IMPACT OF SEWAGE IRRIGATION WATER ON SOIL POLLUTION AND UPTAKE OF HEAVY METALS BY CROPS IN PERI-URBAN AREA OF NAGPUR

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
in partial fulfilment of the requirements
for the Degree of

MASTER OF SCIENCE
IN
AGRICULTURE
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

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Enrolment Number – LL/116

2019

DECLARATION OF STUDENT

I hereby, declare that the experimental work and its interpretation of the Thesis entitled **"IMAPCT OF SEWAGE IRRIGATION WATER ON SOIL POLLUTION AND UPTAKE OF HEAVY METALS BY CROPS IN PERI-URBAN AREA OF NAGPUR"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis/publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place: Nagpur **(Patle Shweta Ramesh)**

Date: 13 / 08 /2019 Enrolment No. LL/116

CERTIFICATE

This is to certify that thesis entitled **"IMPACT OF SEWAGE IRRIGATION WATER ON SOIL POLLUTION AND UPTAKE OF HEAVY METALS BY CROPS IN PERI-URBAN AREA OF NAGPUR"** submitted in partial fulfilment of the requirement for the degree of **"Master of Science in Agriculture (Soil Science and Agricultural Chemistry)"** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Patle Shweta Ramesh** under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

Place: Nagpur
Date: 13 /08/2019

(Dr. W. P. Badole)
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THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER (AFTER VIVA-VOCE)

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ACKNOWLEDGEMENTS

I am extremely blessed individual with an overwhelming amount to be thankful for in my life. My family and friends who support me are the backbone of my personal achievements. I thank God for the patience and perseverance to not only set goals, but to have the willpower to achieve them. Pursuing a graduate degree took a leap of faith and I am proud of myself for taking that leap.

I express my deep sense of gratitude and cordially thanks to golden heart personality Dr. W. P. Badole, Head of section of Soil Science and Agricultural Chemistry, College of Agriculture, Nagpur and the Chairman of my advisory committee for suggesting the research topic and also taking keen interest during the course of this investigation, constructive criticism, constant encouragement and guidance, giving valuable suggestions throughout the final shaping of the research topic.

I am extremely thankful to the members of my Advisory Committee, Dr. S. S. Balpande, Associate Professor of Soil Science and Agricultural Chemistry, College of Agriculture Nagpur, Dr. A. R. Mhaske, Assosiate Professor of Agril. Engg. and Dr. Y. R. Khobragade, Associate Professor of Horticulture for their creative criticism and suggestions in the preparation of thesis and for their helpful nature during the entire course of investigation.

I will be highly improper if I do not acknowledge the kind advices from Dr. W. P. Badole, Head of section, Soil Science and Agricultural Chemistry, College of Agriculture, Nagpur for providing necessary facilities required for the present investigation.

I gratefully acknowledge my indebtedness and sincere thanks to Dr. D. M. Panchbhai, Associate Dean, College of Agriculture, Nagpur for providing necessary facilities to carry out my research work.

I wish to express my sincere thanks to the academic staff members, Dr.O. D. Kuchanwar, Professor (CAS), Dr. R. M. Ghodpage, Professor (CAS), Dr. S. S. Balpande**,** Associate professor, Dr. P. Kausidikar, Associate professor, Dr. P.D. Raut, Assistant Professor of Soil Science and Agricultural Chemistry, College of Agriculture, Nagpur.

I am also thankful to Shri. N. D. Raut and Shri. Anil Sahare for their valuable help in time to time during the entire course of my study.

I extend my sincere thanks to my seniors Indranil Pathare, Nikhil Sarnaik, Pallavi Godbole, Dipali Dahule for their relentless help and suggestions during the analytical work.

I warmly thanks to my colleagues Harish Bajad, Shivani Karwadwe, Tejswini Umbarkar, Ruchika Nagmote, Swati Thombe, Priya Gadge, Kirti Sarnaik, Babita Patel, Jagriti Patel, Premanand Panghate and Yogesh Jaybhaye for their help, co-operation and constant encouragement during the course of study.

I again thankful to my juniors Sanjana Reddy, Yogesh and Ramesh for their painstaking efforts in efficient work processing of manuscript in time. I do express my heartfelt thanks to my friends Puja Baghele, Rekha Samrit and Durga Baghele for their help and constant encouragement, guidance and inspiration in time to time.

Finally, I have no words to acknowledge with thanks the warm affectionate love, constant inspiration and encouragement that I received from my beloved Father Shri Ramesh Karubhau Patle mother Sau. Nutan Ramesh Patle my Brother Dheeraj Ramesh Patle and my sister Nikita Ramesh Patle who are the architects of my past and present and my other family members.

I am thankful to all authors whose literature has been cited in this investigation.

Above all I am once again hearty thankful to all of them who really supported me during my PG course and due to lack of space their names are not mentioned here.

I am very much thankful to all authors whose literature has been referred to formulate the field trial and making my result thoughtful.

Place: Nagpur

Date: 13/08/2019 **Patle Shweta Ramesh**

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(D) Abbreviations

%	-	Per cent
mg kg^{-1}	-	Milligram per kilogram
mg m^3	-	Milligram per meter cube
>	-	More than
<	-	Less than
dS m^{-1}	-	Desi seimen per meter
DTPA	-	Diethylene triamine penta acetic acid
EC	-	Electrical conductivity
et al.	-	et alia (and associates)
Mg L^{-1}	-	Milligram per litre
APHA	-	American Public Health Association
AOAC	-	Association of Official Analytical Chemistry
J	-	Journal
cm h^{-1}	-	Centimeter per hour
kg ha^{-1}	-	Kilogram per hectare
Zn	-	Zinc
Cu	-	Copper
Fe	-	Ferrous
Mn		Manganese
Cd	-	Cadmium
Co	-	Cobalt
Hg	-	Mercury
Pb	-	Lead
BIS	-	Beauro of Indian standrad
TSS	-	Total Soluble Solids
Viz.	-	Videlicet
WHO	-	World Health Organization
Cr	-	Chromium

