ -ವಸಂತನಗರ, ವಿಲೇಜ್ ನ್ಯಾಚುರಲ್ಸ್ - ಇಸ್ರೋ ಲೇಔಟ್, ಗ್ರಾಮೀಣ ಅಂಗಡಿ - ರಾಜಾಜಿನಗರ, ನಾಮಧಾರಿ ತಾಜಾ - ಇಂದಿರಾನಗರ ಮತ್ತು ದೇಸಿ ಆರ್ಗ್ಯಾನಿಕ್ಸ್ ಮತ್ತು ನ್ಯಾಚುರಲ್ಸ್ , ಶಾಂತಿನಗರ, ಹೆಬ್ಬಾಳ ಮತ್ತು ರಾಜ ರಾಜೇಶ್ವರಿನಗರ). ಬದನೆಕಾಯಿ, ಟೊಮೆಟೊ, ಕ್ಯಾಪ್ಸಿಕಂ, ಬೀನ್ಸ್, ಕ್ಯಾರೆಟ್, ಹಸಿರು ಮೆಣಸಿನಕಾಯಿ, ಈರುಳ್ಳಿ, ಆಲೂಗಡ್ಡೆ, ಪಾಲಕ್ ಮತ್ತು ಕೊತ್ತಂಬರಿ ಹೀಗೆ ಒಟ್ಟು ಹತ್ತು ತರಕಾರಿಗಳನ್ನು ಈ ಪ್ರತಿಯೊಂದು ಮಾರುಕಟ್ಟೆಯಿಂದ ಜೋಡಿಯಾಗಿ ಸಂಗ್ರಹಿಸಲಾಗಿದೆ. ಪ್ರತಿ ಪ್ರಕಾರದ ಅಂಗಡಿ/ಮಾರುಕಟ್ಟೆಯಿಂದ ನೂರು ಮಾದರಿಗಳನ್ನು ವಿಶ್ಲೇಷಿಸಲಾಗಿದೆ (ನಕಲುಗಳಲ್ಲಿ 10 ತರಕಾರಿಗಳು = 20 x 5 ಅಂಗಡಿಗಳು/ಮಾರುಕಟ್ಟೆಗಳು = 100 ಮಾದರಿಗಳು). ನುವಾವ್-ಅಲ್ಟಾ, ಮೈಕ್ರೊವೇವ್ ಡೈಜೆಸ್ಟನ್ ಎಕ್ಸ್‌ಟ್ರಾಕ್ಷನ್ ಸಿಸ್ಟಮ್‌ನಲ್ಲಿ ಪೂರ್ವ-ಸ್ವಯಂಚಾಲಿತ ಪ್ರೋಗ್ರಾಂ ಅನ್ನು ಬಳಸಿಕೊಂಡು ಒಟ್ಟು 400 ತರಕಾರಿ ಮಾದರಿಗಳನ್ನು ಸಂಗ್ರಹಿಸಲಾಗಿದೆ, ಸಂಸ್ಕರಿಸಲಾಗಿದೆ ಮತ್ತು ಜೀರ್ಣಗೊಳಿಸಲಾಗಿದೆ ಮತ್ತು ಹೆವಿ ಮೆಟಲ್‌ಗಳ ವಿಷಯಕ್ಕಾಗಿ (Cd, CO, Cr, Cu, Fe, Mn, Ni, Pb, ಮತ್ತು Zn) ವಿಶ್ಲೇಷಿಸಲಾಗಿದೆ.) ಶಿಮಾಡ್ಜು ಪರಮಾಣು ಹೀರಿಕೊಳ್ಳುವ ಸ್ಪೆಕ್ಟ್ರೋಫೋಟೋಮೀಟರ್ 6300 ಮಾದರಿಯನ್ನು ಬಳಸುವುದು. ಫಲಿತಾಂಶಗಳನ್ನು mg/kg ಒಣ ತೂಕ ಎಂದು ಪ್ರತಿನಿಧಿಸಲಾಗುತ್ತದೆ.

FAO/WHO ಸೂಚಿಸಿದಂತೆ ತರಕಾರಿಗಳಲ್ಲಿ ಭಾರೀ ಲೋಹಗಳ (mg/kg) ಅನುಮತಿಸುವ ಮಿತಿಗಳು; ಕ್ಯಾಡ್ಮಿಯಮ್ - 0.2, ಸೀಸ - 0.3, ನಿಕಲ್ - 67.9, ಕಬ್ಬಿಣ - 425.5, ತಾಮ್ರ - 73.3, ಸತು - 99.4, ಕ್ರೋಮಿಯಂ - 2.30, ಮ್ಯಾಂಗನೀಸ್ - 500. ತರಕಾರಿಗಳಲ್ಲಿನ ಭಾರವಾದ ಲೋಹಗಳ ಸಾಂದ್ರತೆಯು ವಿವಿಧ ಮಳಿಗೆಗಳಲ್ಲಿ ವಿಭಿನ್ನವಾಗಿದೆ. ಚಿಲ್ಲರೆ ಮಾರುಕಟ್ಟೆಯ ಮಾದರಿಗಳಲ್ಲಿ, ಕೊತ್ತಂಬರಿಯು

ಮ್ಯಾಂಗನೀಸ್ (499.60 mg/kg) 500 mg/kg ಮತ್ತು ಕಬ್ಬಿಣದ (514.05 mg/kg) ಅನುಮತಿಸುವ ಮಿತಿಯಾದ 424.5 mg/kg ಗೆ ವಿರುದ್ಧವಾಗಿ ಮ್ಯಾಂಗನೀಸ್ ಅನ್ನು ಹೊಂದಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಬಿಗ್ ಬಜಾರ್ ಮತ್ತು ಮೆಟ್ರೋ ಕ್ಯಾಶ್ ಮತ್ತು ಕ್ಯಾರಿಯಿಂದ ಪಡೆದ ಮಾದರಿಗಳು. ಮಲ್ಲೇಶ್ವರಂ ಮಾರುಕಟ್ಟೆಯಿಂದ ಪಡೆದ ಮಾದರಿಗಳಿಂದ ಪಾಲಕ್ (256.20 mg/kg) ಮತ್ತು ಆಲೂಗಡ್ಡೆ (239.70 mg/kg) ಕಬ್ಬಿಣದ ಹೆಚ್ಚಿನ ಸಾಂದ್ರತೆಯನ್ನು ಹೊಂದಿತ್ತು. ಸಾವಯವ ಪ್ರಪಂಚದಿಂದ ಪಡೆದ ಬೀನ್ಸ್‌ನಲ್ಲಿ ಕಬ್ಬಿಣದ ಸಾಂದ್ರತೆಯು 810.20 mg/kg ವರೆಗೆ ಇತ್ತು. ಕೊತ್ತಂಬರಿಯಲ್ಲಿ ಕಬ್ಬಿಣದ ಸಾಂದ್ರತೆಯು 945.70 mg/kg ಮತ್ತು ಪಾಲಕ್ ಸೊಪ್ಪಿನಲ್ಲಿ 554.58 mg/kg ವಿಲೇಜ್ ನ್ಯಾಚುರಲ್ಸ್‌ನಿಂದ ಪಡೆಯಲಾಗಿದೆ. ಹಾಪ್‌ಕಾಮ್ಸ್‌ನಲ್ಲಿ, ಯಲಹಂಕದಿಂದ ಪಡೆದ ಮಾದರಿಗಳಲ್ಲಿ ಈರುಳ್ಳಿ 592.18 ಮಿಗ್ರಾಂ / ಕೆಜಿ ಮತ್ತು ಶಾಂತಿನಗರದಿಂದ ಪಡೆದ ಪಾಲಕ್‌ನಲ್ಲಿ 448.45 ಮಿಗ್ರಾಂ / ಕೆಜಿ ಕಬ್ಬಿಣವನ್ನು ಹೊಂದಿರುವುದು ಕಂಡುಬಂದಿದೆ.

ರಿಲಯನ್ಸ್ ಫ್ರೆಶ್, ಜಯನಗರವು ಇತರ ನಾಲ್ಕು ಚಿಲ್ಲರೆ ಅಂಗಡಿಗಳಿಗೆ ಹೋಲಿಸಿದರೆ ತರಕಾರಿಗಳಲ್ಲಿ ಭಾರ ಲೋಹಗಳ (Fe, Zn, Mn, Pb, Cu ಮತ್ತು Ni) ಕಡಿಮೆ ಸಾಂದ್ರತೆಯನ್ನು ತೋರಿಸಿದೆ. ಸ್ಥಳೀಯ ಮಾರುಕಟ್ಟೆ ಮಾದರಿಗಳಲ್ಲಿ, ಬನಶಂಕರಿ ಮಾರುಕಟ್ಟೆಯು ಇತರ ನಾಲ್ಕು ಸ್ಥಳೀಯ ಮಾರುಕಟ್ಟೆಗಳಿಗೆ ಹೋಲಿಸಿದರೆ ಭಾರ ಲೋಹಗಳ (Fe, Zn, Mn, Pb, Cu ಮತ್ತು Ni) ಕಡಿಮೆ ಸಾಂದ್ರತೆಯನ್ನು ತೋರಿಸಿದೆ ಆದರೆ ದೇಸಿ ಆರ್ಗಾನಿಕ್ಸ್ & ನ್ಯಾಚುರಲ್ಸ್ ಮತ್ತು ನಾಮಧಾರೀಸ್ ಫ್ರೆಶ್ ಕಡಿಮೆ ಸಾಂದ್ರತೆಯ ಭಾರ ಲೋಹಗಳನ್ನು ತೋರಿಸಿದೆ (Fe, Mn, Pb, Cu, Ni ಮತ್ತು Cd) ಇತರ ಮೂರು ಸಾವಯವ ಮಳಿಗೆಗಳಿಗೆ ಹೋಲಿಸಿದರೆ. HOPCOMS - ಲಾಲ್‌ಬಾಗ್‌ನ ತರಕಾರಿ ಮಾದರಿಗಳು ಇತರ ನಾಲ್ಕು ಮಳಿಗೆಗಳಿಗೆ ಹೋಲಿಸಿದರೆ ಭಾರ ಲೋಹಗಳ (Fe, Zn, Mn, Pb, Cu ಮತ್ತು Ni) ಕಡಿಮೆ ಸಾಂದ್ರತೆಯನ್ನು ತೋರಿಸಿದೆ.

ಅಧ್ಯಯನದ ಅಂತಿಮ ಒಳನೋಟಗಳು, ಬೆಂಗಳೂರು ನಗರದಲ್ಲಿನ ವಿವಿಧ ತರಕಾರಿಗಳಿಗೆ ನಾಲ್ಕು ವಿಭಿನ್ನ ವರ್ಗಗಳಿಗೆ (ಚಿಲ್ಲರೆ ಅಂಗಡಿಗಳು, ಸ್ಥಳೀಯ ಮಾರುಕಟ್ಟೆಗಳು, ಸಾವಯವ ಮಳಿಗೆಗಳು ಮತ್ತು ಹಾಪ್‌ಕಾಮ್‌ಗಳು) ಸೇರಿದ ಇಪ್ಪತ್ತು ಅಂಗಡಿಗಳು/ಮಾರುಕಟ್ಟೆಗಳು, ದೇಸಿ ಆರ್ಗ್ಯಾನಿಕ್ಸ್ ಮತ್ತು ನ್ಯಾಚುರಲ್ಸ್, ವಾಜರಹಳ್ಳಿ ಮತ್ತು ನಾಮಧಾರೀಸ್ ಫ್ರೆಶ್, ಇತರ ಎಲ್ಲ ಮಳಿಗೆಗಳಿಗೆ ಹೋಲಿಸಿದರೆ ಇಂದಿರಾನಗರದಲ್ಲಿ ಭಾರ ಲೋಹಗಳ ಸಾಂದ್ರತೆ ಕಡಿಮೆ ಇರುವುದು ಕಂಡುಬಂದಿದೆ. ಇದಲ್ಲದೆ, ವಿವಿಧ ಅಂಗಡಿಗಳು/ಮಾರುಕಟ್ಟೆಗಳಲ್ಲಿ ತರಕಾರಿಗಳ ಮೂಲ ಮತ್ತು ಅದರ ಮಾಲಿನ್ಯವನ್ನು ಅರ್ಥಮಾಡಿಕೊಳ್ಳಲು, ವಿವರವಾದ ಅಧ್ಯಯನವನ್ನು ಪ್ರಸ್ತಾಪಿಸಬಹುದು. ಮೂಲದಲ್ಲಿ ಹೆವಿ ಮೆಟಲ್ ಮಾಲಿನ್ಯಕ್ಕೆ ತರಕಾರಿಗಳನ್ನು ಒಡ್ಡಿಕೊಳ್ಳುವುದನ್ನು ಕಡಿಮೆ ಮಾಡಲು ಇದು ನಮಗೆ ಸಹಾಯ ಮಾಡುತ್ತದೆ ಮತ್ತು ಆ ಮೂಲಕ ಮಾನವರಿಗೆ ಆರೋಗ್ಯದ ಅಪಾಯವನ್ನು ಕಡಿಮೆ ಮಾಡುತ್ತದೆ.

ತರಕಾರಿಗಳ ಖಾದ್ಯ ಭಾಗವು ಭಾರವಾದ ಲೋಹಗಳ ಹೈಪರ್ಕ್ಯುಮ್ಯುಲೇಟರ್ಗಳು ಎಂದು ಪ್ರಸ್ತುತ ಅಧ್ಯಯನದಿಂದ ಸ್ಪಷ್ಟವಾಗಿದೆ. ಆದ್ದರಿಂದ, ಈ ತರಕಾರಿಗಳ ಸೇವನೆಯಿಂದ ಉಂಟಾಗುವ ಆರೋಗ್ಯದ ಅಪಾಯಗಳನ್ನು ಪರಿಗಣಿಸಿ, ತರಕಾರಿ ಕೃಷಿಗೆ ತ್ಯಾಜ್ಯ ನೀರನ್ನು ಮೂಲವಾಗಿ ಬಳಸಬಾರದು ಎಂದು ಸೂಚಿಸಲಾಗಿದೆ. ಹಸಿರು ಮತ್ತು ತರಕಾರಿಗಳಲ್ಲಿ ವಿಷಕಾರಿ ಲೋಹದ ಶೇಖರಣೆ ಮತ್ತು ಗ್ರಾಹಕರಿಗೆ ಅವುಗಳ ಸನ್ನಿಹಿತ ಅಪಾಯದ ಬಗ್ಗೆ ರೈತರಿಗೆ ಅರಿವು ಮೂಡಿಸಬೇಕು. ಆಹಾರ ಬೆಳೆಗಳನ್ನು ಬೆಳೆಯುವ ರೈತರಿಗೆ, ಸಂಬಂಧಿಸಿದ ಪ್ರಾದೇಶಿಕ ಕೃಷಿ ಇಲಾಖೆ ಅಥವಾ ಮಾಲಿನ್ಯ

ನಿಯಂತ್ರಣ ಮಂಡಳಿಯಿಂದ ಮಣ್ಣು ಮತ್ತು ನೀರಿನ ಪರೀಕ್ಷೆಯನ್ನು ಕಡ್ಡಾಯಗೊಳಿಸಬೇಕು. ನಿರ್ದಿಷ್ಟವಾಗಿ ಹೇಳುವುದಾದರೆ, ಹೆದ್ದಾರಿಗಳ ಎರಡೂ ಬದಿಗಳಲ್ಲಿ ಈ ಬೆಳೆಗಳನ್ನು ಬೆಳೆಯುವ ರೈತರು ಮಣ್ಣು ಪರೀಕ್ಷೆಗೆ ಹೋಗಬೇಕು. ರೈತರು ಅನೈತಿಕ ಬೇಸಾಯ ಪದ್ಧತಿಗಳನ್ನು ಆಶ್ರಯಿಸಬಾರದು, ಉದಾಹರಣೆಗೆ ಒಳಚರಂಡಿ ಮತ್ತು ಕೊಳಚೆ ನೀರಿನಿಂದ ಬೆಳೆಗಳಿಗೆ ನೀರುಣಿಸುವುದು . ಬೆಂಗಳೂರಿನ ತರಕಾರಿ ಮಾರುಕಟ್ಟೆಯಿಂದ ಖರೀದಿಸಿದ ಪಾಲಕ್ ಸೊಪ್ಪನ್ನು ತಿನ್ನುವುದನ್ನು ತಡೆಯಲು ಸಲಹೆ ನೀಡಲಾಗುತ್ತದೆ. ಬದಲಾಗಿ, ಈ ಸೊಪ್ಪನ್ನು ಮನೆಯ ಮೇಲ್ಛಾವಣಿ ತೋಟಗಳು, ಕಿಟಕಿ ತೋಟಗಳು ಮತ್ತು ಬಾಲ್ಕನಿ ತೋಟಗಳಲ್ಲಿ ಸಾವಯವವಾಗಿ ಬೆಳೆಸಬಹುದು . ಉಪನಗರ ಪ್ರದೇಶದ ರೈತರು ಒಳಚರಂಡಿ ಮತ್ತು ಹೊರಹರಿವಿನ ನೀರನ್ನು ಬಳಸಿಕೊಂಡು ಹಸಿರು ಮತ್ತು ತರಕಾರಿಗಳನ್ನು ಬೆಳೆಯಲು ಕಾನೂನಿನಲ್ಲಿ ಅನುಮತಿಸಬಾರದು . ಈ ಗ್ರೀನ್ಸ್ ಮತ್ತು ತರಕಾರಿಗಳಲ್ಲಿ ವಿಷಕಾರಿ ಲೋಹದ ಮಾಲಿನ್ಯವನ್ನು ತಳ್ಳಿಹಾಕಲು ನಿರಂತರ ಮೇಲ್ವಿಚಾರಣೆಯನ್ನು ಶಿಫಾರಸು ಮಾಡಲಾಗಿದೆ.

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Heavy metals contamination in edible parts of vegetables is presently a challenging environmental issue worldwide. The present study determined the accumulated amount of Cadmium (Cd), Lead (Pb), Nickel (Ni), Zinc (Zn), Copper (Cu), and Manganese (Mn) and Iron (Fe) in ten vegetables namely Brinjal, Coriander, Spinach, Capsicum, Green Chilly, Onion, Carrot, Potato, Tomato and Beans obtained from five retail stores, local markets, organic stores and HOPCOMS of Bengaluru city. The samples were digested using tri-acid solution prior to heavy metals analysis by atomic absorption spectrometric method. Among the samples obtained from Retail Stores, Chromium was found to be in higher concentration in all vegetable samples (320.0 - 422.2 mg/kg) except in Potato and Beans in Spar store. Manganese was found in higher concentration in samples (159.7 - 499.7 mg/kg) except in Brinjal and Spinach and Cadmium was found in higher concentration (52.18 - 54.68 mg/kg) in all vegetables except Carrot in samples obtained from Big Bazar. Lead concentration was found to be higher in all vegetable samples obtained from Yeshwanthpur local market (131.7 - 175.15 mg/kg). In the vegetable samples obtained from Organic Stores, the concentration of Cadmium, Nickel and lead were below detectable limit. Among the vegetable samples collected from HOPCOMS, Lead concentration was below detectable limit in samples collected from Lalbagh, Yelahanka and Shanthinagar stores whereas Nickel concentration was below detectable limit in samples obtained from all areas. Therefore, it is recommended that the concentration of heavy metals in crops and its related health risks be regularly monitored to avoid significant health risks in the future.

10. Keywords: Markets/stores, vegetables, tri-acid digestion, heavy metals analysis
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1.0 INTRODUCTION

1.1 Background

Metals are found all over the earth, including the atmosphere, earth crust, and water bodies, and can also accumulate in biological organisms, including plants and animals. Heavy metals have a high specific density and an atomic weight greater than 40.04. They are distributed in the environment by natural processes such as volcanic eruptions, spring waters, erosion, and bacterial activity, as well as by anthropogenic activities such as fossil fuel combustion, industrial processes, agricultural activities, and feeding (Florea et al., 2004). Rapid urbanisation and industrialization have raised heavy metal levels in the environment and, as a result, in the food chain.