(E) THESIS ABSTRACT

a) Title of the thesis	:	**"IMPACT OF SEWAGE IRRIGATION WATER ON SOIL POLLUTION AND UPTAKE OF HEAVY METALS BY CROPS IN PERI-URBAN AREA OF NAGPUR"**
b) Full name of student	:	**PATLE SHWETA RAMESH**
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d) Degree to be awarded	:	M.Sc. (Agri.)
e) Year of award of degree	:	2019
f) Major subject	:	Soil Science & Agricultural Chemistry
g) Total No. of pages in thesis	:	61
h) Number of words in abstract	:	442
i) Signature of the student	:	
j) Signature, Name and Address of forwarding Authority	:	**(Dr. W. P. Badole)** **Professor** Soil Science and Agriculture Chemistry Section, College of Agriculture, Nagpur.

ABSTRACT

The study was conducted on “Impact of sewage irrigation water on soil pollution and uptake of heavy metals by crops in peri-urban area of Nagpur” to estimate the characteristics of sewage water of Nag river and to assess the possible impact on soil properties and concentration of micronutrients and heavy metals in edible parts of vegetables and cereal crop during the year of 2018-2019. Experiment was in completely randomized design with 9 replications and 3 treatments. Total 27 sample were collected from 9 villages. Sewage water sample, sewage water irrigated soil and plant samples of Brinjal, Tomato, Cauliflower and Wheat were collected and analysed for different plant nutrient and heavy metals. The data revealed that sewage water samples were slightly acidic to neutral in reaction (6.17 to 6.94) and EC was 1.25 to 2.06 dS m^{-1}. The concentration of cation and anion were in the order of Na^{+} > Mg^{2+} and HCO^{3-} > Cl^{-} > CO^{3-} > SO_4^{2-} respectively. Total hardness and Ca-hardness of sewage water sample was ranged from 170.78 to 273.3 mg L^{-1} and 117.4 to 197 mg L^{-1}. The COD of sewage water sample was less than ISI standard. TSS and ammonia of sewage water were reported maximum at Narsala village. The concentration of micronutrients and heavy metals in sewage water sample were in order of Mn > Cu > Fe> Zn and Pb > Co > As > Cd > Cr > Hg.

The bulk density and hydraulic conductivity of sewage water irrigated soil was varied in range 1.42 g cm^3 and 2.43 cm h^{-1}. Available N, P and K of sewage water irrigated soil were ranged between 280.04 to 324.95, 10.1 to 15.63 and 596.07 to 686.6 kg ha^{-1} resulted under low, very low and very high category, respectively. The DTPA-extractable micro-nutrients and heavy metals of sewage water irrigated soil were in order of Mn > Fe > Cu > Zn and Pb > Co > Cr > Cd, respectively. The mean concentration of Fe, Mn, Zn and Cu in Brinjal was 438.91, 33.06, 53.26 and 22.34 mg kg^{-1}. The concentration Fe was more in Tomato followed by Brinjal and Cauliflower. The concentration

of Pb, Co, Cr and Cd in Wheat ranged from 2.5 to 6.9, 2.1 to 7.9, 3.49 to 16.9 and 0.4 to 2.2 mg kg^{-1}. The concentration of heavy metal in Brinjal, Tomato, Cauliflower and Wheat was found above the permissible limit.

Based on this result it was observed that concentration of micronutrients and heavy metals in sewage water were maximum at Narsala and minimum at Bhamewada. Sewage water of Nag-river should be used after giving secondary treatment before use for protective irrigation.

Chapter I

INTRODUCTION

1.1 Background Information

Water is an indispensable resource for every aspect of human society. The increase in the human population together with rapid industrial and urban development has resulted in a sharp rise in the demand for water, while the available fresh water supplies have remained nearly constant. On an average the total available supplies may appears sufficient to meet the human needs, but they are not easily accessible or evenly distributed in space and time. About 92 per cent of the harnessed water resources are used in agriculture for irrigation. Increasing the efficiency of water use in this sector is, therefore, crucial for national development. Morever, huge quantity of sewage water is available from the urban areas which are left in the rivers and ultimately it goes to lakes, dams as a pollutant. The untreated sewage water is used by the farmers for irrigating the vegetables and fruit crops in peri-urban areas. The monsoon rainfall became erratic and uncertain due to climatic change, which given high intense rainfall for short duration and therefore most of the portion of the rainfall is going waste as runoff instead of recharging the ground water table. Looking to this condition utilization of the sewage water for the irrigation of the crops after proper treatment is need of the day (Bahri, 1999). However, little investment has been made in the past on sewage treatment facilities while water supply and treatment often received more priority than wastewater collection and treatment. Currently there is a growing awareness of the effect of sewage contamination on rivers and lakes.

About thousand hectares of agricultural land are being irrigated with sewage effluent. Despite the level of content of metal cations in sewage effluent, the soils irrigated with sewage may receive considerable amount of metal cations over the long period. Such practice of sewage irrigation continues for longer period, without knowing pollutant load, this may lead to chemical degradation of lands

and possible entry of pollutants / toxicants in the food chain of human being and animal. In view of this, it is necessary to assess and monitor the sewage fed soils and groundwater sources, of the area of influence, to avoid any adverse effects on soil health, groundwater and plant growth (Gupta, 1998).

Soil and ground water resources are critically important components of the earth's biosphere and are directly related to human health. Soil and water plays an important role, not only in the production of food and fiber, but also in the maintenance of environmental quality. Thus, soil and groundwater contamination by trace metals is an environmental concern. Use of untreated sewage in agriculture is of public concern due to possible phyto-toxicity and/or incorporation of metal cations into the food gradients. Excess nitrogen and phosphorous in effluents can leach and pollute groundwater under continuous sewage effluent use for long periods. The impact of long term use of poor quality water on soil health, groundwater pollution and food chain contamination is governed by water quality and site-specific soil, climate and crop conditions. Therefore, it is pertinent to be in touch with such problems for better environmental health.

Agriculture is a major consumer of water that is why irrigation water is sourced from all available sources including wastewater sources. Globally, over 70% of freshwater utilization is devoted to agricultural activities (FAO, 2008). Recently, declining productivity of commercial farms has led to international policy networks to recommend the promotion of urban and peri-urban agriculture as an escape from food crisis situations.

Water is a vital to all living creature, as it makes up to 50-97% of plant and animal and about 70% of average human body weight, but regrettably it is the most poorly managed resource in the World. Ground water resources in most areas of world are shrinking at an alarming rate and may not meet the ever increasing demands from agriculture and industry in future. Estimates reveled that agriculture

sector consumes maximum of the ground water and ~80 per cent of actual water resources are utilized in agriculture for irrigation purpose. Many farmers in areas near to urban/per-urban localities are even compelled to use waste water to irrigate their crops, due to absence of better alternatives. The implications associated with heavy-metal contamination are of great significance, particularly in agricultural production system. Tremendously escalating human population and expanding industry and urbanization has not only used a large area of World productive lands, but is also generating a large volume of waste water every day.

Land and water are natural finite resources but due to indiscriminate and unscrupulous utilization, these resources are diminishing at an alarming rate. Water is becoming the most important limiting natural resources now a days. More food has to be produced per unit of water available for agriculture and to meet the increased demand of agricultural production. Hence, it's multiple uses and re-use is becoming more and more important. However use of waste water as a supplemental source of irrigation is inevitable for increased agricultural production in many arid and semi-arid regions where irrigation supplies are insufficient to meet crop water needs. Use of domestic sewage water in agriculture undoubtedly leads to soil contamination and groundwater pollution is the major environmental concern and also helps to recycle useful nutrients through the food chain. But it also poses risks simultaneously for the profitability of the cultivated crop and human health because of the possible presence of toxic elements in the irrigation water. However in addition to that the domestic sewage water also contains residues of pesticides, heavy metals and many other toxic materials, chemicals which may be hazardous and it may affect the soil micro-flora, soil texture, plant growth, development and quality. So in this context it is one of the essential task to study about the effect of sewage water irrigation on soil health.

1.2 Importance of study

With the rapid process of urbanization, industrialization and economic development, fresh water availability has become an important limiting factor to people's lives and agriculture. Alternatively farmers have begun to use municipal and industrial effluent for irrigation purposes in peri-urban setting. Waste water application to agricultural land is a common practice as it contains organic matter and some essential plant nutrients like N and P which have fertilizers value. Its application enhances soil productivity and improves soil physical conditions. In addition to this, waste water application to agricultural land is also an alternative due to its practical and economic concerns. Although, application of municipal and industrial effluents enhances crop yield and soil conditions, it contains high concentration of toxic heavy metal. Long term application of untreated municipal and industrial effluent of high metal concentrations is elevation the metal concentrations in the soils. Therefore heavy metal contamination of arable land has becoming serious problem in peri-urban setting.

Use of sewage water in agriculture has been an age-old practice and can contribute to a reduction in stress on the utilizable water resources. It will not only reduce disposal problems of sewage water but also contribute towards the up-gradation of soil fertility as it contains appreciable amounts of macro and several micronutrients (Mitra and Gupta, 1999).

When sewage water rich in effluents is added to agricultural lands, initially soil acts as filters for toxic chemicals and may adsorb and retain heavy metals from wastewater. But when the capacity of soils to retain toxic metals is reduced due to continuous loading of pollutants or changes in pH, soils can release heavy metals into groundwater or soil solution available for plant uptake. Kimberly and William, (1999) reported that the amount of heavy metals mobilized in a soil environment is a function of pH, clay content, organic matter content, cation exchange capacity and other soil properties making

each soil unique in terms of pollution management with the exception of Mo, Se and As, heavy metal mobility decreases with increasing soil pH due to precipitation of hydroxides, carbonates or formation of insoluble organic complexes (Smith, 1996). Heavy metals are capable of forming insoluble complex compounds with soil organic matter and according to Sauve *et al.,* (2000) solid-solution partitioning of Cd, Cu, Ni, Pb and Zn is dependent on soil solution pH, total metal content and soil organic matter.

1.3 Objective of study

The present study on Impact of sewage irrigation water on soil pollution and uptake of heavy metals by crops in peri-urban area of Nagpur was conducted with the following objectives.

1. To study the properties of sewage water at different location used for irrigation.
2. To assess the physical and chemical properties of soil.
3. To evaluate the contamination of heavy metals in different soils and crops.

1.4 Hypothesis

The use of waste water contain plant nutrients, micronutrients along with toxic heavy metals, but toxic metals substances in waste water can be reduced to some extent by phytorid technology which also enhances plant nutrient, micronutrients with the use of a number of treated sewage water for irrigation. Utilization of waste water is important to agriculture production and bioavailability of toxic elements.

1.5 Scope and limitations

The average availability of water is reducing steadily with the growing population and it is estimated that by 2025 India will become a water stressed nation. Hence, the use of waste water has been a common practice, especially in peri-urban areas (Narain *et al*., 2013) to meet the challenges of scare water resources in terms of sustainability,

food and income security and environmental safety. An estimated 38,354 million liters per day of sewage water is generated in major cities of India. The sewage water is a potential water resources with stability of water quantity and reliable supply. Nutrients and water being the most critical inputs in agriculture, harvesting the nutrients and irrigation potential of sewage water are of prime importance for maximizing the food, fodder and fuel production. Sewage water is a rich source of both beneficial and harmful elements. Many small to medium scale industries operating in peri-urban residential areas of cities dispose their contaminated effluents directly in sewage system. Disposal of waste water on agricultural soils in the longer-term could potentially adversely affect the soil health. The implications associated with heavy metals contamination of agricultural land should have the highest priority of all strategies to protect soil, crop and water quality and ultimately human and animal health. However, where soil contamination has occurred, strategies are needed to control the transfer of contaminants from the soil through the food chain to animal or humans.