Vegetables are a major portion of the human diet, providing micro and macronutrients, fibers, vitamins etc., In addition, a wide range of antioxidants such as ascorbic acid, carotenoids, tocopherols, glutathione, phenolic acids, and flavonoids are found in vegetables (Sara et al, 2005) that are known to have positive effects on human health as they play a crucial role in preventing a number of chronic diseases (Agarwal et al., 2007). Vegetables can grow on all types of land, which is commonly contaminated with heavy metals. Depending on the vegetables, some of them have a greater potential to accumulate higher concentrations of heavy metals than others. That may have an impact on human health by consuming contaminated food. Differential plant tolerance to heavy metals is the cause of the leafy vegetables' varying metal uptake rates (Itanna, 2002). Leafy greens have a higher accumulator of metal ions than root vegetables and legumes (Alexander et al., 2006). Some heavy metals, such as cobalt, chromium, copper, magnesium, iron, molybdenum, manganese, selenium, nickel, and zinc, are essential nutrients that are required for various physiological and biochemical functions in the body and may result in deficiency diseases or syndromes if inadequate amounts but then in large doses they can cause acute or chronic toxicities. Long term accumulation of heavy metals in the body may result in slowing the progression of physical, muscular and neurological degenerative processes that mimic certain diseases such as Parkinson’s disease and Alzheimer’s disease (Jaishankar et .al, 2014).

Heavy metal contamination is a matter of serious concern in different countries of the world (Khalid et.al. 2021). Linked with environmental pollution, water pollution is also a problem of worldwide concern and ground water is extremely polluted due to unplanned disposal of untreated domestic sewage and industrial effluents into watercourses (Mashiatullah et al., 2005). Long-term irrigation with waste water could result in heavy metal toxicity in agricultural plants and soils. Potential difficulties with food safety are among the most serious issues due to the health dangers in the environment (Cui et al. 2004). A heavy metal is any metallic element that has a relatively high density and is toxic or poisonous even at low concentrations.

The uptake and bioaccumulation of heavy metals in vegetables are influenced by a number of factors such as climate, atmospheric depositions, the concentrations of heavy metals in soil, the nature of soil on which the vegetables are grown and the degree of maturity of the plants at the time of harvest (Lake et al.,

1984; Scott et al., 1996; Voutsa et al., 1996). Air pollution may pose a threat to post-harvest vegetables during transportation and marketing, causing elevated levels of heavy metals in vegetables are reported from the areas having long-term uses of treated or untreated wastewater (Sinha et al., 2005; Sharma et al., 2006, 2007). Other anthropogenic sources of heavy metals include the addition of manures, sewage sludge, fertilizers and pesticides, which may affect the uptake of heavy metals by modifying the physico-chemical properties of the soil such as pH, organic matter and bioavailability of heavy metals in the soil. Whatmuff (2002) and McBride (2003) found that increasing concentrations of heavy metals in soil increased the crop uptake.

Heavy metals are significant environment pollutants and their toxic response is a problem of increasing implication meant for ecological, evolution, nutritional and environmental reasons concern Enhancement of heavy metals concentration in soil can be characteristic to contribution of effluent from waste water treatment structure, mining, industries, power or energy stations and farming of crops (Jaishankar M, et.al 2014). Heavy metals are extremely persistent environmental contaminants. Mostly they are non-thermo degradable as well as non-biodegradable in features therefore readily accumulate to toxic levels (Hazrat Ali, et.al 2019).

Increasing industrialization has been accompanied throughout the world by the extraction and distribution of mineral like substances from their normal deposits. Different other pollutants also associated with the environments, due to non-biodegradable nature of metals and they can undertake bio magnifications in living beings (Alengebawy, A et.al 2021). Uptake and accumulation of heavy metals by plants is either via the roots and foliar surfaces. Some other factors which also affect the uptake of metals include soil pH, solubility of metal, soil nature of conductivity, different phases of plant growth and types of plant species. (Alengebawy, A et.al 2021).

Industrial wastewater contains high range of heavy metals that may pollute the environment once it is discharged to the nature. Metals are mostly including like As, Cr, Co, Zn, Al, Cd, Pb, Fe, Ni, Hg and Ag. (Kinuthia et. Al 2020) They are some of the most toxic types of water pollutants" at least 20 metals are considered to be toxic, in addition to approximately half of these metals are emitted to the environment in quantities that are hazardous to the environment, additionally to the health of mankind. Many people could be at hazard of adverse health effects from consuming vegetables developed in contaminated soil areas.

Many investigators have exposed that several vegetables are capable of accumulating rich ranges of metals from the soil or water". Heavy metals are one of a range of significant category of contaminants that can be established on the surface along with in tissues of fresh vegetables. Heavy metals, such as Cd, Cr, Pb. Co and Hg are environmental pollutants, particularly in areas under imitation with wastewater. Contamination of heavy metal in agricultural soils may lead to the disorder of soil functionality and

retardation of plant growth and influence the human health from side to side a contaminated food chain"(Kinuthia et. Al 2020)**.** Soils may become contaminated by accumulation of metalloids and heavy metals through emissions from the speedily expanding areas of industries, mine tailings, high metal wastes disposal, leaded gasoline, paints, and application of fertilizers on land, sewage sludge pesticides, wastewater irrigation and residues of coal combustion, petrochemicals spillage, and atmospheric deposition"(Alengebawy, A et.al 2021). Biochemical progressions can assemble to heavy metals so they polluted the water supplies and in directly showed the impact on food chains. Potential soil and water pollutants concern heavy metals are Cu. Cr. Cd. Ni and Pb".

1.2 Toxic impacts of heavy metals

According to scientific evidence, heavy metals are toxic. At a lower range, it plays a vital role in the metabolism of a cellular system, whereas at a higher range, it becomes toxic, and thus these elements are called trace elements. After interacting with water, soil, and air, heavy metals can become highly poisonous, and humans and other living organisms can be exposed to them through the food chain (Jaishankar, M. et.al 2014).

Cadmium (Cd)

Cd is a byproduct of the formation of Zn, and it is a dangerous element because it can be absorbed through the digestive tract, easily cross the placenta during pregnancy, and damage DNA. Cd accumulation at higher concentrations is also subject to the bio remediation phenomena associated with Cd and soil. "Chronic Cd exposure can lead to acute liver and lung toxicity, induce renal toxicity and impair immune system function."

Lead (Pb)

Lead (Pb) is one of a limited class of elements that can be described as purely toxic. Pb spreading has caused extensive environmental pollution in addition to health problems. Pb is a collective toxicant that affects multiple body systems and is found at low levels in the earth's crust. Pb has a number of known levels which have shown significant responses in the body. Studies on animals investigate the mechanism of toxicity of Pb and it is found that there is no evidence shown threshold to exposure". Lead (Pb) can enter your body through breathing Pb-contaminated air. “The toxicity of Pb is monitored in the body system by encephalopathies in the central nervous system (CNS), impacts of Pb on children's behavior, abortion and preterm delivery in women, and alterations in sperm and declination of fertility in men.

Zinc (Zn)

Zinc is an important and necessary element for human nutrition, working as a co-factor for more than 300 enzymes and their activities. Zn is found in all tissues and various functioning enzymes. Zn participates in catalytic functions of enzymes, the maintenance of structural stability and regulatory functions. Zn is also involved in DNA and RNA synthesis and cell proliferation anhydrase activity. The body contains 1.5-

2.5g of Zn. Deficiency of Zn affects the reproduction process in both males and females due to the alteration in hormones status and a range of enzymes which involved in reproduction. Large amount of Zn intake reduces Cu and Fe utilization and vitamin A. Zn also accumulated along with Cd with more interaction in plant and in rhizoid bacterial species on the process of metal uptake.

Chromium (Cr)

Chromium (Cr) is mostly found in rocks, soil layers, animals and plants. Cr can be solid, liquid and in the form of gas. Cr compounds are very much persistent in water sediments. They can occur in many different forms such as divalent Cr, tetra valent Cr, penta valent Cr and hexavalent state. Cr (VI) and Cr (III) are the most stable forms and only their relation to human exposure is of high interest. The Cr supplementation could result in potentiating of insulin sensitivity in the redistribution of body fat, protein and water. Exposure of higher amounts of Cr compounds in humans can lead to the inhibition of erythrocyte glutathione reductase activity directly which in turn lowers the capacity to reduce methemoglobin to hemoglobin. Cd sorption and transport process is easily possible in varieties of soils with different metal contents.

Copper (Cu)

Copper is critical for energy production in the cells. It is also involved in conduction of nerve, connective tissue, the cardiovascular system and the immune system. Cu is closely related to estrogen metabolism, and is required for women's fertility and to maintain pregnancy. The deficiency of Cu effect upon thyroid function, anticipated vascular lesions, central nervous system disorder and convulsion, hair abnormalities. Higher concentration of Cu decreased the hemoglobin and erythrocyte levels, death and cancer". The Cu micronutrient activates the normal plant growth. Cu is strongly bound to soils it is very immobile in nature therefore plant roots are frequently higher in Cu content than other plant tissues. Duration of time and moisture content directly affect to the bioavailability of Cu in the soil.

Iron (Fe)

Iron (Fe) is a trace mineral because body requires in very small amounts. Every tissue in the body and numerous cellular mechanisms need Fe. The metal is a part of hemoglobin in red blood cells that help in the oxygen transport and storage. Fe content is responsible for neurotransmitters functions, hormone synthesis and process of detoxification. Fe causes anemia, shortness of breath, overweight in children and adolescents. High doses of Fe can decrease the absorption of Zn and caused liver cancer and heart disease. Fe is essential for chlorophyll and protein formation, photosynthesis mechanism, electron transfer process, oxidation and reduction of nitrates and sulphate along with the activities of enzymes. Fe is one of the potential nutrients for plant growth and development.

Manganese (Mn)

Manganese is naturally occurring element found in rock, soil, water and food. In humans, manganese is an essential nutrient that plays a role in bone mineralization, protein and energy metabolism, metabolic regulation, cellular protection from damaging free radical species and formation of glycosaminoglycans. Mild or unnoticeable effects may be caused by low but physiologically excessive amounts of manganese and these effects appear to increase in severity as the exposure level or duration of exposure increases. Chronic exposure leads to permanent neurological damage, inability to perform rapid hand movements and some loss of co-ordination and balance. Symptoms of forgetfulness, anxiety or insomnia are also noticed. (www.ncbi.nlm.nih.gov).

Nickel (Ni):

Nickel fumes can irritate the lungs and lead to pneumonitis. In people who are sensitive to nickel and its compounds, exposure to these substances can cause the development of "nickel itch," dermatitis. Itching is typically the initial sign, and it can last for up to 7 days before a skin eruption starts. Erythematous or follicular skin eruption is the initial skin eruption, and skin ulceration may follow. Once developed, nickel sensitivity seems to last forever. Power plants and waste incinerators emit nickel into the air. Once it settles or falls to the ground, raindrop reactions cause it to do so. The removal of nickel from the air typically takes a long period.

1.3 Sources of Vegetables to Bangalore city

Earlier Bengaluru city used to get its vegetables from K R Puram and other villages surrounding the city. Now the city has grown from 250 sq km to 850 sq km in area. The population has almost reached a crore, and the demand for vegetables too has gone up multiple times. Bengaluru is the city that consumes the most vegetables in Karnataka, as almost a fifth of the state's population resides here. The city on a daily basis gets around 2,000 tonnes of vegetables.

Vegetable supply to the city is managed through multiple channels - HOPCOMS (Horticultural Producers' Cooperative Marketing and Processing Society Limited), APMC (Agricultural Produce Market Committee) and other informal markets supply vegetable through farmers' networks from various cities. Besides, recent changes in the government rules facilitate direct selling of vegetables from farmers, to retailers or consumers. HOPCOMS presently covers Bengaluru Urban, Kolar, Chikkaballapur, Ramnagar and Bengaluru Rural. Everyday over 70 tonnes of vegetable and fruits are supplied to the city through HOPCOMS alone. HOPCOMS has its own shops from where it sells vegetables at a fixed price. Companies like Namdharis grow vegetables in their own land using the methods of organic farming. It is different in other stores like Reliance Fresh, Food World or More Mega Mart. Some of them get their stock of vegetables from HOPCOMS, RMC or APMC yard. Sometimes they buy it directly from farmers in Devanahalli, Chickballapur and Kolar. According to the comprehensive data generated from Horticulture Department through various sources and methods, few vegetables exclusively come from selected places, due to the nature of the land and atmosphere.

(https://bengaluru.citizenmatters.in/bangalore-vegetable-supply-chain-6920#:~:text=Vegetables%20come%20from%20places%20like,Sulibele%2C%20Chintamani%20and%20Kolar.%E2%80%9D).

2.0 LITERATURE REVIEW

2.1 Sources of Heavy Metals in Vegetables

Heavy metal contamination of an ecosystem is one of the major and most widely discussed ecotoxicological problems. Some heavy metals (Cu, Fe, Ni, Zn, Mn, etc.) are essential for the growth and development of plants when present in trace amounts, but at excessive concentrations these become toxic. Both natural and anthropogenic sources are responsible for increasing the levels of heavy metals in the environment. Natural sources include parent geologic rock material, volcanic outcropping, spontaneous contributions or forest fires, whereas anthropogenic sources include sew- age sludge, pesticides, organic matter, composts, fertilizer supplements (Lopez-Alonso *et al*. 2000; Singh and Agrawal 2007), industrial waste, mining, smelting and metallurgical industries (Singh 2001) and use of treated or untreated in- dustrial and municipal effluents for irrigation purposes (Barman *et al*. 2000; Singh *et al*. 2004; Mapanda *et al*. 2005; Singh and Kumar 2006; Sharma *et al*. 2006, 2007). In Mexico, mining activities have caused considerable in- crease in concentrations of As, Ni, Co and Cu in the soil (Razo *et al*. 2004). Mining and smelting processes have also contaminated wide areas of Japan, Indonesia and China with Cd, Cu and Zn (Herawati *et al*. 2000). Agricultural practices like the use of pesticides, fungicides and organic and inorganic fertilizers have increased the concentrations of heavy metals (Cd, Ni, Mn, Co and Cu) in the top layer of the soil and consequently in crops via their uptake (McBride 2003).

Aerosols also cause heavy metal contamination of Cd, Pb, Zn, Cr and Ni in soil through atmospheric deposition, which are consequently absorbed and accumulated by plants or get adsorbed on aerial surfaces of the plants (Tem- merman and Hoenig 2004). Energy supplying power sta- tions such as coal burning power plants, petroleum combus- tion, nuclear power stations and high-tension electric lines also contribute heavy metals (Se, B, Cd, Cu, Zn, Cs and Ni) to the environment (Verkleij 1993). Electricity supply like power lines/cables contributed to 31% of the total antimony, 42% of the total cadmium, 38% of the total cobalt and 43% of the total Hg in ambient air in Australia. Metal ore mining also contributed substantially to the reported emission of metallic ions such as beryllium (93%), chromium VI (26%), copper (60%), manganese (~100%), and nickel (74%). Sew- age and drainage services in Australian states and territories contributed about 32% and hospitals about 36% of the total heavy metal contamination. Petroleum refining was a major contributor of chromium III compound emission (about 85%; NPI 2001). Vegetable-growing areas, mostly situated in or near the smelters such as Boolaroo and Port Kembla, have an elevated risk of potential contamination. These smelters are an important source of Pb pollution which can affect human health (Kachenko and Singh 2006).

2.2 Accumulation of Heavy Metals in Vegetables

Literature on contamination and accumulation of heavy metals in leafy and non-leafy vegetables from different sources has been widely reported in the past studies by researchers. Concentrations of heavy metals in vegetables varied from below the detection limit to above the safe limits depending upon the sources of heavy metal contamination. Vegetable samples were collected from two different agricultural lands of Greece irrigated by municipal, domestic and some industrial discharges (Stalikas *et al*. 1997). Among all the metals (As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, V and Zn), higher concentrations of Cd, Cu, and Pb (0.043, 2.45, and 0.134 mg kg^{-1}, respectively) were found in Spinach plants than in other leafy and non-leafy vegetables.

Dogheim *et al*. (2004) assessed the heavy metal concentrations in leafy vegetables and some aromatic medicinal plants from local markets of Egypt. Leafy vegetables were found to be contaminated by heavy metals more frequently than other vegetables. Among the total samples about 97% of the leafy vegetables were contaminated with heavy metals and 39% of leafy vegetables exceeded the maximum limits established for Cd, Cu and Pb. Cu was accumulated more frequently in leafy vegetables, being recorded in 97% of the samples. A greater ac- cumulation of heavy metals in the leaves of leafy vegetables may be due to their higher biomass accumulation as compared to other parts such as stem, root and fruits. The higher uptake of heavy metals in leafy vegetables is due to higher transpiration rate of plant to maintain the growth and moisture content of plant (Tani and Barrington 2005).

Atmospheric deposition also contributes to elevating the levels of heavy metals in vegetables. In a study done by Jassir *et al*. (2005) the vegetable samples were randomly divided into two fractions. The first fraction was soaked in tap water for 15 minutes to remove the soil impurities, and then washed twice. The second fraction was subjected to digestion without washing and hence labeled as unwashed samples then analyzed the heavy metal concentrations in the edible portions of commonly consumed green leafy vegetables *Coriandrum sativum* (coriander), watercress, parsley, *Portulaca oleracea* (purslane) and lettuce collected from different selling points at Riyadh city in Saudi Arabia before and after washing with tap water. Collectively in all the leafy vegetables the reductions due to washing of the samples were about 41% for Pb, 26% for Cd, 42% for Cu and 24% for Zn. The order of levels for Pb concentration in washed samples from highest to lowest was coriander > lettuce > purslane > watercress > parsley > garden rocket. The concentrations of Cu (20.18 mg kg^{-1}) and Zn (41.93 mg kg^{-1}) were highest in purslane and Cd (0.384 mg kg^{-1}) in garden rocket. Cd accumulation was more in leafy vegetables than in other vegetables.

Singh and Kumar (2006) assessed heavy metal concentrations in vegetables spinach and *Abelmoschus esculentus* L. (lady's finger) grown in peri urban areas of Delhi (India), contaminated with heavy metals through industrial effluents, sewage sludge and vehicular emission. Results showed that

the concentrations of heavy metals (mg kg^{-1}) varied from 7 to 50 for Cu, 51 to 282 for Zn, 1.4 to 9.0 for Cd and 1.7 to 9.2 for Pb in spinach and in lady's finger it varied from 12 to 29 for Cu, 39 to 156 for Zn, 0.4 to 6.0 for Cd and 0.8 to 7.3 for Pb. It was further observed that the accumulation of all the heavy metals was higher in *S. oleracea* compared to *A. esculentus*. This difference is due to the physiology and morphology of plants like variation in root interception of metal ions, variation in entry of the metal ions through mass flow and diffusion and translocation of metal ions from the root to shoot, their accumulation tendency and retention capacity (Carlton-Smith and Davis 1983).

The study conducted by Sharma *et al*. (2006) in suburban areas of Varanasi, India, where the use of treated and untreated wastewater is one of the most common agronomic practices, showed that the concentration of heavy metals (mg kg^{-1}) in the edible portion of vegetables including *Spinacia oleracea* (palak), lady's finger, *Solanum melongena* (brinjal), amaranthus, *Lycopersicon esculentus* (tomato) and cabbage collected in late autumn ranged between 0.55 and 10.30 for Cu, 29.35 and 469.45 for Zn, 1.55 and 6.90 for Cd, 9.00 and 28.0 for Pb, 4.05 and 15.0 for Ni, and 2.75 and 51.15 for Cr. Palak accumulated more Cu, Cr, Pb, Ni and C d than amaranthus and cabbage. Among different metals, Cu and Cr concentrations were found to be higher in leafy vegetables (Palak, Amaranthus and Cabbage) than in non- leafy vegetables (brinjal, lady's finger and tomato). In the edible portion of palak, the concentrations of heavy metals (mg kg^{-1}) varied from 10.95 to 28.58 for Cu, 2.22 to 41.51 for Zn, 0.5 to 4.36 for Cd, 3.09 to 15.74 for Pb, 1.81 to 7.57 for Ni and 5.37 to 27.83 for Cr. The study showed that Zn, Cr and Mn concentration in plants are influenced by seasonal variations. At the Dinapur site of Varanasi the concentration of Cd (4.2 mg kg^{-1}), Zn (29 mg kg^{-1}) Cr (18 mg kg^{-1}) and Mn (125 mg kg^{-1}) were found to be higher during summer and Cu (16.5 mg kg^{-1}), Pb (16.0 mg kg^{-1}), and Ni (7.5 mg kg^{-1}) during winter (Sharma *et al*. 2007). Due to high decomposition rate of organic matter during the summer season there is more release of heavy metals in soil solution for uptake by plants (McGrath *et al*. 1994).

Intawongse and Dean (2006) analyzed heavy metal concentrations in lettuce, spinach, *Raphanus sativus* (radish) and *Daucus carota* (carrot) grown in compost containing soil through batch culture. The study showed that the accumulation of Cd, Zn, Mn was higher in the leafy portion than in the root portion of the plants. The concentrations of heavy metals (mg kg^{-1}) ranged, respectively for Cu, Pb and Zn from 12.8 to 274.9, 1.2 to 4.9 and 73.9 to 2611, respectively in lettuce and from 25.8 to 182.4, 0.9 to 16.3 and 137.4 to 1351, respectively in spinach.

Liu *et al*. (2006) analyzed the concentrations of metals in 23 vegetable species from agricultural soil of four sampling sites located in the suburb of Zhengzhou city, Henan Province, China. Maximum concentration of Cd (0.20 mg kg^{-1}) was recorded in radish leaves and in *Brassica compestris* L. spp. Pekinensis (Lour) Olsson (Chinese cabbage) (0.2 mg kg^{-1}) followed by radish leaves (0.18 mg kg^{-1}). Mohamed *et al*. (2003) collected 15 different species of vegetables including cucumber, *Cucurbita pepo*

(vegetable marrow), tomato, *Solanum tuberosum* (potato), green pepper, *Solanum melon- gena* (eggplant), carrot, *Petroselinum crispum* (parsley), lettuce, spinach, *Allium cepa* (onion), *Allium porrum* (leek), *Nasturtium officinales* (watercress) and cabbage from Al-Taif district of Saudi Arabia. Results showed that concentra tions (ppm) of Cd (1.22), Ni (42.62) and Zn (105.2) were highest in the watercress and of Cu and Pb were highest in vegetable marrow (5.71 ppm) respectively. Among different vegetables watercress showed higher element concentrations than other vegetables. The variations in concentrations of heavy metals between test vegetables were d u e to the differences in the metal selectivity and their accumula- tion tendency in vegetables from soil solution.

Demirezen and Aksoy (2006) found that the levels of heavy metals such as Cd, Pb, Cu and Ni in vegetables like cucumber, tomato, green pepper, lettuce, parsley, onion, bean, eggplant, peppermint, pumpkin and okra obtained from urban areas affected from municipal, domestic, traffic and some industrial discharges were higher than those of the rural areas affected by traffic and industrial activities except Zn having higher concentration in rural areas of Turkey. Concentrations of heavy metals (mg kg^{-1}) in vegetables like cucumber, tomato, green pepper, lettuce, parsley, onion, bean, eggplant, peppermint, pumpkin and okra collected from urban areas of Kayseri ranged from 0.34 to 0.97 for Cd, 5.3 to 10.7 for Pb, 32.6 to 76.5 for Cu, 1.8 to 13.45 for Ni and 3.56 to 39.5 for Zn, whereas in rural areas the concentrations ranged from 0.24 to 0.63 for Cd, 3.00 to 8.00 for Pb, 22.19 to 60.40 for Cu, 0.44 to 4.10 for Ni and 47.13 to 259.20 for Zn (Demirezen and Aksoy,2006). The results showed that peppermint had the ability to accumulate more concentration of Cd, Cu, Pb, and Ni than other vegetables. Enhanced levels of heavy metals observed in vegetables showed a direct correlation with the concentrations of metals in the soil.

A market-based study was conducted by Radwan and Salama (2006) to assess the atmospheric deposition of heavy metals in fruits and vegetables sold in Egyptian markets. The average concentrations of metals ranged from0.01 to 0.87, 0.01 to 0.15, 0.83 to 18.3 and 1.36 to 20.9 mg kg^{-1} for Pb, Cd, Cu and Zn, respectively. Among all the vegetables, leafy vegetables, lettuce and spinach accumulated highest concentrations of Pb and Cd.

Varalakshmi et al., (2010) assessed the concentration of heavy metals of vegetables grown in wastewaters from four water bodies viz, Bellandur, Varthur, Byramangala and Nagavara. Analysis revealed high concentrations of Cd and Cr in waters of all the tanks, exceeding the recommended levels. Concentration of Cd was highest in waters of Bellandur and concentration of Cr was highest in waters of Byramangala tank. Among the different tanks, Bellandur and Varthur were found to be highly contaminated with Cd, Pb and Ni. The Cd and Pb contents were highest in the vegetables near Varthur and Bellandur tanks, while Cr was highest in vegetables near Byramangala. Among all the vegetables, Amaranthus and palak, accumulated higher concentrations of heavy metals followed by carrot and radish. The Cd concentration of all the vegetables grown near Varthur and Bellandur tanks exceeded the PFA safe limit. Pb and Ni concentrations exceeded the safe limits in all the vegetables.

Eight agriculture and vegetable samples each used for commercial consumption, which were irrigated by waste-water and tube-well water in the Lahore district were considered for analysis of metals such as, i.e., Fe, Na, K, Mg and Ca. The metal concentration in vegetables and soil irrigated with tube-well water was less than the soil and vegetables grown using waste-water. The concentration in leafy vegetables was higher as compared to non-leafy vegetables. Heavy metal concentration in vegetables irrigated by wastewater was observed as K > Na > Ca > Mg > Fe, while in vegetables irrigated by tube-well water, a trend was observed as K > Ca > Na > Mg > Fe (Ghosh et al.,2011).

Seid-mohammadi et al. (2013) estimated the concentration of heavy metals in vegetables that are irrigated by using contaminated water compared with those irrigated with fresh water in Hamadan, west of Iran in 2012. The mean concentration of Pb, Cr, and Cd, regardless of the kind of vegetables irrigated with contaminated water, was 6.24, 1.57, and 0.15 mg/kg, respectively. Because of tolerability, the uptake of metal concentration by the vegetables differed from one another. The higher concentration of the heavy metals in vegetables is due to the use of untreated sanitary and industrial wastewater by the farmers for the irrigation of vegetables.

Green leafy vegetables such as Spinach, Fenugreek, Amaranthus collected from agricultural fields across Vrishabhavathi river at five different stations were analysed for heavy metals Fe, Zn, Cd, Cr, Cu, Mn, and Pb. The results show higher concentration of iron content in plants followed by manganese. Chromium content is lower in leafy vegetable species. Spinach has higher transfer factor for the heavy metals among the three leafy vegetables followed by Fenugreek and Amaranthus. Highest transfer factor is recorded for zinc followed by manganese. Lowest transfer factor is recorded for chromium and lead. The average transfer factor observed in the selected green leafy vegetables is in the order of Zn>Mn>Fe>Cu>Ni>Pb>Cr Jayadev et al (2013).

Swapna Priya et al. (2014) estimated the heavy metals in leafy vegetables from surroundings of Musi River (Hyderabad, Andhra Pradesh) which is polluted with sewage, domestic effluents and industrial wastes flows. The leaf samples were analyzed for the heavy metals namely Cu, Zn, Pb, Fe, Cd and Mn. The extent of heavy metal contaminations was investigated in three leafy vegetables viz., Palak (*Beta vulgaris*), Thotakura (*Amaranthus*) and Chukkakura (*Rumex* sp.), soil and water of Musi River. Results showed that, leafy vegetable Chukkakura had the highest metal load followed by Palak and Thotakura.

A study focused on the concentration of heavy metals (Cr, Co, Cd and Pb) in vegetables (Cabbage, potato, and khat) of eastern Ethiopia cultivated through wastewater irrigation. The findings revealed that, apart from Co, all metal concentrations in the vegetables were found to be above the safe limits that various international organizations for consumption, causing a significant health risk to humans. As a result, frequent monitoring of effluents, soils, and vegetables is essential for preventing toxic heavy metal build up in food (Deribachew et al., 2015).

A comparative analysis of heavy metals in *Brassica campestris* and *Raphanus sativus* irrigated with municipal waste water of Sargodha city was carried out. Vegetable samples collected from three experimental sites i.e, Bhalwal Road, Ajnala Road and Faisalabad Road were selected for analysis of heavy metals such as Cu, Cr, Pb, Cd, Ni, Zn, Co, Ar, Mn, Fe, Mg and Mo. The leaves of *Brassica campestis* accumulated higher concentration of heavy metals at three different growth stages while the roots of *Raphanus sativus* have least significant lower concentration of heavy metals. The field experimental data showed that due to sewage application, Zn content was much higher in leaves of *Brassica campestris*. Cadmium accumulation in the vegetables irrigated with sewage water was also much higher. Nickel showed the similar trend for its accumulation in the vegetables (Imran Khan et al.,2016).

A study assessed the heavy metal concentration in vegetables (swiss chard, lettuce, cabbage, collard green, tomato, green pepper, and carrot) irrigated with wastewater in Gamo, Ethiopia. The study revealed that the mean levels of Cd in most vegetables and Cr and Pb in some vegetables were higher than the maximum recommended limits set by the World Health Organization/Food and Agriculture Organization, 2001. Among the vegetables, cabbage had the highest heavy metal content followed by Swiss-chard, carrot, tomato, collard green, green pepper, and lettuce. The study recommended regular monitoring of heavy metal content in vegetables to prevent their excessive accumulation in food chains (Feseha et.al., 2021).

Abrham and Gholap (2021) assessed the heavy metal levels in water, soil, and vegetables (swiss chard, lettuce, cabbage, collard green, tomato, green pepper and carrot) irrigated with waste water in Gamo, Ethiopia. The samples of soils, water, and vegetables were randomly collected, processed, and analyzed for heavy metals using atomic absorption spectrophotometry. The results obtained show that the irrigational water is profoundly contaminated with heavy metals Cd, Cr and Ni and Pb, Zn and Cu had the lowest concentration in irrigation water. The levels of Cd in Kulfo river area and Chamo Lake area and Ni in most of the farm soils were also found to be higher than the guideline values. The study also revealed that the mean levels of Cd in most vegetables and Cr and Pb in some vegetables were higher than the maximum recommended limits set by WHO/FAO. Cabbage was maximally contaminated with potential toxic elements followed by Swiss-chard, carrot, tomato, collard green, green pepper and lettuce. Hence, from Kulfo river area frequent consumption of cabbage and Swiss chard may cause serious health risks to consumers.

3.0 OBJECTIVE

- To estimate the concentration of heavy metals in vegetables obtained from retail hypermarkets, local markets, organic stores and HOPCOMS
- To compare the concentration of heavy metals among the vegetable samples from different types of stores

4.0 MATERIALS AND METHODS

4.1 Experimental Area

The vegetable samples have been collected from five different retail markets, local markets, organic stores and HOPCOMS. The details of vegetable samples collected are as below:

Table 1. List of stores/markets for vegetable sample collection

Type of market/store			
Retail markets	**Local markets**	**Organic stores**	**HOPCOMS**
Big Bazar, BTM Layout	Malleshwaram	Organic World, Vasanthanagar	Lalbagh
Metro Cash & Carry Kanakapura Road	Yeshwantpur	Village Naturals, ISRO layout	Yelahanka
Spar, Vega City Mall, Bannerghatta Road	Banashankari	Grameena Angadi, Rajajinagar	Shanthinagar
More Mega Mart, Bannergatta Road	Gandhi Bazar	Namdhari's Fresh, Indiranagar	Hebbal
Reliance Fresh, Jayanagar	K.R.Market	Desi Organics and Naturals, Vajrahalli	Raja Rajeshwarinagar

4.2 Collection and preservation of vegetable samples

Samples of vegetables were collected randomly in duplicates from five different retail markets, local markets, organic stores and HOPCOMS. Sampling locations of stores/markets for collection of vegetables in Bengaluru city are represented in Figure 1. A total of ten vegetables namely Brinjal, Tomato, Capsicum, Bean, Carrot, Green Chilly, Onion, Potato, Spinach and Coriander were collected in pairs from each of these markets. Hundred samples were analyzed from each type of store/market (10 vegetables in duplicates = 20 x 5 stores/markets = 100 samples). Therefore, a total of 400 vegetable samples were collected and analysed for heavy metal content.

Vegetable samples from the aforesaid stores were randomly collected in duplicate and were properly sealed in labelled, fresh and sterile zip - lock bags and brought back to the laboratory in ice chest and kept at 4°C for further processing. The salient features of vegetables selected for the present study is represented in the following Table 2.

4.3 Preparation, digestion and analysis of vegetable samples

Prior to analysis, the vegetable samples are pre-processed. The vegetables are washed in tap and distilled water and are air dried for a period of 24 hours. The dried sample is cut with stainless steel knife into small pieces, followed by drying in hot air over for 48 hours at 80^0C. The dried samples are ground to the powder form and sieved through a 0.2 mm sieve to obtain fine powder and stored in butter paper until further processing.

Table 2. Scientific names of vegetables along with their family

Vegetable name	Botanical/Scientific name	Family
Carrot	*Daucus carota subsp. sativus*	Apiaceae
Green Chilli	*Capsicum spp.*	Solanaceae
Common bean	*Phaseolus vulgaris*	Fabaceae (Leguminosae)
Coriander	*Coriandrum sativum*	Apiaceae (Umbelliferae)
Brinjal	*Solanum melongena*	Solanaceae
Onion	*Allium cepa*	Amaryllidaceae
Potato	*Solanum tubersum*	Solanaceae
Spinach	*Spinacia oleracea*	Amaranthaceae
Tomato	*Solanum lycopersicum L.*	Solanaceae
Capsicum	*Capsicum frutescens*	Solanaceae

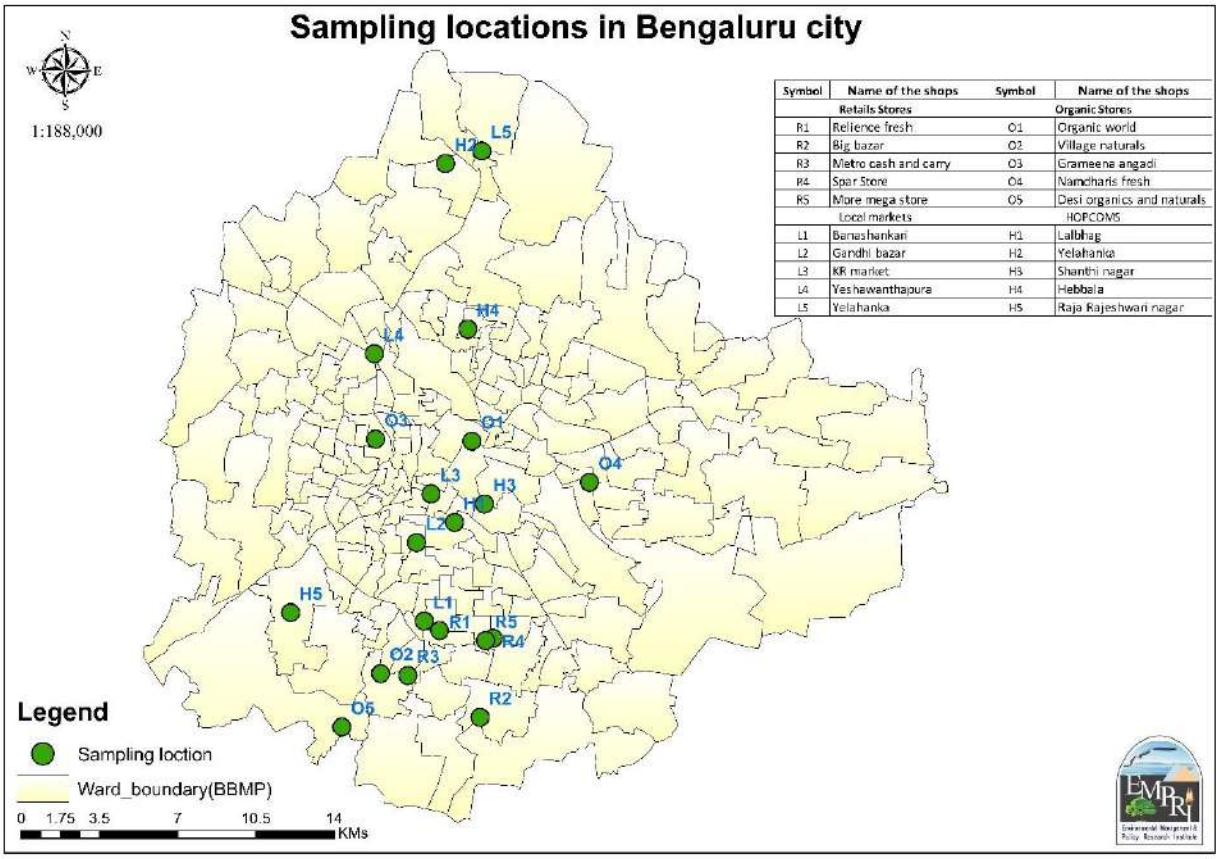


Figure 1. Sampling locations of stores/markets for collection of vegetables in Bengaluru city

The vegetable samples were digested using a high-performance microwave assisted digestion. About 0.2g of powdered vegetable sample was mixed with 11ml HNO_3, 2.2ml H_2SO_4, and 2.2 ml of $HClO_4$ using a pre-automated program in NuWav-Ultra Microwave Digestion Extraction System. The pre-automated program designed for digestion is as follows:

a.10 minutes at 130°C at 400W power

b. 5 minutes at 150°C at 400W power

c.10 minutes at 180°C at 500W power

The digested solution was then left for automatic ventilation for 10 minutes and the temperature was allowed to cool down to 50°C. After cooling, the sample was filtered through Whatman filter paper No. 40. The filtered sample was made up to 100 ml volume with metal-free distilled water and stored in a PPE bottles ready for analysis.

A Shimadzu Atomic Absorption Spectrophotometer 6300 model with air-acetylene flame of an average fuel flow rate between 0.8 and 4.0 L/min, and the support gas flow rate AAS were of Hamamatsu

Photonics Co. Ltd., L2433 was used for the analysis. The standard references for the given metals were procured from Inorganic Ventures Inc. and Sisco Research Laboratories, Mumbai Ltd. between 13.5 and 17.5 L/min was used. The single element hollow cathode lamps used in Calibration curves for various elements obtained from these standards were of first order reaction. The vegetable samples were analyzed for heavy metals namely Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn. The results are represented as mg/kg dry weight.

Table 3. FAO/WHO maximum permissible values for metals in vegetables (mg/kg)

Metals	FAO/WHO maximum permissible limit (mg/kg)
Cd	0.2
Pb	0.3
Ni	67.9
Fe	425.5
Cu	73.3
Zn	99.4
Mn	500
Cr	2.30

Photographs showing the collection, processing and analysis of vegetable samples

Photo 1. Local market - Malleshwaram

Photo 2. Researcher purchasing the vegetables

Photo 3. Sorting the vegetables

Photo 4. Cleaning of vegetables with tap water

Photo 5. Cut vegetables in Petri dish

Photo 6. Cut vegetables placed in hot air oven for drying

Photo 7. Vegetable pieces dried in hot air oven

Photo 8. Different vegetables dried in hot air oven

Photo 9. Ground and powdered vegetable

Photo 10. Ground and powdered vegetable

Photo 11. Vegetable sample placed in microwave digester for digestion

Photo 12. Digested vegetable sample

Photo 13. Digested vegetable samples kept for cooling

Photo 14. Digested vegetable samples made up to the volume with distilled water

Photo 15. Filtered vegetable samples ready for analysis

Photo 16. Filtered vegetable samples being analysed for heavy metals using Atomic Absorption Spectrophotometer

5.0 RESULTS & DISCUSSION

Samples of vegetables were collected randomly in duplicates from five different Retail Markets, Local Markets, Organic Stores and HOPCOMS. A total of ten vegetables namely Brinjal, Tomato, Capsicum, Bean, Carrot, Green Chilly, Onion, Potato, Spinach and Coriander were collected in pairs from each of these markets. Hundred samples were analyzed from each type of store/market (10 vegetables in duplicates = 20 x 5 stores/markets = 100 samples). Therefore, a total of 400 vegetable samples were collected and analyzed for heavy metal concentration.