A comprehensive study on the contamination profile of pesticides and heavy metals in the environments, especially soils and water sources, is necessary. This information, which is currently sparse and limited, is important for the formulation of environmental management strategies. As a first step, the accumulation of baseline information of the setting up of an organized database on the extent and nature of environmental contamination should be developed. Also, development of reliable, scientifically sound indicators of ecological change is necessary. These indicators of environmental changes should be monitored intensively, often and over long periods of time.

Consideration for remediation strategies should be similarly and simultaneously developed according to the ecosystem components involved. Equal emphasis should be given to preventive and remedial measures. Bioremediation should be given priority as a safe and cost-

effective approach, but systems that work in tandem with physical and other methods should not be ignored. Environment-friendly pesticides and fertilizers with appropriate application technology and formulation should be considered.

Research on natural products and after native control methods should also be given emphasis such as biological control, resistant crops, cultural practices sterilization, physical control methods and integrated pest control. The quantitative and qualitative characterization of the effluent, ground water and soil may help in detecting the pollution load in these resources, which is helpful in planning irrigation practices and use of groundwater resources for various purposes. This may help in planning restorative and improvement measures by way of improved farm management practices and to protect human health by way of consumption of good quality food.

The present investigation comprised of the study of contaminated water bodies during late rainy season and winter season, the impact of effluent irrigation on soil and groundwater quality of the selected study area.

This study is limited to few sites for sewage, ground water and soil quality assessment and may limit the scope for further extrapolation of these results areas. However, holistic approach pertaining to sewage-soil-groundwater model is required for detailed investigation and for extrapolation of the results in extensive areas. For meeting site specific objectives, factors like water quality parameters, soil characterization, crop tolerances and rainfall pattern have to be given due consideration.

Chapter II

REVIEW OF LITERATURE

In India, the domestic and waste water are being used for irrigation in peri-urban areas, depending on the sources of the sewage water. It contains significant quantities of N, P, K, heavy metals and micronutrients. Long term application of the metal rich sewage water for irrigation of cultivated land may cause more accumulation of heavy metals in surface soil than the sub-surface soil and plants grown there on. Consumption of metal rich crops plants raised on the metal-contaminated soils cause clinical problem in animals and human beings. The major emphasis has been directed towards the benefits and potential problems that can result from discharge of municipal sewage water on agricultural lands. Considerable attention has been given to determine the chemical composition of sewage water and its impact on soils and crops.

The literature has been reviewed for the present investigation "Impact of sewage irrigation water on soil pollution and uptake of heavy metals by crops in peri-urban area of Nagpur" in the given following heads:

2.1 Chemical composition of sewage water

2.2 Effect of sewage water irrigation on physico-chemical properties of soil

2.3 Effect of sewage water irrigation on heavy elements content in soil and plants

2.1 Chemical composition of sewage water

Shrivastav and Banerjee (2003) evaluated chemical partitioning of Cu, Zn, Pb, Ni, Cr and Cd in sewage sludge and agricultural soils repeatedly amended with sludge. The sum of the metal content in the fractions compared well with the total metal content in sewage sludge, the ratios averaging 1.02, 1.04, 1.07, 0.94, 1.06, and 1.12 mg L^{-1} for

Cu, Zn, Pb, Ni, Cr, and Cd, respectively. The metal recovery efficiency in sludge-amended soils was found to be: 108±6%, 102±5%, 115±8%, 111±4%, 104±7% and 124±28% for Cu, Zn, Pb, Ni, Cr and Cd respectively.

Patel *et al*. (2004) analyzed the industrial effluent in Gujarat and found that the COD value of effluents from Ankleshwar sites was extremely high, while the BOD values were within the safe limit in all the cases. The effluents from Ankleswar site were the most polluted with respect to Fe, Cu, Mn, Cd, Ni, Co and Cr elements.

Antil and Narwal (2005) analyzed the sewage waters of different locations in Haryana and found that the pH, EC, organic carbon, TSS and BOD ranged from 1.1-8.0, 0.64-4.4 dS m^{-1}, 15-105 mg L^{-1}, 700-3000 mg L^{-1} and 36-127 mg L^{-1} respectively. The soluble N, P, K, Cu, Zn, Fe and Mn concentration in sewer waters ranged from 0.132.70, 0.88-17.25, 16.0-500, Tr-1.0, 0.1-6.8, Tr-56.5 and Tr-8.0 mg L^{-1}, respectively.

Minhas (2005) studied the composition of sewage waters of Haryana and found that the pH, EC, TDS and BOD ranged from 7.1, 8.3, 0.9-3.2 dSm^{-1}, 60.330 mg L^{-1} and 176-345 mg L^{-1} respectively. The content of Cu, Zn, Fe and Mn in these sewage waters ranged from 10-415, 10-330, 130-1887 and Tr.-420 µg L^{-1}, respectively.

Narwal and Kuhad (2005) analyzed the sewage waters of some cities of India and reported that, Cu, Zn, Fe, Mn, Cd, Pb, Ni and Cr content in these sewage waters ranged from 0.18-6.30, 0.14-11.00, 4.10-205.00, 0.10-37.80, 0.01-5.80, 0.03-40.00, 0.35-6.40 and 0.18 - 29.30 mg L^{-1}, respectively.