Table 3. Concentration of heavy metals in vegetable samples collected from Big Baz, BTM Layout

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Brinjal	38.70	32.20	150.80	181.80	BDL	15.00	77.3*	52.30*
Coriander	144.90	48.80	136.00	499.60		29.50	88.3*	53.30*
Spinach	216.20	49.70	157.50	242.90		8.70	71.8*	53.50*
Capsicum	55.00	53.60	152.30	180.80		6.60	67.60	53.80*
Green Chilly	49.20	44.10	160.40	189.10		8.70	76.6*	53.70*
Onion	185.90	23.40	182.60	159.70		10.10	97*	54.60*
Carrot	210.10	78.60	204.80	171.10		8.20	98.3*	54.60*
Potato	178.50	53.00	203.30	170.00		12.00	95.5*	54.30*
Tomato	174.10	38.90	214.40	161.60		9.20	84.1*	54.30*
Beans	161.20	317.10*	210.00	174.70	12.20	9.90	98.50	52.10*
Maximum	216.20	317.10	214.40	499.60	12.20	29.50	98.50	54.60
Minimum	38.70	23.40	136.00	159.70	-	6.60	67.60	52.10
Average	141.38	73.94	177.21	213.13	-	11.79	83.05	53.65
Standard Deviation	216.20	86.69	214.40	499.60	-	6.63	21.85	54.60
No. of samples above safe limit	0	1	-	0	-	0	8	10

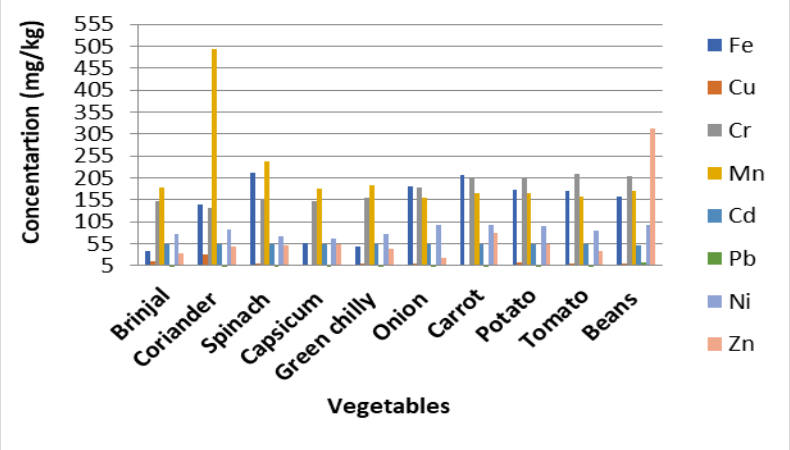


Table 4. Concentration of heavy metals in vegetable samples collected from Metro Cash and Carry, Kanakapura Road

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Brinjal	151.33	BDL	270.65	143.85	BDL	2.63	53.13	45.97*
Coriander	514.05	16.65	262.53	184.73		9.8	64.38	46.52*
Spinach	401.15	26.28	244.03	248.33		9.98	79.35*	47.82*
Capsicum	237.73	24.80	213.73	148.91		9.45	76.85*	47.32*
Green Chilly	193.65	16.28	186.35	149.13		11.55	78.35*	48.82*
Onion	193.98	21.35	187.08	149.35		6.13	86.32*	48.75*
Carrot	153.13	44.78	189.30	143.48		8.4	96.30*	49.95*
Potato	250.60	35.98	170.83	147.95		7.88	93.30*	49.70*
Tomato	229.35	27.48	174.50	149.25		7.53	74.85*	51.22*
Beans	240.95	53.13	173.78	165.70		7.88	78.85*	51.97*
Maximum	514.05	53.13	270.65	248.33	-	11.55	96.30	51.97
Minimum	151.33	BDL	170.83	143.48	-	2.63	53.13	45.97
Average	269.27	25.88	209.52	168.54	-	7.95	77.59	48.83
Standard Deviation	114.62	16.10	36.27	32.49	-	2.46	12.72	1.96
No. of Samples above safe limit	0	0	-	0	0	0	8	10

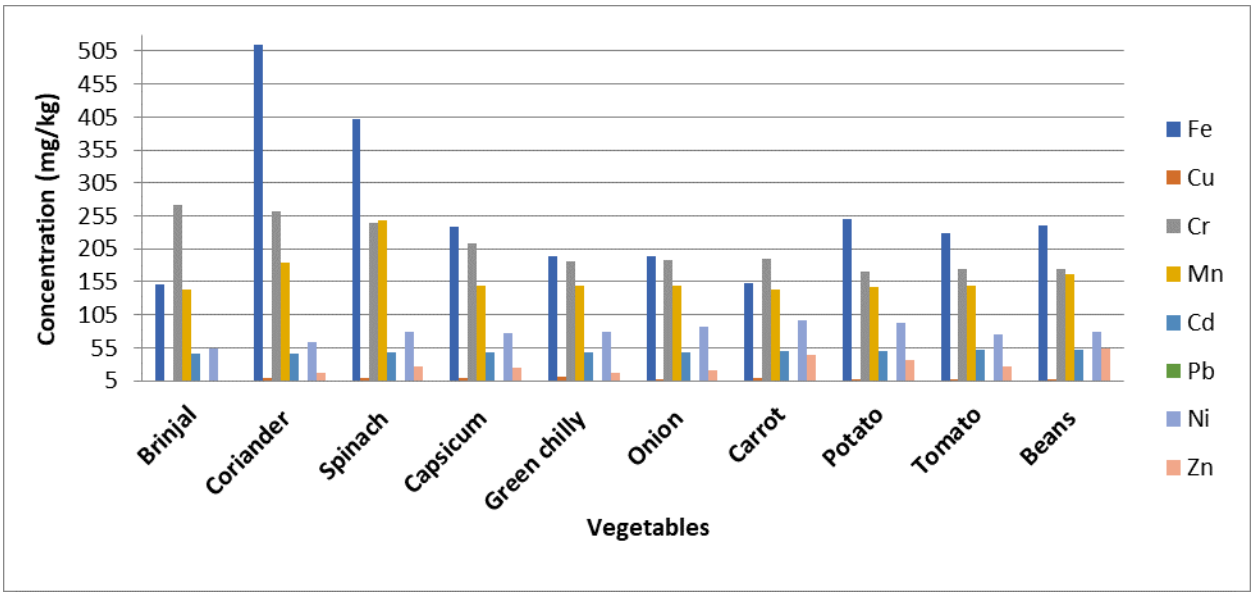


Table 5. Concentration of heavy metals in vegetable samples collected Spar, Vega City Mall, Bannerghatta Road

Vegetables	Heavy metals (mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Brinjal	78.50	BDL	422.23	148.30	BDL	BDL	3.00	30.60*
Coriander	194.60		400.05	186.28		BDL	35.43	30.90*
Spinach	257.33		421.53	238.10		4.73	32.93	32.55*
Capsicum	85.23		421.50	152.75		BDL	14.73	32.33*
Green Chilly	83.33		413.38	160.88		4.58	22.95	34.83*
Onion	57.25		371.23	155.13		BDL	46.40	35.83*
Carrot	140.25		380.10	158.90		BDL	36.45	38.95*
Potato	161.15		343.88	159.23		1.23	61.88	38.80*
Tomato	57.90		320.93	158.65		1.23	55.65	41.35*
Beans	90.73		271.40	182.03		1.40	47.65	45.40*
Maximum	257.33	-	422.23	238.10	-	4.73	61.88	45.40
Minimum	57.25	-	271.40	148.30	-	BDL	3.00	30.60
Average	126.74	-	371.65	173.89	-	-	35.16	36.46
Standard Deviation	66.21	-	50.88	26.85	-	3.34	18.32	4.89
No. of Samples above safe limit	0	0	-	0	0	0	0	10

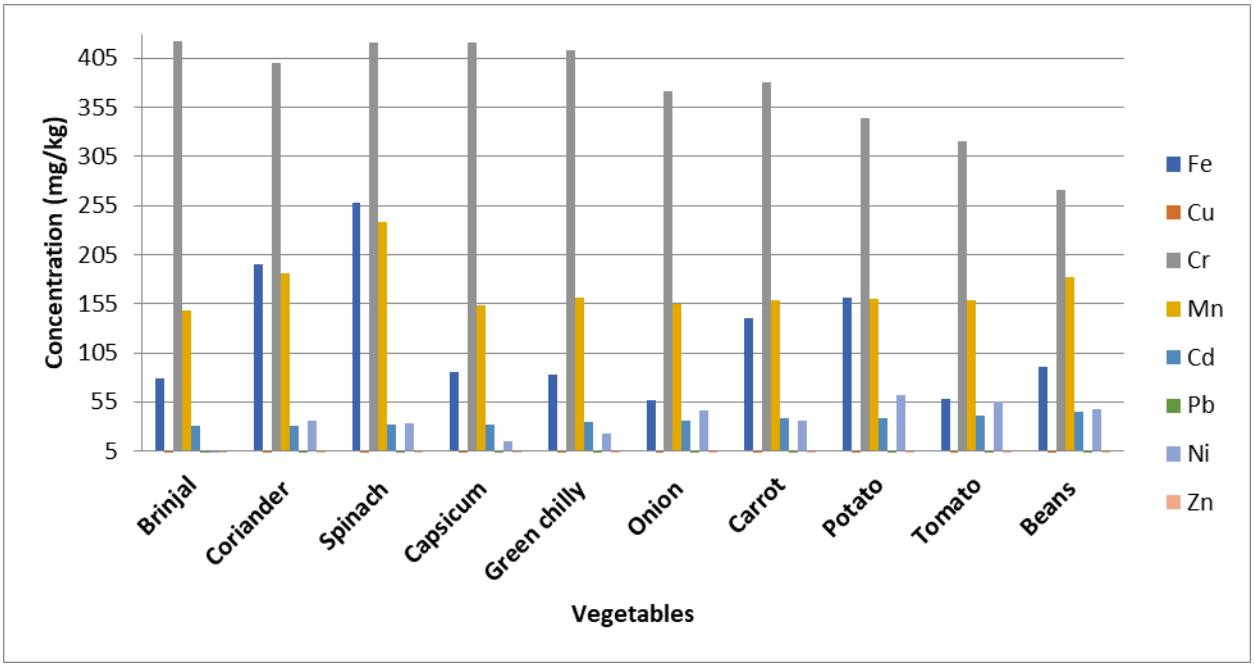


Table 6. Concentration of heavy metals in vegetable samples collected from More Mega Mart, Bannerghatta Road

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Brinjal	59.93	BDL	278.80	98.83	BDL	19.08	22.43	23.25*
Coriander	111.18		315.03	168.30		17.85	11.38	25.10*
Spinach	238.20		334.98	201.63		27.88	16.90	26.90*
Capsicum	102.25		332.03	120.45		20.13	BDL	27.15*
Green Chilly	104.55		355.68	126.35		21.53	BDL	27.63*
Onion	106.85		363.08	127.85		25.6	BDL	28.68*
Carrot	57.63		357.18	130.58		23.1	5.95	159.1*
Potato	94.75		370.48	132.33		25.95	6.28	28.63*
Tomato	100.25		378.63	152.30		24.35	2.98	29.75*
Beans	77.75		386.03	143.00		27.88	21.83	29.58*
Maximum	238.20	-	386.03	201.63	-	27.88	22.43	159.15
Minimum	57.63	-	278.80	98.83	-	17.85	-	23.25
Average	112.43	-	344.73	141.84	-	23.25	6.37	49.02
Standard Deviation	50.48	-	32.58	28.51	-	3.59	11.88	41.71
No. of Samples above safe limit	0	0	-	0	0	0	0	10

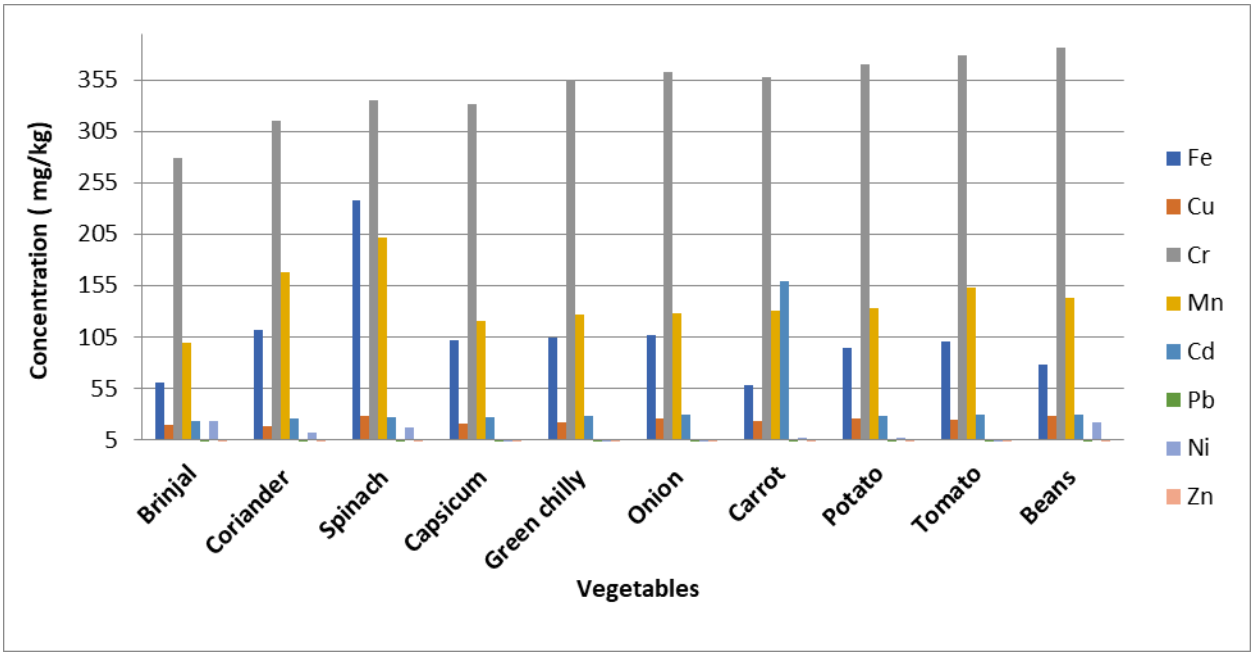
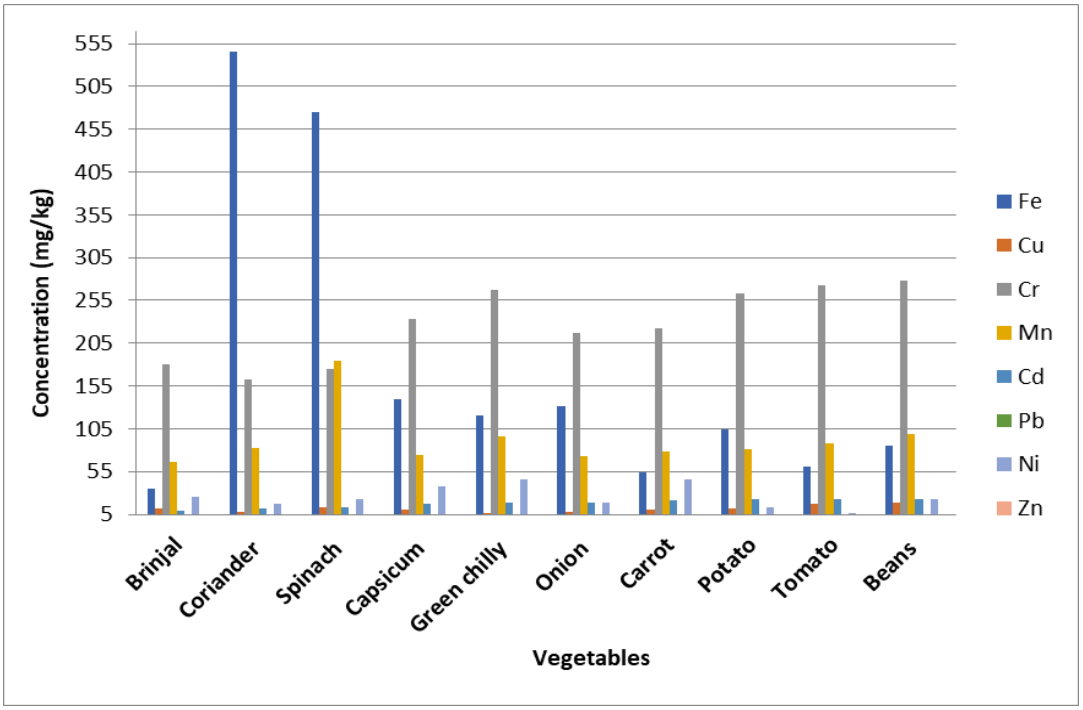


Table 7. Concentration of heavy metals in vegetable samples collected from Reliance Fresh, Jayanagar

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Brinjal	35.00	BDL	180.40	66.00	BDL	11.20	25.70	9.70*
Coriander	546.20*		162.70	82.10		7.40	17.20	12.10*
Spinach	474.80*		175.30	183.70		13.10	23.30	13.20*
Capsicum	139.00		233.70	74.40		10.00	37.30	17.00*
Green Chilly	120.60		267.00	95.80		7.00	45.80	18.00*
Onion	131.90		217.40	73.10		7.70	19.00	18.00*
Carrot	54.10		222.60	78.00		10.80	46.10	20.70*
Potato	104.50		263.30	80.80		11.70	13.40	22.10*
Tomato	60.40		272.10	87.80		17.00	7.00	22.60*
Beans	84.80		278.00	98.50		19.00	22.20	22.60*
Maximum	546.20	-	278.00	183.70	-	19.00	46.10	22.60
Minimum	35.00	-	162.70	66.00	-	7.00	7.00	9.70
Average	194.38	-	226.10	97.49	-	11.74	25.84	17.36
Standard Deviation	180.81	-	43.06	33.74	-	3.99	13.30	4.63
No. of Samples above safe limit	2	0	-	0	0	0	0	10



5.1 Concentration of heavy metals in vegetables from Retail markets

Samples of vegetables were collected randomly in duplicates from five different Retail Markets across Bengaluru city. They were Big Bazar - BTM Layout, Metro Cash and Carry - Kanakapura Road, Spar, Vega City Mall - Bannerghatta Road, More Mega Mart - Bannerghatta Road and lastly Reliance Fresh, Jayanagar. A total of ten vegetables namely Brinjal, Tomato, Capsicum, Bean, Carrot, Green Chilly, Onion, Potato, Spinach and Coriander were collected and analyzed for heavy metals (Cd, CO, Cr, Cu, Fe, Mn, Ni, Pb, and Zn). Therefore, a total of 100 samples were analyzed in the five retail stores.

In the samples collected from Big Bazar, BTM layout the concentration of Nickel and Cadmium were found to be beyond permissible limit in all the vegetables. The highest Iron concentration was found to be in Spinach (216.20 mg/kg) and the lowest was in Brinjal (38.70 mg/kg). Zinc concentration was highest in Beans (317.10 mg/kg) and lowest in Onion (23.40 mg/kg). The highest concentration of Chromium in Tomato was 214.40 mg/kg. Coriander was recorded to have highest concentration of Mn (499.60 mg/kg) and Beans was seen to have highest concentration of Lead (12.20 mg/kg). The concentration of Lead in other vegetables were below detectable limit. Copper was recorded to be in higher concentration in Coriander (29.50 mg/kg) and lowest concentration in Capsicum.

In the samples collected from Metro Cash and Carry, Kanakapura Road, the concentration of Nickel and Cadmium was found to be beyond permissible limit in all the vegetables. The highest Iron concentration was found to be in Coriander (514.05 mg/kg) and the lowest was in Brinjal (151.33 mg/kg). Zinc concentration was highest in Beans (53.13 mg/kg) and was below detectable limit in Brinjal. The highest concentration of Chromium in Brinjal was 270.65 mg/kg. Spinach was recorded to have highest concentration of Mn (248.33 mg/kg). The concentration of Lead in all vegetables were below detectable limit. Copper was recorded to be in higher concentration in Green Chilly (11.55 mg/kg) and lowest concentration in Brinjal (2.63 mg/kg).