Rattan *et al*. (2005) conducted an experiment in peri-urban agricultural lands under Keshopur Effluent Irrigation Scheme (KEIS) of Delhi, India and selected various cereals, millets, vegetable and fodder crops have successfully been grown and irrigated by sewage water. Results indicated that sewage effluents contained much higher amount

of P, K, S, Zn, Cu, Fe, Mn and Ni compared to groundwater. While, there was no significant variation in Pb and Cd concentrations in these two sources of irrigation water and metal content were within the permissible limits for its use as irrigation water.

Dubey *et. al*., (2007) characterize the sewage waters of Haryana and reported that, most of the sewage waters were rated suitable for irrigation as they were having electrical conductivity 0.9-3.2 dSm^{-1}, sodium adsorption ratio 1.4-6.2 (m mol L^{-1})1/2 and residual sodium carbonate 0-8.6 meq L^{-1}.

Rusan *et. al*., (2007) found that treated waste water contain 952 mgl^{-1} TDS, 29.4 mg L^{-1} NO_3-N, 15.5 mg L^{-1} PO_4, 33.3 mg L^{-1} K besides Cu (0.01 mg L^{-1}), Zn (0.19 mg L^{-1}), Fe (0.87 mg L^{-1}), Mn (0.07 mg L^{-1}), Cd (0.02 mg L^{-1}) and Pb (0.77 mg L^{-1}), respectively.

Chonkar *et. al*., (2008) assess the impacts of long-term sewage irrigation on soil health. The results showed that, use of sewage for irrigation improved the clay content to 18–22.7%, organic carbon to 0.51–0.86% and fertility status of soils. Build up in total N was up to 2,713 kg ha^{-1}, available N (397 kg ha^{-1}), available P (128 kg ha^{-1}), available K (524 kg ha^{-1}) and available S (65.5 kg ha^{-1}) in the surface (0.15m) soil. Long-term sewage irrigation has also resulted a significant build-up of DTPA extractable Zn (314%), Cu (102%), Fe (715%), Mn (197.2), Cd (203%), Ni (1358%) and Pb (15.2%) when compared with the adjacent rain-fed reference soil. Soils irrigated with sewage exhibited a significant decrease in microbial biomass carbon (−78.2%), soil respiration (−82.3%), phosphatase activity (−59.12%) and dehydrogenase activity.

Dash *et al.* (2009) observed that sewage water of Bhubaneswar city is being used as a source of irrigation in E-block of Central Farm, Orissa University of Agriculture and Technology, Bhubaneswar. Sewage water samples, sewage water irrigated soils and leaf of plants of rice, mustard, sunflower, maize, tomato, amaranthus, cabbage,

cauliflower, brinjal, lady's finger and water hyacinth (sewage channel) were collected and analyzed for different plant nutrients and heavy metals. The data revealed that SW samples were non saline, acidic in reaction (pH 6.5-6.89) and had optimal level of BOD (48-55 mg L^{-1}) and COD (90 -105 mg L^{-1}).The concentration of cations were in the order of Ca >Mg >Na >K. Residual sodium carbonate was nil. Based on SAR and EC rating, SW belonged to C_1S_1 category. Concentration of NH_4-N, NO_3-N, PO_4, Zn and B ranged from 48.3-52.6, 8.1-8.3, 2.4-2.5, 1.5-2.5 and 0.7-0.75 mgl^{-1}, respectively. Concentration of heavy metals was in the order of As > Pb >Hg >Ni >Co > Cd >Se.

Pinto *et al.* (2011) evaluate pollution indicators on Rio Ave and surrounding environment. Plants, soil, surface water and ground water samples were collected seasonally at five different sampling sites along the Ave valley. The results showed an increase on conductivity of waters from the origin to the mouth of the river. Nitrite levels were also higher than expected, especially in areas of wide industrialization and agricultural practices, where fertilizers widely used. Moreover, heavy metals in plants presented higher values as compared to those found in soils revealing that increased levels of heavy metals on soils are reflected similarly in plants.

Lokhande *et al.* (2011), assess pollution due to toxic heavy metals in the industrial wastewater effluent collected from Jalaja industrial belt of Mumbai. It was observed that paint manufacturer industries are the major contributor of toxic Cr, Zn and Pb amounting to 35.2, 33.1 and 31.4 mg L^{-1} respectively. It was also observed that major contribution of Cu 33.3 mg L^{-1} was from dyes manufacturing units, while maximum Fe concentration of 12.8 mg L^{-1} was found in efficient sample released from textile industries.

Yadav *et al.* (2013) assess level of different heavy metals like Fe, Cd, Ni, Pb, Cu and Zn in vegetable irrigated with water from different source industrial area of Naini Allahabad. Heavy metals in irrigated water ranged from 0.249 to 0.257 mg L^{-1} for Fe, 0.049 to

0.056 mg L^{-1} for Zn, 0.028 to 0.036 mg L^{-1} for Cd, 0.015 to 0.019 mg L^{-1} for Cu, 0.035 to 0.042 mg L^{-1} for Pb and 0.031 to 0.038 mg L^{-1} for Ni which is lower than recommended maximum tolerable levels possessed by joint FAO/WHO expert committee on food additive (2007), with the exception of Cd and Fe which exhibited elevated content.

Parshar and Fazal (2013) studied the impact of sewage irrigation water on heavy metal contamination in Spinach, Cabbage, Beetroot, Reddish, Okra, Tomatoes and Cucumber is widely cultured and consumed in urban India, particularly by the poor. Samples of irrigation water, soil, and the edible portion of all the vegetables were collected monthly during the winter seasons and were analyzed for Fe, Cd, Cu, Zn, and Pb. Heavy metals in irrigation water were below the internationally recommended (WHO) maximum permissible limits set for agricultural use for all heavy metals except Cd at all the sites.

Roy and Gupta (2016), conducted experiment in urban region of Asansol, where wastewater from that Nunia nala is widely being used by poor farmers for irrigating vegetables on long-term basis. The trend of mean metal concentration in well water and waste water were Pb >Mn> Zn> Cr> Cd> Cu respectively.

Bhokare *et al.* (2017) collected soil and ground water sample in Jaysingpur town from railway station to Akshay hotel located at Sangali- Kolhapur road to study the possible impact of sewage waste effect on soil and ground water quality. The chemical parameters such as pH, hardness, electrical conductivity, total dissolved solids, alkalinity, calcium, magnesium, chloride content, sulphate, phosphate and the metals like sodium, potassium, copper, manganese, were studied using various analytical techniques. It has been found that most of the parameters of water are not in the acceptable limit in accordance with the WHO standards.

Safana *et al.* (2018) analyzed some heavy metals in vegetables and irrigation water of Ginzo waste channel in Katsina. Results shows that mean levels of heavy metals in irrigation water were; Cadmium (0.14 mg L^{-1}), Chromium (0.10 mg L^{-1}), Iron (0.55 mg L^{-1}), Lead (0.09 mg L^{-1}) and Zinc (0.05 mg L^{-1}).

2.2 Effect of sewage water irrigation on physio-chemical properties of soil

Selem *et al.* (2000) studied the effect of sewage irrigation on some chemical properties of soil and found that the soil pH decreased and cation exchange capacity and total soluble salts increased in surface layer with the increasing period of irrigation.

In Haryana state, Antil and Narwal (2002) reported that pH decreased but EC, organic carbon and metal content of the soil increased with sewer water irrigation. The continuous irrigation with these waters resulted in accumulation of salt and toxic metals in the soil.

Singh *et al*. (2002) noticed that pH, EC, organic carbon and organic matter percentage increases from 7.4-7.7, 135-315 dS m^{-1}, 1.20 to 2.30 per cent and 2.0 to 4.0 per cent respectively with sewage water irrigation upto 20 years.

Yadav *et al*. (2002) observed that long-term irrigation with sewage water adds large amounts of carbon, major and micronutrients to the soil. Use of sewage for irrigation in various proportions improved the organic matter to 1.24–1.78% and fertility status of soils especially down to a distance of 1km along the disposal channel. Build up in total N was up to 2908 kg ha^{-1} available P (58 kg ha^{-1}), total P (2115 kgha^{-1}), available K (305 kg ha^{-1}) and total K (4712 kg ha^{-1}) in surface 0.15 m soil.

Chandrasekaran and Rajkannan (2003) studied the continuous long term application of sewage effluent on soil physical properties and

observed that sewage irrigation tend to improve porosity, bulk density, hydraulic conductivity and water holding capacity in both surface and sub- surface soil.

Malik *et al.* (2004) also analyzed sewage irrigated soil of Haryana and found that pH, electrical conductivity, organic carbon and calcium carbonate varied from 7.2-8.9, 0.1-1.4 dS m^{-1}, 0.1-1.4 percent and 0.3 6.8 percent, respectively. The maximum pH, EC were found in Kaithal district where as organic carbon and $CaCO_3$ content in Punchkula.

Dahatonde *et al.* (2005) observed that waste water irrigation had increased the electrical conductivity, organic carbon content and available nitrogen of soil by 0.01%, 0.21% and 94 kg ha^{-1} respectively to that of normal water irrigation.

Kaupai *et al*. (2006) conducted experiment in Borkhar regon in Isfahan province in central Iran with two water treatment of wastewater and groundwater under sprinkler and surface irrigation system for the 3 crops of sugarbeet, corn and sunflower. The accumulation of Pb, Mn, Ni and Co in the soil increased significantly in the wastewater treatment as compared to the ground water treatment. The irrigation system had a significant effect on infiltration rate, bulk density and total porosity under sprinkler irrigation system the infiltration rate increased significantly.

Recently Malla and Totawat (2006) also observed that application of sewage water as such has decreased the pH and $CaCO_3$, but increased the EC and organic carbon content of the soils as compared to application of diluted sewage water (well water and sewage water, 1:1) and well water as such.

Hazarika *et al*. (2007) reported that the content of total exchangeable basic cations ($Ca^{2+,}$ $Mg^{2+,}$ K^{+} and $Na^{+)}$ in effluent irrigated soil was about 4 times higher than those found in the shallow tube-well water irrigated soils. Further, they also revealed that the

exchangeable sodium percentage (ESP), sodium adsorption ratio (SAR) and chloride content of effluent irrigated soil were 170%, 120% and 358% more than the soil of sewage treated water irrigated field.

Singh *et al*. (2009) study the effect of wastewater irrigation on physio-chemical properties of soil and availability of heavy metal in soil and vegetable. Heavy metal concentration increased negatively and positively correlated with soil hydrogen (pH) and organic carbon (OC) respectively.

Dash *et al*. (2009) observed that available N, P_2O_5, K_2O and SO_4-S content of sewage water irrigated soils were higher than normal soil. The DTPA extractable Fe, Mn, Zn, Cu, Mo and B ranged between 63.3 to 122.2,13.4 to 62.6, 3.6 to 44.7 ,2.4 to 11.6, 3.8 to 4.0 and 0.52 to 1.15 mg L^{-1} in SW soils and 60.6,15.1,0.8 ,0.8,0.6 and 0.52 mg L^{-1} in normal soil, respectively. Heavy metals in SW soils were in order of As >Se > Pb > Cr >Ni >Hg > Cd.

Ambika *et al.* (2010) observed that effect of sewage irrigation water on crop growth and soil properties. Sewage water have high nutrient load, suspended load, dissolved nitrate, pesticide, heavy metal and many other toxic material which may be hazardous and it may affect the soil micro flora, soil texture and quality and also plant growth and development.

Malhi *et al.* (2010) observed that heavy-metal concentration in underground and surface water, soil, and crop plants growing in farmers' fields near the industrial city of Ludhiana, Punjab, India. The concentrations of lead (Pb), chromium (Cr), cadmium (Cd), and nickel (Ni) in sewage-contaminated water were 18, 80, 88, and 210 times higher than in shallow hand pump water, and 21, 133, 700, and 2200 times higher than in deep tube-well water respectively. Soil shows high EC, CEC, OC and clay content but shows low pH and calcium carbonate content.