In the samples collected from Spar, Vega City Mall, Bannerghatta Road the concentration of Zinc and Lead were below detectable limit in all the vegetable samples. The highest concentration of Iron in Spinach was 257.33 mg/kg whereas highest concentration of Chromium was found in Brinjal (422.23 mg/kg). The Manganese concentration was highest in Spinach (238.10 mg/kg) whereas lowest in Brinjal (148.30 mg/kg). The concentration of Copper in Brinjal, Coriander, Capsicum, Onion and Carrot were found to be below detectable limit, whereas highest concentration was found in Spinach (4.73 mg/kg). The highest concentration of Nickel was seen in Potato (61.88 mg/kg) and the lowest concentration was seen in Brinjal (3.0 mg/kg). Cadmium was found to be below detectable limit in all the vegetable samples.

In the samples collected from More Mega Mart, Bannerghatta Road the concentration of Zinc and Lead were below detectable limit in all the vegetable samples. The highest concentration of Iron in Spinach was 238.20 mg/kg whereas highest concentration of Chromium was found in Beans (386.03 mg/kg). The

Manganese concentration was highest in Spinach (201.63 mg/kg) whereas lowest in Brinjal (98.83mg/kg). The concentration of Copper was highest in Beans (27.88 mg/kg). The Nickel concentration was below detectable limit in Capsicum, Green Chilly and Onion and the highest concentration was in Brinjal (22.43 mg/kg). Cadmium was found to be above permissible limit in all the vegetable samples with highest concentration recorded in Carrot (159.1 mg/kg).

In the samples collected from Reliance Fresh, Jayanagar the concentration of Zinc and Lead were below detectable limit in all the vegetable samples. The highest concentration of Iron in Coriander was 546.20 mg/kg whereas highest concentration of Chromium was found in Beans (278.0 mg/kg). The Manganese concentration was highest in Spinach (183.70 mg/kg) whereas lowest in Brinjal (66.0 mg/kg). The concentration of Copper was highest in Beans (19.0 mg/kg) and Nickel concentration was highest in Carrot (46.10 mg/kg). Cadmium was found to be above permissible limit in all the vegetable samples with highest concentration recorded in Tomato and Beans (22.60 mg/kg).

Among the samples obtained from Retail Stores, Chromium was found to be in higher concentration in all vegetable samples (136 - 422.2 mg/kg) as against the permissible limit of FAO/WHO (2.3 mg/kg). Manganese was found within the permissible limits in all the samples (159.7 - 499.7 mg/kg). Cadmium was found in higher concentration (52.18 - 54.68 mg/kg) in all vegetables except Carrot in samples obtained from Big Bazar.

Table 8. Concentration of heavy metals in vegetable samples collected from local market - Malleshwaram

Vegetables	Heavy metals (mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	256.20	11.28	159.20	68.18	BDL	BDL	26.05	3.95*
Coriander	227.88	39.85	142.53	82.83	3.85*	9.70	40.40	6.98*
Brinjal	138.20	16.68	157.20	36.65	24.28*	5.80	6.30	8.53*
Tomato	111.98	11.65	140.55	26.50	23.00*	BDL	23.78	7.05*
Capsicum	119.58	35.95	173.85	44.35	21.73*	5.60	17.75	11.10*
Potato	239.70	29.00	155.20	35.05	19.18*	1.88	21.48	10.30*
Green Chilly	157.85	25.18	195.83	35.68	20.45*	8.18	38.95	6.98*
Onion	179.90	17.85	182.53	33.10	40.90*	3.23	29.80	11.68*
Carrot	140.83	27.95	207.15	34.08	38.35*	6.65	26.93	6.73*
Beans	128.78	33.30	191.15	44.23	35.80*	3.58	17.20	11.93*
Maximum	256.20	39.85	207.15	82.83	40.90	9.70	40.40	11.93
Minimum	111.98	11.28	140.55	26.50	BDL	1.88	6.30	3.95
Average	172.42	24.98	171.07	45.83	22.37	3.98	24.61	8.42
Standard Deviation	46.25	9.46	23.06	17.70	13.50	3.96	10.20	2.63
No. of samples above safe limit	0	0	-	0	9	0	0	10

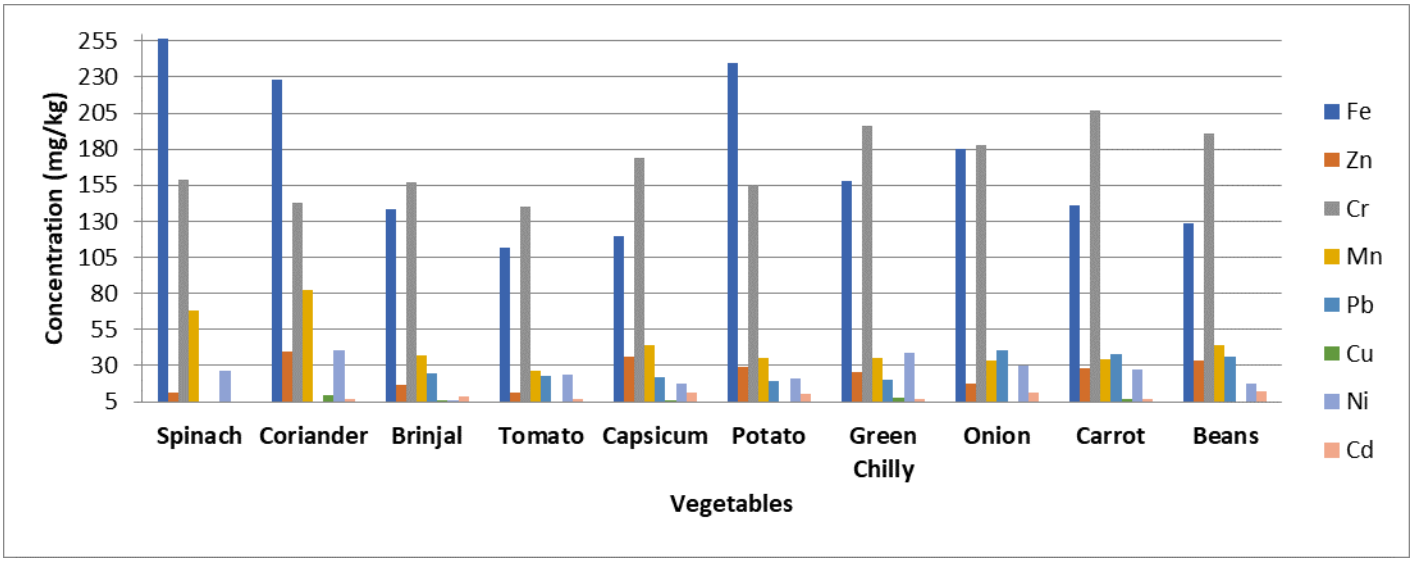


Table 9. Concentration of heavy metals in vegetable samples collected from local market - Yestwanthpur

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	452.6*	BDL	247.8	112.37	131.7*	25.025	BDL	21.3*
Coriander	207.675		239.8	97.225	152.15*	23.5	BDL	14.57*
Brinjal	135.325		235.12	73.175	144.47*	22.65	BDL	19.2*
Tomato	120.9		252.5	60.6	155.97*	20.6	BDL	22.17*
Capsicum	133.725		236.47	58.75	165.15*	21.12	BDL	15.9*
Potato	173.85		261.1	76.375	175.15*	16.85	6.875	18.2*
Green Chilly	118.275		261.77	70.85	153.45*	23.32	15.47	21.17*
Onion	112.845		286.42	59.72	164.95*	21.62	16.32	20.97*
Carrot	150.775		258.45	63.4	164.87*	19.575	7.725	17.9*
Beans	120.1		224.8	76.825	173.875	24.025	5.15	21.5*
Maximum	452.60	-	286.43	112.38	175.15	25.03	16.32	22.18
Minimum	112.85	-	224.80	58.75	131.70	16.85	-	14.58
Average	190.96	-	251.29	76.70	157.38	21.68	-	19.14
Standard Deviation	102.72	-	17.68	17.50	13.44	2.42	-	2.59
No. of samples above safe limit	1	0	-	0	10	0	0	10

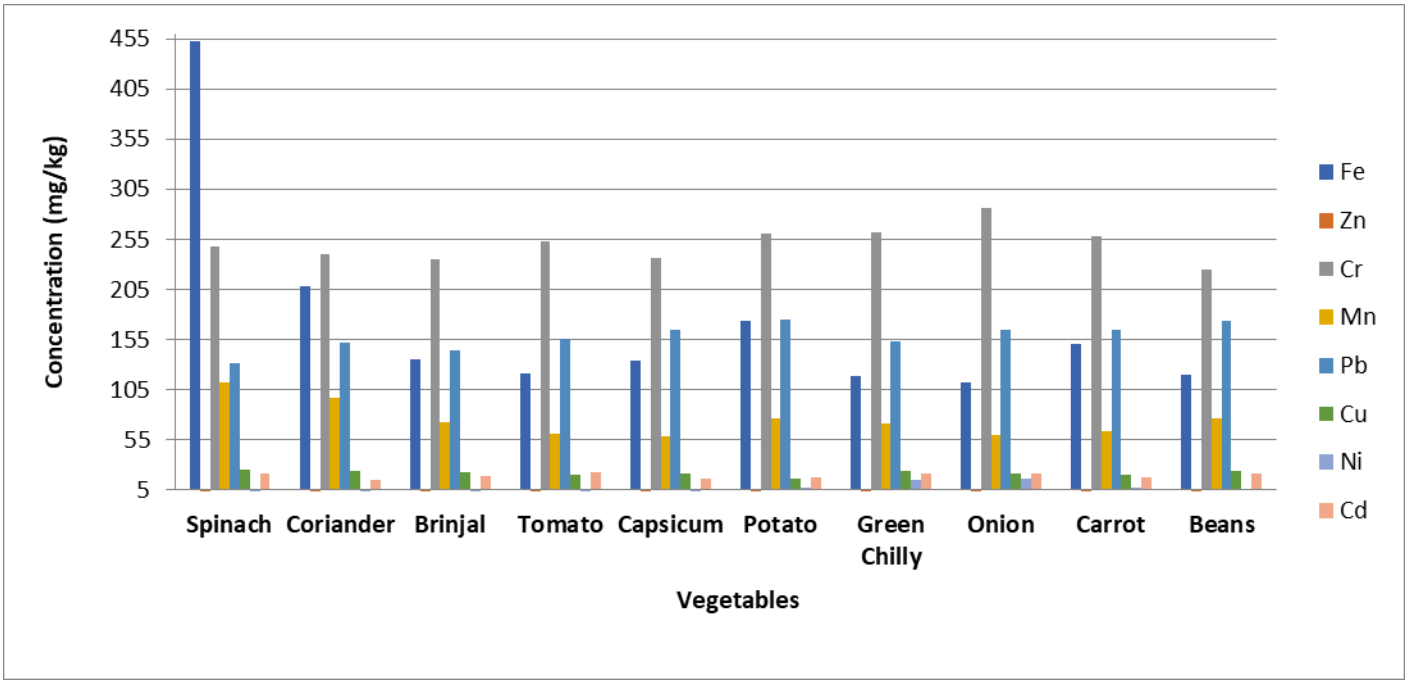


Table 10. Concentration of heavy metals in vegetable samples collected from local market - Banashankari

Vegetables	Heavy metals(mg/kg)							
	Fe	**Zn**	**Cr**	**Mn**	**Pb**	**Cu**	**Ni**	**Cd**
Spinach	61.68	32.80	103.93	83.63	BDL	BDL	BDL	1.05*
Coriander	37.20	32.30	95.25	48.83		BDL	BDL	2.65*
Brinjal	9.13	12.63	69.28	21.15		1.18	13.75	2.38*
Tomato	25.03	11.65	123.90	11.60		BDL	31.23	2.30*
Capsicum	11.35	24.35	107.23	8.68		BDL	31.50	2.98*
Potato	13.93	6.78	98.50	7.70		BDL	25.50	5.83*
Green Chilly	117.23	20.65	127.23	17.10		BDL	19.18	3.43*
Onion	97.80	12.90	129.90	19.93		BDL	18.03	4.88*
Carrot	146.08	29.50	132.58	31.03		BDL	30.38	7.18*
Beans	122.73	14.58	120.55	32.38		BDL	27.23	7.05*
Maximum	146.08	32.80	132.58	83.63	-	-	31.50	7.18
Minimum	9.13	6.78	69.28	7.70	-	-	BDL	1.05
Average	66.44	19.81	109.18	31.11	-	-	16.14	3.99
Standard Deviation	52.38	9.45	19.87	23.19	-	-	15.99	2.13
No. of Samples above safe limit	0	0	-	0	-	0	0	10

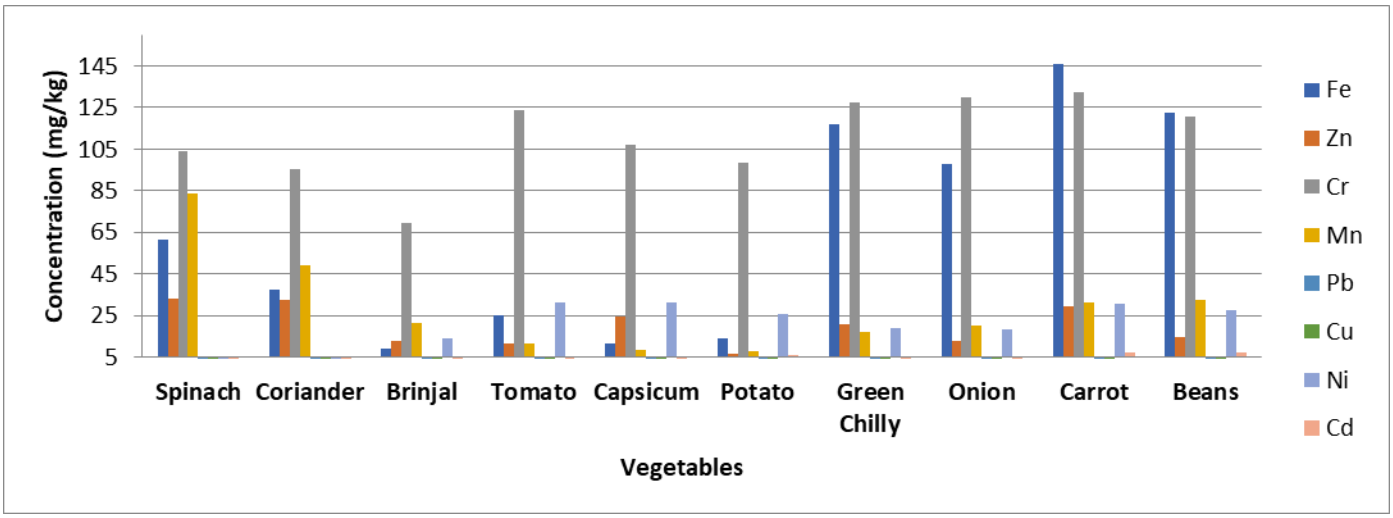


Table 11. Concentration of heavy metals in vegetable samples collected from local market - Gandhi Bazar

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	363.45	12.83	212.48	100.30	27.83*	11.40	38.10	12.98*
Coriander	305.25	BDL	220.48	59.98	65.20*	10.20	31.53	9.63*
Brinjal	139.65	BDL	206.50	43.85	61.38*	11.93	47.28	13.13*
Tomato	222.13	BDL	243.13	43.35	61.38*	11.58	14.33	15.10*
Capsicum	150.50	BDL	213.80	41.90	57.55*	15.50	22.63	14.58*
Potato	200.35	BDL	213.83	39.10	76.70*	8.18	11.78	10.80*
Green Chilly	140.55	BDL	239.80	53.63	81.83*	13.95	16.63	15.18*
Onion	117.50	BDL	261.10	45.45	92.05*	12.60	12.03	16.03*
Carrot	225.00	BDL	242.45	48.75	80.55*	9.70	BDL	15.30*
Beans	129.80	BDL	245.83	58.88	95.90*	7.48	4.88	16.70*
Maximum	363.45	12.83	261.10	100.30	95.90	15.50	47.28	16.70
Minimum	117.50	-	206.50	39.10	27.83	7.48	BDL	9.63
Average	206.26	-	230.58	56.21	68.67	11.29	20.53	13.81
Standard Deviation	81.83	-	18.60	17.91	19.88	2.47	14.97	2.29
No. of samples above safe limit	0	0	-	0	10	0	0	10

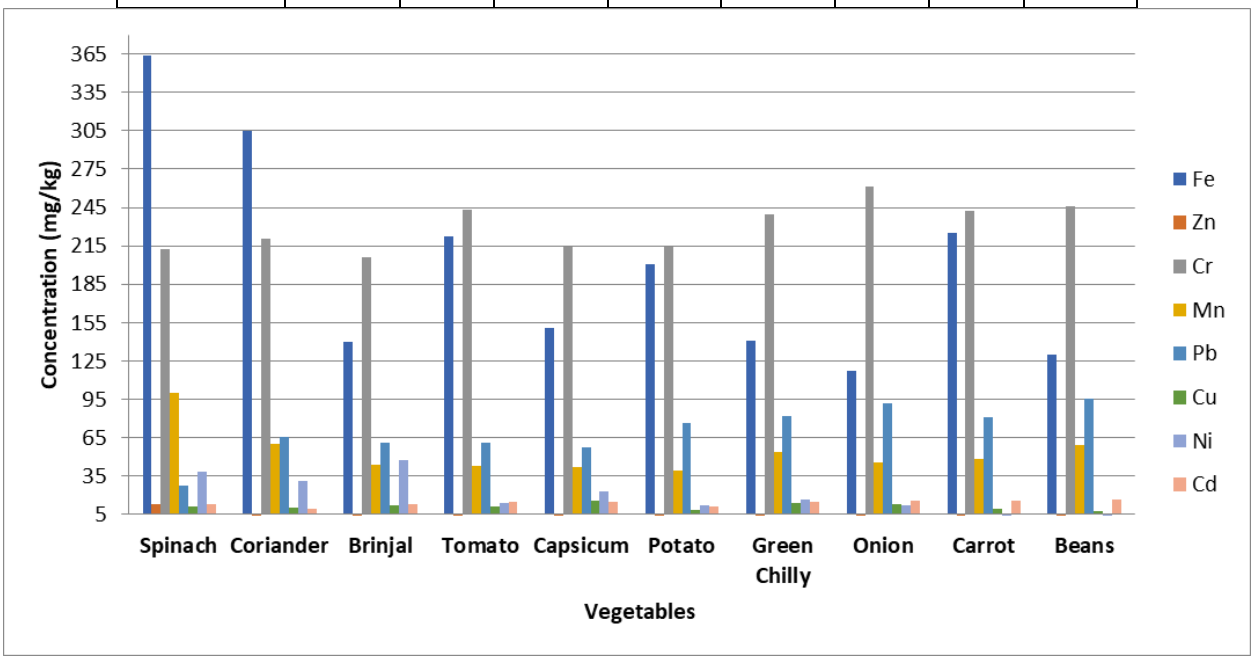
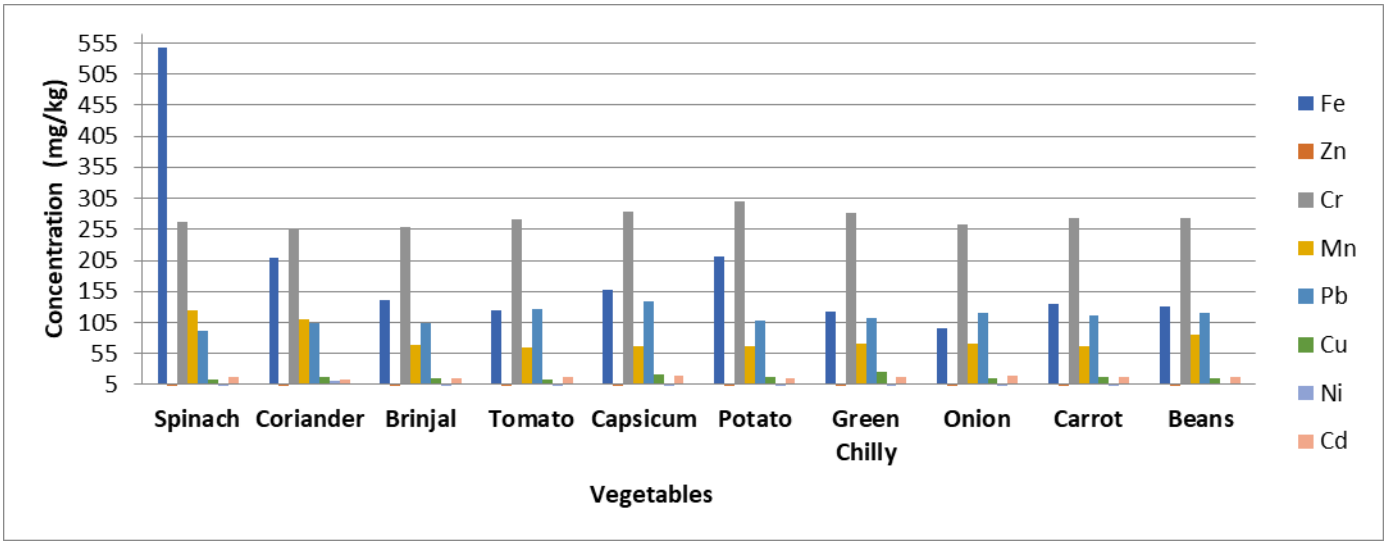


Table 12. Concentration of heavy metals in vegetable samples collected from local market - K.R.Market

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	546.75*	BDL	267.78	123.65	90.78*	13.10	BDL	16.88*
Coriander	209.80		255.78	110.68	104.85*	17.03	12.03	14.05*
Brinjal	141.35		258.45	68.18	103.58*	15.48	BDL	15.98*
Tomato	125.60		270.45	64.25	126.60*	12.95	BDL	17.55*
Capsicum	158.38		284.43	65.83	138.08*	20.78	BDL	19.28*
Potato	211.35		299.75	66.93	107.40*	16.53	BDL	15.78*
Green Chilly	123.00		282.43	70.25	112.50*	25.53	BDL	17.43*
Onion	96.00		263.78	71.95	121.45*	16.00	BDL	18.73*
Carrot	135.65		273.78	66.08	116.35*	17.03	BDL	17.63*
Beans	131.65		273.78	85.75	120.18*	16.18	5.45	17.35*
Maximum	546.75	-	299.75	123.65	138.08	25.53	12.03	19.28
Minimum	96.00	-	255.78	64.25	90.78	12.95	BDL	14.05
Average	210.19	-	273.83	81.79	114.22	17.42	-	17.00
Standard Deviation	131.35	-	13.18	21.05	13.39	3.69	-	1.50
No. of samples above safe limit	0	0	-	0	10	0	0	10



5.2 Concentration of heavy metals in vegetables from Local Markets

Samples of vegetables were collected randomly in duplicates from five different Local Markets across Bengaluru city. They were local markets from Malleshwaram, Yeshwanthpur, Banashankari, Gandhi Bazar and K.R.Market. A total of ten vegetables namely Brinjal, Tomato, Capsicum, Bean, Carrot, Green Chilly, Onion, Potato, Spinach and Coriander were collected and analyzed for heavy metals (Cd, CO, Cr, Cu, Fe, Mn, Ni, Pb, and Zn). Therefore, a total of 100 samples were analyzed in the five local markets.

In the samples collected from local market - Malleshwaram, the concentration of Lead and Cadmium were

above permissible limit with highest concentration in Green Chilly (40.90 mg/kg) and Beans (11.93 mg/kg) respectively. The highest concentration of Iron in Spinach was 256.20 mg/kg whereas highest concentration of Chromium was found in Carrot (207.15 mg/kg). The Manganese concentration was highest in Coriander (82.83 mg/kg) whereas lowest in Tomato (26.50 mg/kg). The concentration of Copper was highest in Coriander (9.70 mg/kg) and below detectable limit in Spinach. The Nickel concentration was highest in Coriander (40.40 mg/kg) and lowest was in Brinjal (6.30 mg/kg). Cadmium was found to be above permissible limit in all the vegetable samples with highest concentration recorded in Beans (11.93 mg/kg).

In the samples collected from local market - Yeshwanthpur, the concentration of Zinc was below detectable limit in all the vegetable samples. The highest concentration of Iron in Spinach was 452.6 mg/kg whereas highest concentration of Chromium was found in Onion (286.42 mg/kg). The Manganese concentration was highest in Spinach (112.37 mg/kg) whereas lowest in Capsicum (58.75 mg/kg). The concentration of Copper was highest in Beans (24.02 mg/kg). Nickel was below detectable limit in Spinach, Coriander, Brinjal, Tomato and Capsicum and the highest concentration was recorded in Onion (16.32 mg/kg). Cadmium was found to be above permissible limit in all the vegetable samples with highest concentration recorded in Tomato (22.17 mg/kg).

In the samples collected from local market - Banashankari, the concentration of Lead was below detectable limit in all the vegetable samples. The highest concentration of Iron in carrot was 146.08 mg/kg whereas highest concentration of Chromium was found in Carrot (132.58 mg/kg). The Manganese concentration was highest in Spinach (83.63 mg/kg) whereas lowest in Potato (7.70 mg/kg). The concentration of Copper was highest in Brinjal (1.18 mg/kg) and in the remaining vegetables it was below detectable limit. The Nickel concentration was highest in Capsicum (31.50 mg/kg). Cadmium was found to be above permissible limit in all the vegetable samples with highest concentration recorded in Carrot (7.18 mg/kg).

In the samples collected from local market - Gandhi Bazar, the concentration of Zinc was below detectable limit in all the vegetable samples except in Spinach (12.83 mg/kg). The highest concentration of Iron in Spinach was 363.45 mg/kg whereas highest concentration of Chromium was found in Onion (261.10 mg/kg). The Manganese concentration was highest in Spinach (100.30 mg/kg) whereas lowest in Potato (39.10 mg/kg). The concentration of Copper was highest in Capsicum (15.50 mg/kg). The Nickel concentration was highest in Brinjal (47.28 mg/kg). Cadmium was found to be above permissible limit in all the vegetable samples with highest concentration recorded in Beans (16.70 mg/kg).

In the samples collected from local market – K.R.Market, the concentration of Zinc was below detectable limit in all the vegetable samples. The highest concentration of Iron in Spinach was 546.75 mg/kg whereas highest concentration of Chromium was found in Potato (299.75 mg/kg). The Manganese concentration was highest in Spinach (123.65 mg/kg) whereas lowest in Tomato (64.25 mg/kg). The concentration of Copper was highest in Green Chilly (25.53 mg/kg). The Nickel concentration was highest in Coriander (12.03 mg/kg) and in other vegetable the concentration was below detectable limit. Cadmium was found to be in highest concentration in Capsicum (19.28 mg/kg).

Lead concentration was found to be higher in all vegetable samples obtained from Yeshwanthpur local market (131.7 - 175.15 mg/kg) as against the permissible limit of Pb (0.3 mg/kg) set by WHO/FAO.

5.3 Concentration of heavy metals in vegetables from Organic Stores

Samples of vegetables were collected randomly in duplicates from five different Organic Stores across Bengaluru city. They were Organic World - Vasanthnagar, Village Naturals - ISRO Layout, Grameena Angadi - Rajajinagar, Namdhari's Fresh, Desi Organics and Natural, Vajrahalli - A total of ten vegetables namely Brinjal, Tomato, Capsicum, Bean, Carrot, Green Chilly, Onion, Potato, Spinach and Coriander were collected and analyzed for heavy metals (Cd, CO, Cr, Cu, Fe, Mn, Ni, Pb, and Zn). Therefore, a total of 100 samples were analyzed in the five Organic Stores.

In the samples collected from Organic World, Vasanthnagar the concentration of Lead, Nickel and Cadmium were below detectable limit in all the vegetable samples. The concentration of Zinc was highest in Beans (145.08 mg/kg). The highest concentration of Iron in Beans was 810.20 mg/kg whereas highest concentration of Chromium was found in Capsicum (310.88 mg/kg). The Manganese concentration was highest in Spinach (131.63 mg/kg) whereas lowest in Tomato 56.93 mg/kg). The concentration of Copper was highest in Brinjal (156.0 mg/kg).

In the samples collected from Village Naturals, ISRO Layout the concentration of Lead, Nickel and Cadmium were below detectable limit in all the vegetable samples. The highest concentration of Iron in Coriander was 945.70mg/kg whereas highest concentration of Chromium was found in Tomato (324.0

mg/kg). The Manganese concentration was highest in Spinach (228.90 mg/kg) whereas lowest in Brinjal (47.30 mg/kg). The concentration of Copper was highest in Brinjal (165.70 mg/kg).

In the samples collected from Grameena Angadi, Rajajinagar the concentration of Lead, Nickel and Cadmium were below detectable limit in all the vegetable samples. The concentration of Zinc was highest in Coriander (36.03 mg/kg). The highest concentration of Iron in Spinach was 370.23 mg/kg whereas highest concentration of Chromium was found in Carrot (297.78 mg/kg). The Manganese concentration was highest in Coriander (137.63 mg/kg) whereas lowest in Tomato (17.53 mg/kg). The concentration of Copper was highest in Spinach (12.43 mg/kg).

In the samples collected from Namdhari's Fresh, Indiranagar the concentration of Lead, Nickel and Cadmium were below detectable limit in all the vegetable samples. The concentration of Zinc was highest in Spinach (150.88 mg/kg). The highest concentration of Iron in Spinach was 183.15 mg/kg whereas highest concentration of Chromium was found in Green Chilly (319.08 mg/kg). The Manganese concentration was highest in Spinach whereas lowest in Potato (79.73 mg/kg). In Spinach, the concentration of Manganese (287.0 mg/kg) and Copper (25.68 mg/kg) were the highest.

In the samples collected from Desi Organics and Natural, Vajrahalli the concentration of Lead, Nickel and Cadmium were below detectable limit in all the vegetable samples. The concentration of Zinc was highest in Beans (131.45 mg/kg). The highest concentration of Iron in Spinach was 360.50 mg/kg whereas highest concentration of Chromium was found in Capsicum (316.65 mg/kg). The Manganese concentration was highest in Carrot (125.60 mg/kg) whereas lowest in Tomato (77.30 mg/kg). The concentration of Copper was highest in Green Chilly (5.93 mg/kg).

In the vegetable samples obtained from Organic Stores, the concentration of Cadmium, Nickel and lead were below detectable limit.

5.4 Concentration of heavy metals in vegetables from HOPCOMS

Samples of vegetables were collected randomly in duplicates from five different HOPCOMS stores across Bengaluru city. They were HOPCOMS from various areas such as Lalbagh, Yelahanka, Shanthinagar, Hebbal and Rajarajeshwarinagar. A total of ten vegetables namely Brinjal, Tomato, Capsicum, Bean, Carrot, Green Chilly, Onion, Potato, Spinach and Coriander were collected and analyzed for heavy metals (Cd, CO, Cr, Cu, Fe, Mn, Ni, Pb, and Zn). Therefore, a total of 100 samples were analyzed in the five HOPCOMS.

In the samples collected from HOPCOMS - Lalbagh, the concentration of Lead and Nickel were below detectable limit in all the vegetable samples. The highest concentration of Iron in Spinach was 370.23 mg/kg whereas highest concentration of Chromium was found in Potato (306.80 mg/kg). The Manganese

concentration was highest in Coriander (137.63 mg/kg) whereas lowest in Tomato (17.53 mg/kg). The concentration of Copper was highest in Spinach (12.43 mg/kg). Cadmium was found to be highest in Tomato (5.23 mg/kg). Zinc concentration was highest in Tomato (26.90 mg/kg).

In the samples collected from HOPCOMS - Yelahanka, the concentration of Lead and Cadmium is below detectable limit in all the vegetable samples. In Nickel, the highest concentration recorded was in Onion (6.43 mg/kg) and was below detectable limit in the remaining vegetable samples. The highest concentration of Iron in Onion was 592.18 mg/kg whereas highest concentration of Chromium was found in Tomato (287.08 mg/kg). The Manganese concentration was highest in Carrot (146.68 mg/kg) whereas lowest in Onion (62.93 mg/kg). The concentration of Copper (241.98 mg/kg) and Zinc (48.18 mg/kg) were highest in Spinach.

In the samples collected from HOPCOMS - Shanthinagar, the concentration of Lead was below detectable limit in all the vegetable samples. The highest concentration of Iron in Spinach was 448.45 mg/kg whereas highest concentration of Chromium was found in Beans (295.30 mg/kg). The Manganese concentration was highest in Coriander (137.63 mg/kg) whereas lowest in Potato (73.15 mg/kg). The concentration of Copper was highest in Coriander (20.13 mg/kg). Cadmium was found to be highest in Tomato (3.68 mg/kg).
Zinc concentration was highest in Spinach (135.53 mg/kg).

In the samples collected from HOPCOMS - Hebbal, the concentration of Nickel was below detectable limit in all the vegetable samples. The highest concentration of Iron in Potato was 212.78 mg/kg whereas highest concentration of Chromium was found in Brinjal (292.85 mg/kg). The Manganese concentration was highest in Coriander (158.20 mg/kg) whereas lowest in Capsicum (92.1 mg/kg). The concentration of Copper was highest in Beans (64.0 mg/kg). Cadmium was found to be highest in Potato (3.80 mg/kg).
Zinc concentration was highest in Spinach (32.50 mg/kg).

In the samples collected from HOPCOMS - Rajarajeshwarinagar, the concentration of Nickel was below detectable limit in all the vegetable samples. The highest concentration of Iron in Coriander was 466.35 mg/kg whereas highest concentration of Chromium was found in Potato (290.38 mg/kg). The Manganese concentration was highest in Spinach (179.85 mg/kg) whereas lowest in Onion (67.63 mg/kg). The concentration of Copper was highest in Onion and Carrot (18.95 mg/kg). Cadmium was found to be highest in Spinach (1.50 mg/kg). Zinc concentration was highest in Coriander (388.70 mg/kg).

Among the vegetable samples collected from HOPCOMS, Lead concentration was below detectable limit in samples collected from Lalbagh, Yelahanka and Shanthinagar stores whereas Nickel concentration was below detectable limit in samples obtained from all areas

Table 13. Concentration of heavy metals in vegetable samples collected from Organic World - Vasanthnagar

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	340.80	131.45*	286.28	131.63	BDL	2.38	BDL	BDL
Coriander	304.13	19.15	291.20	116.45		84.13*		
Brinjal	316.00	BDL	281.38	66.33		156.0*		
Tomato	32.45	BDL	278.08	56.93		1.38		
Capsicum	19.40	9.28	310.88	68.10		3.15		
Potato	165.25	4.20	308.43	70.80		2.78		
Green Chilly	175.55	9.55	279.73	62.23		4.35		
Onion	90.98	BDL	257.58	61.98		45.03		
Carrot	157.35	20.93	273.18	61.05		BDL		
Beans	810.20 *	145.08*	269.85	66.13		4.73		
Maximum	810.20	145.08	310.88	131.63	-	156.00	-	-
Minimum	19.40	BDL	257.58	56.93	-	BDL	-	-
Average	270.14	38.73	283.75	79.18	-	37.63	-	-
Standard Deviation	229.90	56.53	16.50	25.79	-	52.22	-	-
No. of samples above safe limit	1	2	-	0	0	2	0	0

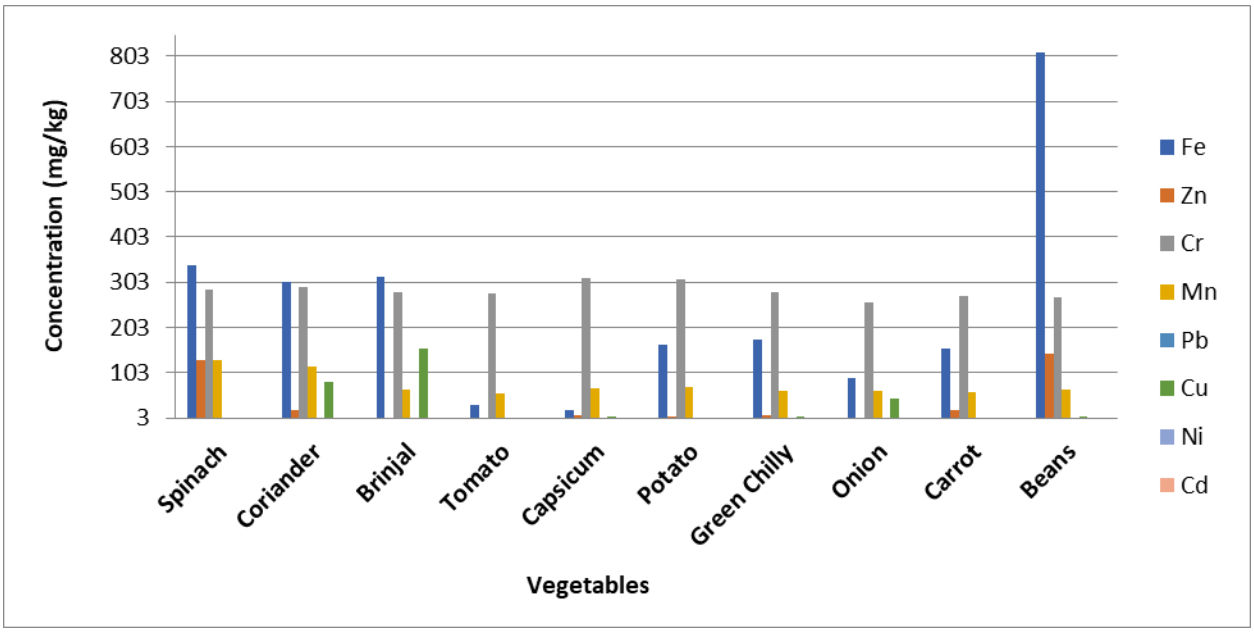


Table 14. Concentration of heavy metals in vegetable samples collected from Village Naturals, ISRO Layout

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	554.58*	55.55	285.48	228.90	BDL	11.48	BDL	BDL
Coriander	945.70*	27.70	320.73	107.05		17.98		
Brinjal	98.55	5.00	316.63	47.30		165.70*		
Tomato	116.73	1.55	324.00	62.68		46.23		
Capsicum	149.50	BDL	315.00	54.83		62.40		
Potato	219.53	BDL	310.90	65.75		4.73		
Green Chilly	129.78	4.80	303.50	52.10		8.70		
Onion	103.40	BDL	315.80	65.40		8.50		
Carrot	137.05	BDL	310.90	49.53		24.23		
Beans	114.90	BDL	297.75	63.53		101.50*		
Maximum	945.70	55.55	324.00	228.90	-	165.70	-	-
Minimum	98.55	BDL	285.48	47.30	-	4.73	-	-
Average	301.16	10.48	309.18	89.44	-	51.82	-	-
Standard Deviation	277.88	19.49	11.59	55.08	-	52.31	-	-
No. of samples above safe limit	2	0	-	0	0	2	0	0

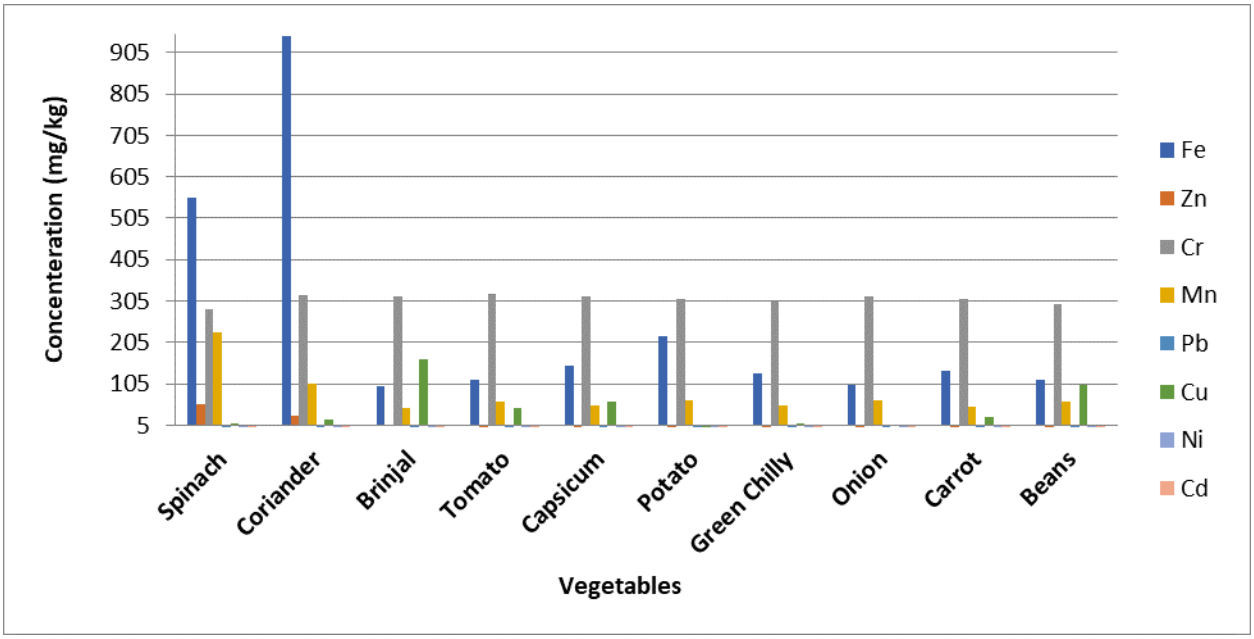


Table 15. Concentration of heavy metals in vegetable samples collected from Grameena Angadi - Rajajinagar