Assouline and Narkis (2011) the impact of 15 year of irrigation with waste water on hydraulic properties and flow process in a clay soil, compared to fresh water use. Result shows that saturated hydraulic conductivity, sorptivity and infiltration rate are consistently lower in the waste water irrigated soil sample at all depths.

Deshmukh *et al*. (2011) observed that in the peri-urban area of New Delhi have been irrigated with treated wastewater from the Keshopur Effluent Irrigation Scheme (KEIS) since 1979. Results indicate that there was a significant decrease in soil pH and electrical conductivity (EC) of sewage water-irrigated fields as compared to tube well water-irrigated fields. Organic carbon (OC) content in 20 years sewage irrigated soil (0–15 cm) increased by 244 % over tube well water-irrigated soil. There was an increase in (DTPA)-extractable Zn content in 20, 10, and 5 years sewage irrigated soils (0–15 cm) to the extent of 86, 38, and 36 % over tube well water-irrigated soils, respectively, while only 20 years sewage-irrigated soils showed a significant increase in DTPA-extractable Cu (289 %) in surface layer (0–15 cm) over tube well− irrigated soils. In case of Fe, 127, 88% and 76.6 % increases in available Fe content (DTPA Fe) were recorded under 20, 10, and 5 years sewage-irrigated soils, respectively, over controls.

Khurana and Singh (2012) observed that field application of all types of waste water significantly increases soil OC percentage, soil EC, cation exchange capacity (CEC), total and DTPA-extractable heavy-metal/micro-nutrient content, available macro-nutrient (N, P and K) content with significant decreases in calcium carbonate content of surface soil. However, high content of nitrogen, phosphorus and potassium strengthens its high fertigation / manural value for field crops. Significantly higher heavy-metal accumulation in soils irrigated with WW than ground water has been observed in surface layer than the lower depths of soil profile.

Reddy *et al*. (2013) observed that improvement in soil physical properties like bulk density, water retention and hydraulic conductivity due to application of sewage water. The physio-chemical properties like pH, EC was increased and chemical properties like presence of high amount of organic carbon and build-up of soil available N, P, K and micronutrient status in the sewage irrigated soil and improving soil fertility status.

Agrawal *et al.* (2014) conducted an experiment to investigate the impact of domestic waste water for irrigation purpose on soil fertility. The use of the domestic wastewater improves the physico-chemical properties of the soil as compared to the application of ground water. Application of domestic water increases total N, P, K and organic carbon content of soil & thereby increases the yield of crops compared to irrigation with ground water.

Alghobar and Suresha (2016) conducted a survey was conducted to ascertain the addition of heavy metals into agricultural fields through sewage water irrigation for grass crop in the farmlands of selected areas of Vidyaranyapuram in Mysore city. For Cl, in irrigation with SW has no effect on the Cl of soil. For heavy metals in comparison to the standard, the SW has ($P < 0.05$) effect in all elements except significant increase was noticed for Fe. In the grass, our investigation showed that irrigation with SW reuse led to a significant increase ($P < 0.05$) of N, P, K, Ca, Mg and Na contents. Heavy metals shown in grass irrigated with sewage water (SW) caused a significant increase ($P < 0.05$) of Fe, Mn, Cu, Zn and Pb as compared to irrigated ground water (GW).

Roy and Gupta (2016) conducted experiment in urban region of Asansol, where wastewater from that Nunia nala is widely is widely being used by poor farmers for irrigating vegetables on long-term basis. Pollution level index (PLI) level in soils were in the order of Cu (2.40) > Cr (2.19) > Cd (2.00) > Mn (1.77) > Pb (1.25) > Zn (0.97).

Khan *et al.* (2017) collected thirty-six sample of wastewater and topsoil each were collected to determine the content of Pb, Cr, Cd, Zn, Ni, Fe and Mn and physio-chemical parameter like pH, EC, total solids, total dissolved solids, total suspended solids and organic matter significant correlation was found between anthropogenic metals like Ni, and Cd in water and Cu and Cr in soil.

Saha *et al*. (2017) apply municipal sewage sludge in agriculture for its safe disposal as it provides an opportunity to recycle plant essential nutrients (N, P, secondary nutrients and micronutrients) and improves soil physical, chemical and biological properties due to high organic matter content. Land application of municipal sewage sludge on crop yield, soil fertility and problems of heavy metals accumulation in edible portion of the crops as well as possible options for remediation of heavy metals toxicity in contaminated soils to explore the possibility of safe recycling this waste in agriculture.

2.3 Effect of sewage water irrigation on heavy elements content in soil and plants

Pradhan *et al.* (2001) reported that, the use of treated domestic sewage water for irrigation of wheat and black gram under different fertilizer levels showed increasing trend on yield attributing characters like number of tillers plant^{-1}, panicle length (cm), number of grains panicle^{-1} and 1,000 grain weight to the tune of 13.29, 1.59. 5.49 and 3.79 per cent respectively over the tube well irrigated. This resulted in increase in yield to the tune of 3.63 per cent with sewage water irrigation. Interactions between irrigation and fertilizer levels were also insignificant. However, sewage water with 60:45:45 responded better on tillering, panicle length, and number of grains panicle^{-1} and yield of wheat. In case of black gram, treated sewage water had non-significant effect on the growth and yield attributing characters.

Saleem *et al.* (2003) field study was conducted to find the effect of sewage/tube well water irrigation on the accumulated concentration

of heavy metal contents in okra fruit and spinach leaves. Okra *(Abelmoschus esculentus*) and spinach (*Spinacea oleracea*) were planted in spring and winter respectively. Both vegetables were given a basal dose of 100 and 50 kg ha^{-1} N and P respectively. The heavy metal and micronutrient contents in both vegetables were present in significantly higher amount in order of sewage and tube well water >tube well water except Cu and Fe which showed variation for both the crops. Spinach leaves showed higher accumulation of heavy metals and micronutrients as compared to okra fruit.