Vegetables	Heavy metals(mg/kg)							
	Fe	**Zn**	**Cr**	**Mn**	**Pb**	**Cu**	**Ni**	**Cd**
Spinach	370.23	35.88	214.80	85.98	BDL	12.43	BDL	BDL
Coriander	361.03	36.03	279.73	137.63		7.50		
Brinjal	96.13	17.08	275.73	73.75		8.10		
Tomato	54.28	19.43	263.20	17.53		6.93		
Capsicum	104.60	3.38	264.15	20.13		4.55		
Potato	200.13	BDL	275.60	21.18		3.75		
Green Chilly	347.33	5.08	276.45	26.35		6.10		
Onion	50.63	BDL	283.83	22.10		7.70		
Carrot	185.58	4.48	297.78	28.93		4.35		
Beans	101.28	20.25	293.65	63.88		6.13		
Maximum	370.23	36.03	297.78	137.63	-	12.43	-	-
Minimum	50.63	-	214.80	17.53	-	3.75	-	-
Average	191.00	13.46	269.79	54.38	-	6.98	-	-
Standard Deviation	128.39	15.09	23.06	39.84	-	2.49	-	-
No. of samples above safe limit	0	0	-	0	0	0	0	0

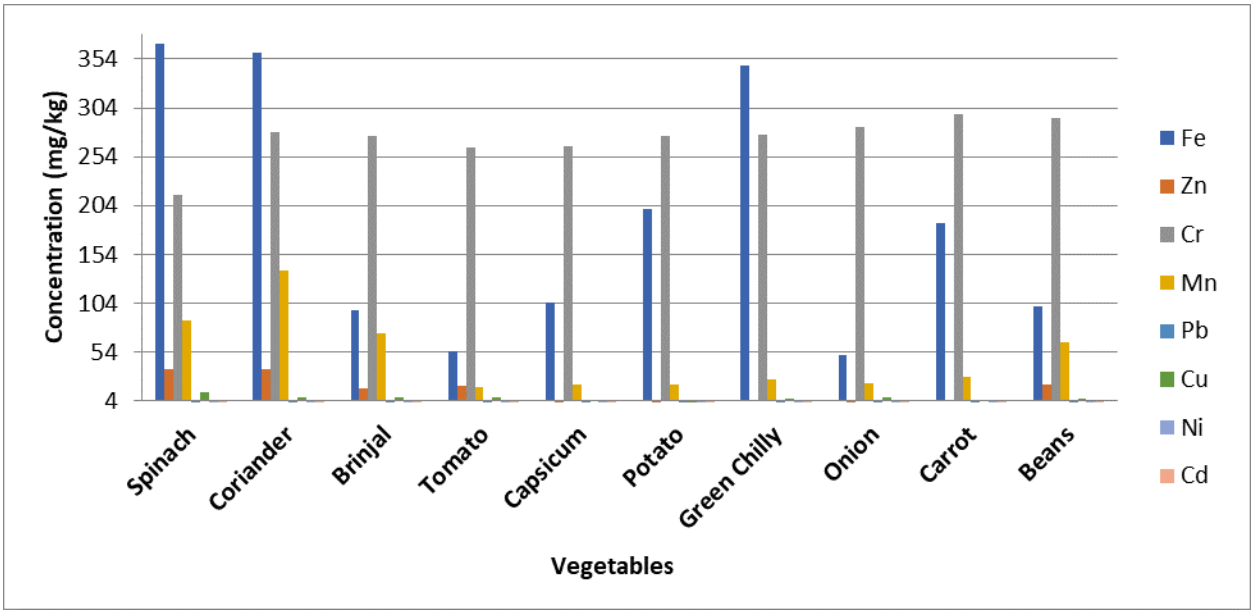


Table 16. Concentration of heavy metals in vegetable samples collected from Namdhari's Fresh - Indiranagar

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	183.15	150.88*	281.35	287.00	BDL	25.68	BDL	BDL
Coriander	115.85	21.63	274.78	86.70		6.13		
Brinjal	49.43	18.48	290.40	86.33		5.93		
Tomato	101.88	15.03	283.00	83.28		10.48		
Capsicum	58.53	18.35	287.10	86.35		6.50		
Potato	137.05	5.28	273.15	79.73		2.38		
Green Chilly	70.98	0.95	319.08	87.53		9.68		
Onion	59.13	2.75	292.85	83.50		BDL		
Carrot	126.45	8.68	295.30	93.03		BDL		
Beans	74.60	6.83	300.23	90.10		5.35		
Maximum	183.15	150.88	319.08	287.00	-	25.68	-	-
Minimum	49.43	0.95	273.15	79.73	-	BDL	-	-
Average	100.80	33.39	290.79	119.19	-	7.82	-	-
Standard Deviation	42.98	44.85	13.47	63.58	-	7.66	-	-
No. of samples above safe limit	0	1	-	0	0	0	0	0

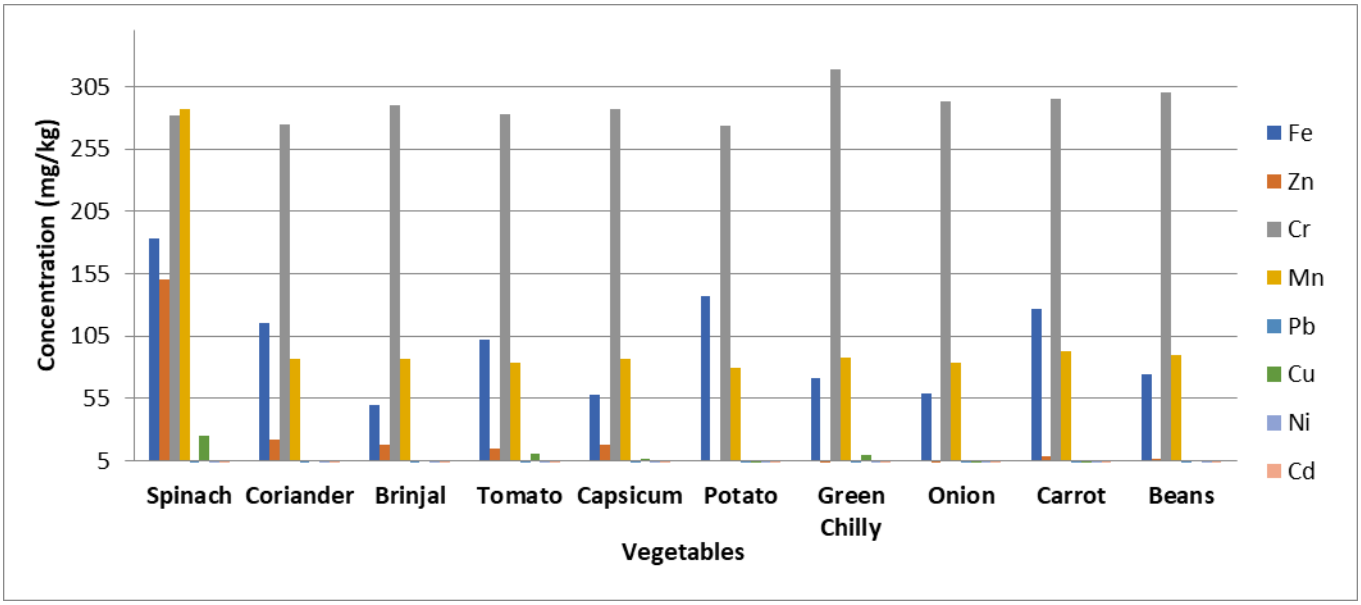


Table 17. Concentration of heavy metals in vegetable samples collected from Desi Organics and Natural – Vajrahalli

Vegetables	Heavy metals (mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	360.50	15.65	290.38	123.85	BDL	5.35	BDL	BDL
Coriander	205.88	46.65	292.83	92.58		0.40		
Brinjal	55.80	27.63	299.40	91.15		BDL		
Tomato	34.58	7.60	273.15	77.30		BDL		
Capsicum	21.83	45.85	316.65	79.63		2.55		
Potato	110.08	8.33	297.75	91.50		2.95		
Green Chilly	30.93	4.53	284.65	84.45		5.93		
Onion	19.40	17.15	290.38	84.93		1.58		
Carrot	158.90	11.65	295.30	125.60		0.38		
Beans	50.95	131.45*	299.40	107.03		BDL		
Maximum	360.50	131.45	316.65	125.60	-	5.93	-	-
Minimum	19.4	4.525	273.15	77.3	-	-	-	-
Average	119.06	37.70	294.14	96.74	-	-	-	-
Standard Deviation	109.76	38.19	11.24	17.33	-	-	-	-
No. of samples above safe limit	0	1	-	0	0	0	0	0

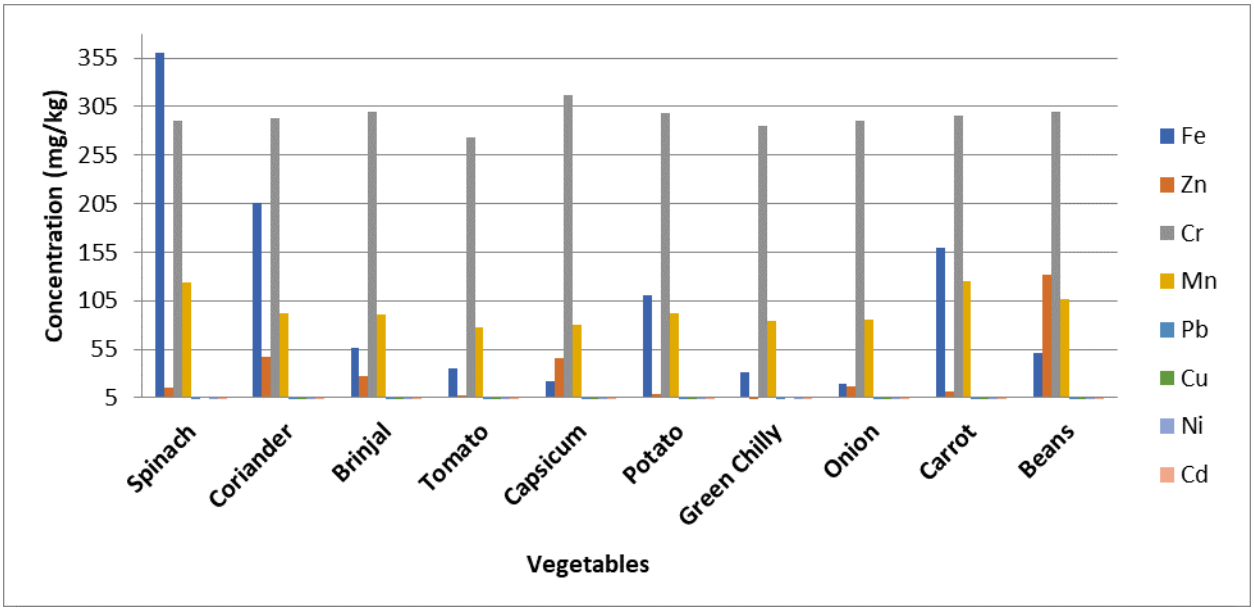


Table 18. Concentration of heavy metals in vegetable samples collected from HOPCOMS – Lalbagh

Vegetables	Heavy metals (mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	370.23	23.30	257.55	85.98	BDL	12.43	BDL	0.93*
Coriander	361.03	23.30	276.45	137.63		7.50		0.93*
Brinjal	96.13	0.68	300.23	73.75		8.10		2.88*
Tomato	54.28	26.90	293.65	17.53		6.93		5.23*
Capsicum	104.60	3.65	292.83	20.13		4.55		BDL
Potato	200.13	BDL	306.80	21.18		3.75		BDL
Green Chilly	347.33	BDL	278.08	26.35		6.10		BDL
Onion	50.63	BDL	270.70	22.10		7.70		BDL
Carrot	185.58	BDL	274.80	28.93		4.35		BDL
Beans	101.28	7.45	269.85	63.88		6.13		BDL
Maximum	370.23	26.90	306.80	137.63	-	12.43	-	5.23
Minimum	50.63	BDL	257.55	17.53	-	3.75	-	-
Average	191.00	8.07	282.11	54.38	-	6.98	-	-
Standard Deviation	128.39	12.32	15.53	39.84	-	2.49	-	-
No. of samples above safe limit	0	0	-	0	0	0	0	4

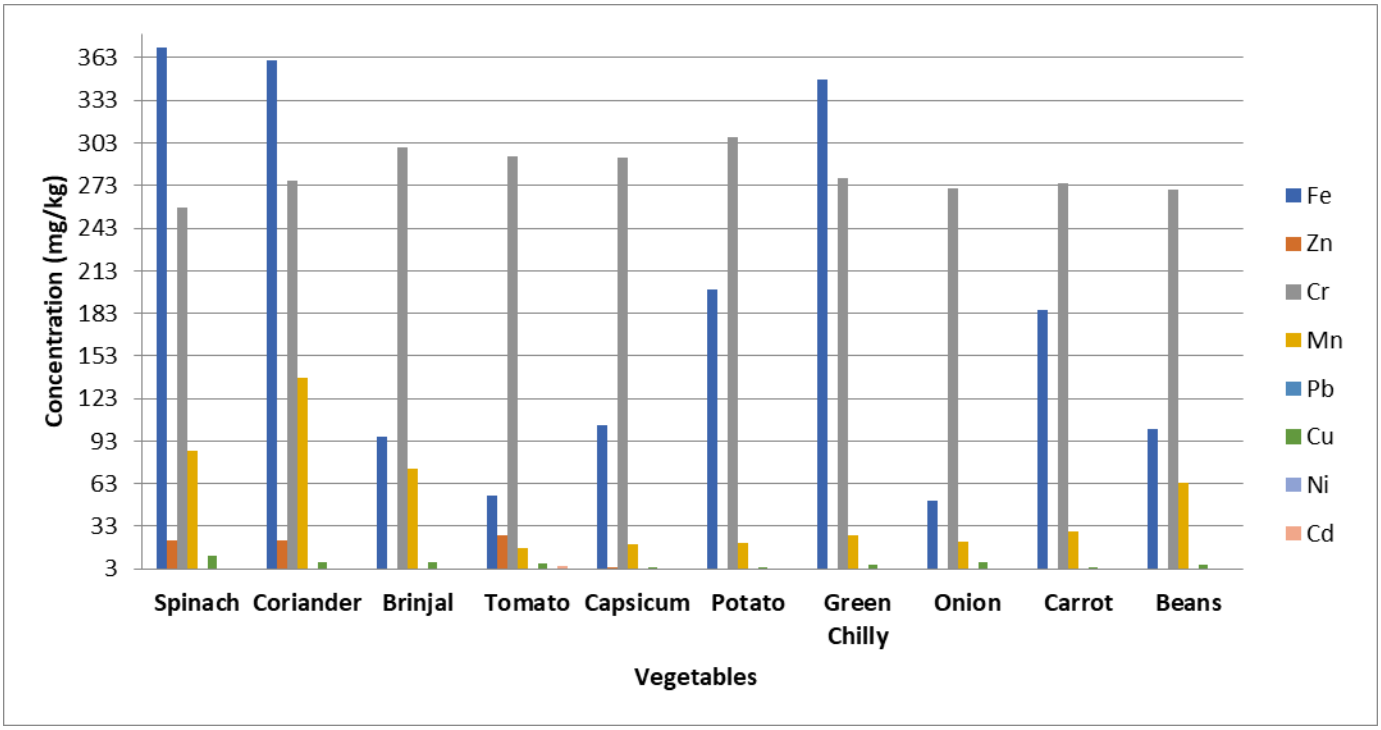


Table 19. Concentration of heavy metals in vegetable samples collected from HOPCOMS - Yelahanka

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	525.78*	48.18	268.23	97.28	BDL	241.98*	BDL	BDL
Coriander	266.83	25.48	269.05	82.70		1.78	BDL	
Brinjal	98.53	8.73	249.38	68.10		5.93	BDL	
Tomato	133.10	6.85	287.08	67.50		4.83	BDL	
Capsicum	161.30	18.90	276.43	71.75		28.05	BDL	
Potato	214.68	21.20	278.88	68.83		6.53	BDL	
Green Chilly	72.18	4.83	265.75	70.35		94.60*	BDL	
Onion	592.18*	0.40	255.10	62.93		51.35	6.43	
Carrot	290.18	39.35	273.98	146.68		38.50	BDL	
Beans	294.13	19.85	257.55	73.53		21.60	BDL	
Maximum	592.18	48.18	287.08	146.68	-	241.98	6.43	-
Minimum	72.18	0.40	249.38	62.93	-	1.78	-	-
Average	276.10	20.19	268.15	84.94	-	61.57	-	-
Standard Deviation	173.88	15.32	11.63	25.08	-	73.38	-	-
No. of samples above safe limit	2	0	-	0	0	2	0	0

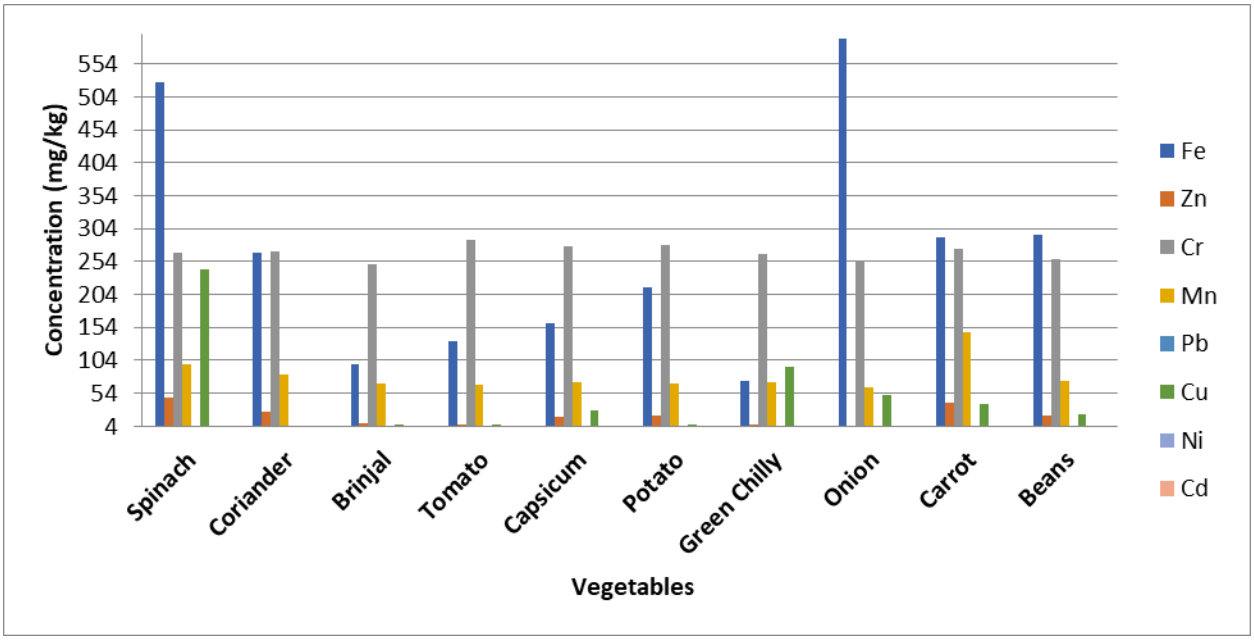


Table 20. Concentration of heavy metals in vegetable samples collected from HOPCOMS - Shanthinagar

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	448.45*	135.53*	246.10	308.40	BDL	19.55	25.00	BDL
Coriander	393.88	112.90*	279.73	157.50		20.13	BDL	2.60*
Brinjal	211.03	39.95	257.58	77.15		3.55	BDL	0.48*
Tomato	109.78	28.65	279.73	116.33		BDL	BDL	3.68*
Capsicum	300.48	10.70	264.13	108.93		BDL	BDL	3.38*
Potato	378.13	17.60	279.73	73.15		5.93	BDL	0.95*
Green Chilly	179.20	17.93	291.20	92.33		2.75	BDL	1.85*
Onion	117.65	3.53	280.55	120.43		2.58	BDL	BDL
Carrot	290.18	10.83	289.58	78.35		BDL	26.45	2.00*
Beans	52.75	12.73	295.30	138.10		BDL	BDL	0.15*
Maximum	448.45	135.53	295.30	308.40	-	20.13	26.45	3.68
Minimum	52.75	3.53	246.10	73.15	-	-	-	-
Average	248.56	44.11	275.42	137.68	-	-	-	-
Standard Deviation	134.68	46.35	15.72	69.44	-	-	-	-
No. of Samples above safe limit	1	2	-	0	0	0	0	8

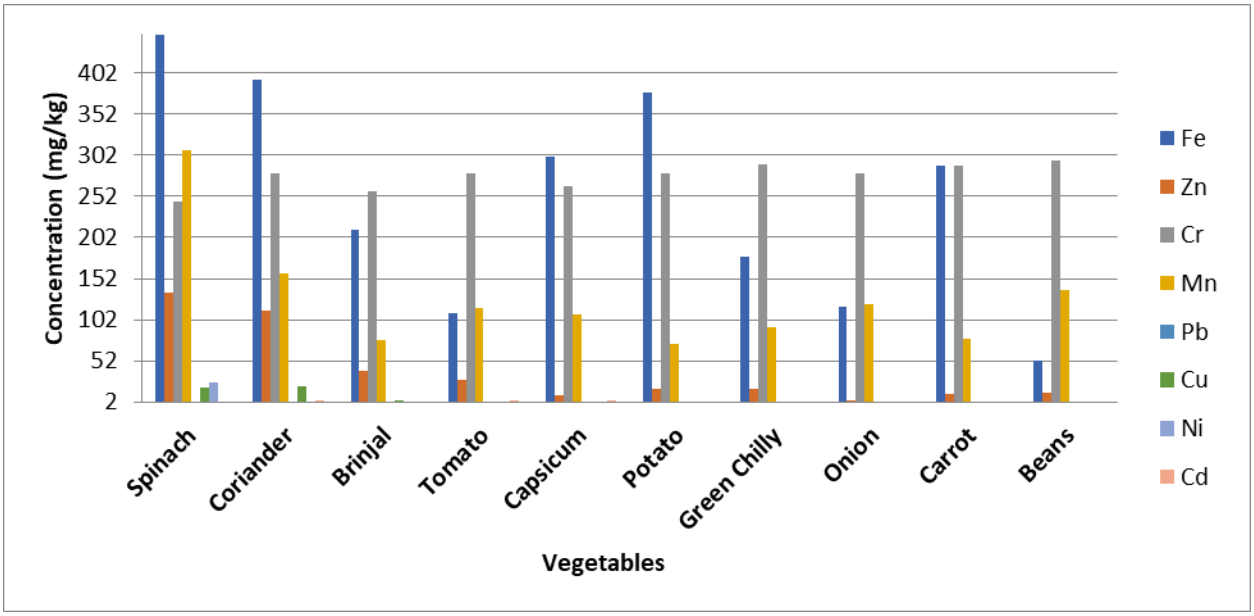


Table 21. Concentration of heavy metals in vegetable samples collected from HOPCOMS - Hebbal

Vegetables	Heavy metals (mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	122.50	32.50	285.48	119.60	49.45*	BDL	BDL	2.65*
Coriander	121.58	11.80	272.35	158.20	47.80*	11.25		1.28*
Brinjal	112.80	5.48	292.85	104.80	24.73*	8.88		2.93*
Tomato	20.63	12.00	281.35	105.85	74.20*	6.50		BDL
Capsicum	3.63	2.70	273.15	92.10	69.23*	6.90		BDL
Potato	212.78	BDL	264.95	92.45	64.28*	BDL		3.80*
Green Chilly	43.35	9.35	284.65	101.15	72.53*	14.20		2.50*
Onion	127.33	30.60	281.35	100.93	51.10*	53.10		0.88*
Carrot	30.00	6.23	269.05	93.15	56.05*	8.13		3.00*
Beans	60.05	9.28	263.30	116.20	74.18*	64.00		1.80*
Maximum	212.78	32.50	292.85	158.20	74.20	64.00	-	3.80
Minimum	3.625	BDL	263.3	92.1	24.725	BDL	-	BDL
Average	89.25	12.30	277.05	111.23	56.87	18.76	-	1.24
Standard Deviation	64.79	11.31	9.73	19.85	15.76	23.06	-	2.20
No. of samples above safe limit	0	0	0	0	10	0	0	8

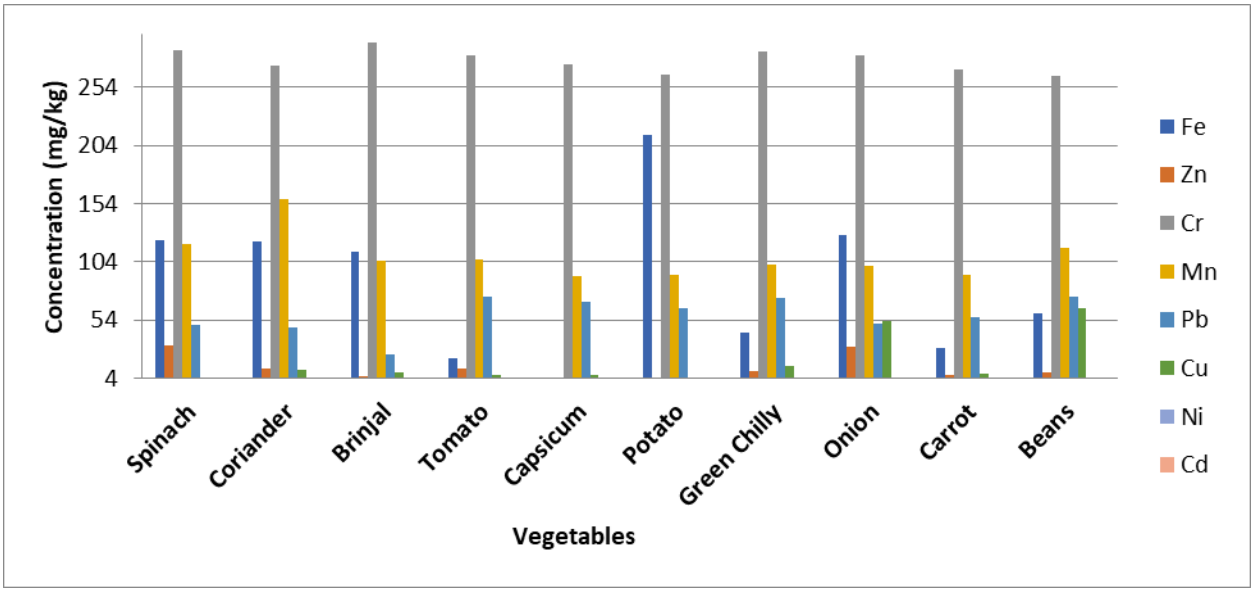
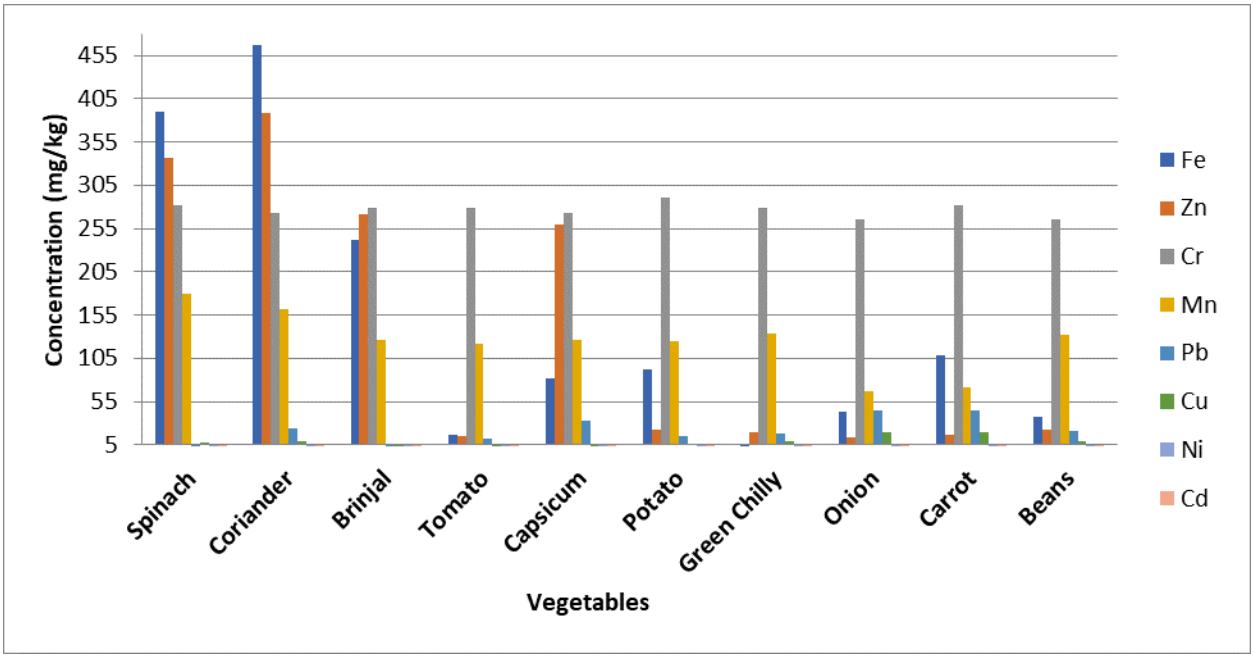


Table 22. Concentration of heavy metals in vegetable samples collected from HOPCOMS - Rajarajeshwarinagar

Vegetables	Heavy metals(mg/kg)							
	Fe	Zn	Cr	Mn	Pb	Cu	Ni	Cd
Spinach	389.33	336.20*	282.20	179.85	BDL	7.50	BDL	1.50*
Coriander	466.35*	388.70*	273.40	161.63	24.73*	9.10		BDL
Brinjal	241.05	271.80*	278.08	126.20	BDL	BDL		BDL
Tomato	17.30	15.10	278.08	121.50	12.38*	BDL		BDL
Capsicum	81.25	259.40*	273.15	125.50	32.98*	4.73		BDL
Potato	92.48	22.03	290.38	124.78	14.85*	5.73		BDL
Green Chilly	3.33	20.25	278.08	134.20	18.13*	9.30		BDL
Onion	43.05	14.30	265.78	67.63	44.50*	18.95		BDL
Carrot	108.85	16.33	281.35	70.80	44.50*	18.95		BDL
Beans	37.90	22.00	265.78	132.10	21.43*	9.68		BDL
Maximum	466.35	388.70	290.38	179.85	44.50	18.95	-	1.50
Minimum	3.33	14.30	265.78	67.63	BDL	BDL	-	-
Average	162.55	147.43	276.87	124.30	13.81	7.75	-	-
Standard Deviation	162.78	156.61	7.50	34.52	25.79	7.46	-	-
No. of Samples above safe limit	1	4	0	0	8	0	0	1



Due to rapid increase in population and industrialization, the natural water resources are under enormous pressure. Industrial and municipal wastewater production has been increasing over a period of time. Industrial effluents contain large number of toxic pollutants like heavy metals and these pollutant rich effluents are drained in water bodies without any treatment. This heavy metal rich waste water is frequently used for irrigation purposes by the peri-urban farmers due to its free and continuous availability throughout the year. These farmers tend to grow the crops with short cultivation period and the vegetables are grown to cater to the needs of the nearby markets. The heavy metals are non-biodegradable, persistent, carcinogenic and mutagenic in nature.

The present research work was carried out to determine the bioaccumulation of heavy metals in the vegetables sold in a variety of markets across Bengaluru city. Even though the source of procurement of these vegetables in the markets were not made in the study, based on the concentration of heavy metals in the sampled vegetables there is future scope of tracing the sources of vegetables.

Among the Retail markets samples, Coriander was found to have highest concentration of Manganese (499.60 mg/kg) and Iron (514.05 mg/kg) in samples obtained from Big Bazar and Metro Cash and Carry. Brinjal (422.23 mg/kg), Spinach (421.53 m/kg) and Capsicum (421.50 mg/kg) had higher concentration of Chromium in samples obtained from Spar whereas Beans (386.03 mg/kg) and Tomato (372.63 mg/kg) had higher concentration of Chromium in samples obtained from More Mega Mart. Samples from Reliance Fresh had higher concentration of Iron in both Coriander (546.20 mg/kg) and Spinach (474.80). Contrary to the present study, heavy metal analysis in vegetable samples of Bengaluru and Tumukur market places revealed that Copper concentration ranged from 45 to 244 ppm and Cr was between 348 to 917 ppm which is greater than the permissible levels recommended by WHO (Gurukiran et.al., 2017).

In leafy vegetables (Spinach, Cabbage and Coriander) the concentration of trace elements (mg/kg dry weight) ranged between 22.34-556.70 for Fe, 13.3-162.5 for Zn, 1.26-67.66 for Cd, 10.69-202.6 for Cu, 11.36-54.8 for Pb and 9.99-506.2 for Ni. The mean Fe concentrations varied from 32.49-351.23 mg/kg which were in good agreement with concentrations (111-378 mg/kg) observed in vegetables by Arora et. al. (2008). The maximum uptake of Fe was in Tomato (351.23mg/kg) followed by Cabbage (292.35mg/kg) and Spinach (69.98 mg/kg), whereas the levels of Fe in all the vegetables were above the prescribed safe limit of WHO. The upper concentrations of Fe in vegetables were also found very similar to the values (2.11-336.9 mg/kg) reported by Kisku et al. (2000) for vegetables irrigated with mixed industrial effluents in India.

Among the local markets samples, Spinach (256.20 mg/kg) and Potato (239.70 mg/kg) had higher concentration of Iron from samples obtained from Malleshwaram market. Iron and Chromium were in higher concentration in Spinach (452.6 mg/kg) and Chromium (286.42 mg/kg) in samples obtained from Yeshwanthpur market. Carrot was found to have higher concentration of both Iron (146.08 mg/kg) and

Chromium (136.58 mg/kg) in samples obtained from Banashankari Market. Similarly in samples obtained from Gandhi Bazar market, Spinach (363.45 mg/kg) and Coriander (305.26 mg/kg) were found to have higher concentration of Iron content along with Chromium metal (261.10 mg/kg) in Onion. Spinach (546.75 mg/kg) was the only vegetable to have higher concentration of Iron in sample obtained from K.R.Market. In another study, by Lokeshappa et al., (2012) the elemental concentration in different agricultural product were estimated revealed that micronutrient such as Cu and Zn was abundant in all varieties and concentration of zinc was high comparable to copper. Mn was present in Bean only with moderate concentration (26 mg/kg). It was observed that maximum concentration of Mn (137.3 mg/kg), Cr (6.62 mg/kg) and Fe (968.25 mg/kg) was found in spinach, exceeding the allowed threshold 2.2 mg/kg, 2.3 mg/kg and 425 mg/kg respectively, as set by WHO/FAO in studies by Latif et.al., (2018).

Beans obtained from Organic world had Iron concentration as high as 810.20 mg/kg. The Iron concentration in Coriander was 945.70 mg/kg and 554.58 mg/kg in Spinach obtained from Village Naturals. Grameema Angadi had highest concentration of Iron and Chromium in Spinach (370.23 mg/kg) and Carrot (297.78 mg/kg) respectively. Chromium and Manganese was highest in Green Chilly (319.08 mg/kg) and Spinach (287.0 mg/kg) respectively in samples obtained from Namdhari's Fresh. Spinach (360.50 mg/kg) and Capsicum (316.65 mg/kg) had higher concentration of Iron and Chromium in samples obtained from Desi Organics and Natural.

Among the HOPCOMS, Onion was found to have 592.18 mg/kg of Iron in samples obtained from Yelahanka and 448.45 mg/kg of Iron in Spinach obtained from Shanthinagar. Brinjal (292.85 mg/kg) was seen to have highest concentration of Chromium in samples obtained from Hebbal. Iron was found to be in higher concentration in Coriander (466.35 mg/kg) and Spinach (389.33 mg/kg) in samples obtained from Rajarajeshwarinagar HOPCOMS.

Reliance Fresh, Jayanagar showed the least concentration of heavy metals (Fe, Zn, Mn, Pb, Cu and Ni) in vegetables compared to the other four Retail stores. Among the local market samples, Banashankari market showed the least concentration of heavy metals (Fe, Zn, Mn, Pb, Cu and Ni) compared to the other four local markets whereas Desi Organics & Naturals and Namdhari's Fresh showed the lowest concentration of heavy metals (Fe, Mn, Pb, Cu, Ni and Cd) compared to the other three organic stores. The vegetable samples from HOPCOMS - Lalbagh showed the least concentration of heavy metals (Fe, Zn, Mn, Pb, Cu and Ni) compared to the other four stores.

The final insights to the study revealed that, out of twenty stores/markets belonging to four different categories (Retail stores, local markets, Organic stores and HOPCOMS) sampled for different vegetables in Bengaluru city, Desi Organics & Naturals, Vajrahalli and Namdhari's Fresh, Indiranagar were found to have lower concentration of heavy metals as compared to all other stores. Further, to understand the source of vegetables and its contamination in different stores/markets, a detailed study may be proposed.

This would help us to reduce the exposure of vegetables to heavy metal contamination at the source and thereby reduce the health risk to humans.

6.0 CONCLUSION

It is very clear from the present study that the edible vegetables are hyperaccumulators of heavy metals. So, taking into consideration the health risks associated with consumption of these vegetables, it is suggested that vegetable cultivation should not use waste water as a source.

- Farmers growing vegetables should use clean surface water for cultivation of the crops
- In case of non-availability of clean water, at least treated water should be used for the purpose of cultivation
- Few vegetables studied had higher amounts of heavy metals than the prescribed limits standardized by various health associations.
- In terms of the eight metals analyzed, the concentrations in vegetables were not very different in the four categories of markets
- Cultivation of root and leafy vegetables which are hyper-accumulators, should be restricted in such polluted areas such as peripherals of the city
- Waste water reuse is the need of the hour because it will help to conserve and replenish the depleting potable water resources. Hence, it should be properly treated to remove the harmful pollutants before its reuse for irrigational purposes
- Awareness campaigns about the cause and effect of such toxic pollutants is the need of the hour
- Combined efforts should be done by the government, industrialists, farmers, soil and water scientists and social organizations to tackle such problems
- Reuse and reduction of materialistic things can be the first step to reduce the amount of pollutants in the environment.

7.0 RECOMMENDATIONS

- ✓ Farmers should be made aware of toxic metal accumulations in greens and vegetables and their imminent threat to consumers
- ✓ For the farmers those who grow food crops, testing of soils and water should be mandated by the concerned regional agricultural department or pollution control board. More particularly, farmers, who grow these crops on either side of highways, must go for soil testing
- ✓ Farmers should not resort to unethical farming practices such as irrigating the crops with drainage and effluent waters
- ✓ It is advised to avoid eating spinach bought from the vegetable markets of the Bangalore. Instead, these greens can be grown organically at home in rooftop gardens, window gardens and balcony gardens

- ✓ Farmers of the suburban areas should not be allowed by law to grow the greens and vegetables utilizing the drainage and effluent waters
- ✓ A continuous monitoring is recommended to rule out toxic metal contamination in these greens and vegetables

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