Adhikari *et al.* (2004) reported accumulation of Pb, Cd, Ni, Co, Cr, Fe, Mn and Zn and Cu mostly in the roots of various crop irrigated with city sewage compared to that of tube-well water irrigated crops. Among the crops, carrot and spinach showed the tendency of higher metal concentration.

Mapanda *et al.* (2005) study the magnitude of contamination, regulatory compliance and annual loadings of soils with copper (Cu), zinc (Zn), cadmium (Cd), nickel (Ni), chromium (Cr) and lead (Pb) were determined at three sites in Harare where wastewater was used to irrigate vegetable gardens for at least 10 years. Heavy metal total concentrations (mg kg^{-1}) in sandy and sandy–clay soils of pH 5.1–8.1 from all sites ranged from 7.0 to 145 for Cu, 14 to 228 for Zn, 0.5 to 3.4 for Cd, <0.01 to 21 for Ni, 33 to 225 for Cr and 4 to 59 for Pb in the 0–20 cm soil depths.

Saraswat *et al.* (2005) found that the treated sewage water irrigated vegetable contained relatively higher amount of micronutrients than tube-well water irrigated vegetables, where okra, cauliflower, radish and broad bean had higher amount of Zn, Fe, Cu and Mn respectively in their edible parts.

Anonymous (2006) reported that the accumulation of heavy metals such as Pb, Cd, Ni, Co, Cr, Fe, Mn, Zn and Cu was higher mostly in the roots of various crops irrigated with sewage effluent

compared to that of tube well water irrigated crops. Amongst the crops, carrot and spinach showed the tendency of higher metal accumulation

Malla and Totawat (2006) reported that sewage water irrigated vegetables under study contained relatively higher amount of micronutrients (Zn, Cu, Fe, Mn) and heavy metals (Pb, Cd, Ni) as compared to well water and mixture of well water and sewage water (1:1).

Paul *et al.* (2006) observed that the sewage irrigated plants exhibited higher uptake and accumulation of nutrients in comparison to the tube-well irrigated ones and this might be due to continuous and indiscriminate application of sewage effluent. They also reported that uptake and accumulation of nutrients were more in leaf followed by stem and fruit in different vegetables.

Jamali *et al.* (2007) studied the mobility and transport of heavy metals such as Cu, Zn, As, Cd, Cr, Ni, and Pb, from soil and soil amended with sewage sludge to sorghum plants. Statistically good correlations were obtained between the total contents of all heavy metals and their respective extractable fractions in soil and domestic wastewater sludge. Transfer factors of all heavy metals from domestic sewage sludge to sorghum grains were determined.

Rusan *et al.* (2007) studied the effect of waste water irrigation for different duration on micronutrients and heavy metals content of barley plant. They reported that the Cu, Zn, Fe, Mn contents in the plant were the highest in the plant grown in the soil receiving waste water in the previous two years. Whereas, the concentration of heavy metals (lead and cadmium) increased significantly with increase in duration of sewage water application upto 10 years as compared to control.

Malhi *et al*. (2010) observed that the mean concentrations of Pb, Cr, Cd, and Ni in crop plants growing on soils irrigated with sewage-contaminated water were 4.88, 4.20, 0.29, and 3.99 mg kg^{-1},

which were 1.2, 2.1, 8.7, and 1.9 times higher than in plants irrigated with deep tube-well water, respectively. The amounts of potentially toxic metals were significantly and positively correlated with cation exchange capacity and organic C content and negatively correlated with soil pH. In conclusion, long-term accumulation of toxic metals in soils and their uptake by crop plants has a high potential for phytotoxicity as well as for entering into the food chain.

Lokhande *et al.* (2011) carried out assessment of pollution due to toxic heavy metals in the industrial waste water effluents collected from Taloja industrial belt of Mumbai. It was observed that paint manufacturing industries are the major contributors of toxic Cr, Zn and Pb amounting to 35.2, 33.1, and 31.4 mg L^{-1} respectively. It was also observed that major contribution of Cu (33.3 mg L^{-1}) was from dyes manufacturing units, while maximum Fe concentration of 12.8 mg L^{-1} was found in effluent samples released from textile industries. The concentration of Cd and Ni was found maximum in effluent samples collected from pharmaceutical industries amounting to 35.8 and 33.6 mg L^{-1}, respectively.

Khurana and Singh (2012) reported that application of sewage water increased the yield of Rabi crops with total N, P, K and organic carbon content of soil compared to irrigation with well water. In the field irrigated with sewage water, the pH of soil slightly decreased before sowing from 7.9 to the range of 7.52–7.63 after harvesting. The organic carbon of sewage irrigation increased from 5.0 g kg^{-1} to 5.59–5.90 g kg^{-1} range and found higher than well water. The effect of irrigation water on fertility status of soil after harvest of *rabi* crops was observed to be significant for available N, P and K. Amongst the *rabi* crops wheat, gram, palak, methi and berseen recorded significantly higher available N in the range of (222.65–283.26), P (19.13–23.92) and K (322.27–343.25) as compared to crops irrigation with well water in which N ranged from (205.92–288.50), P (13.66–23.23) and K (299.41–345.20). The extractable metals consisting of Fe, Mn, Zn, Cu,

Pb, Ni and Cd after harvest were found to be slightly higher than that of well water. The significantly higher grain and straw yield was recorded due to application of screened sewage water over well water irrigation.

Yadav *et al*. (2013) carried out experiment to assess levels of different heavy metals like Iron, Cadmium, Nickel, Lead, Copper and Zinc in vegetables irrigated with water from different sources industrial area of Naini Allahabad. The order of heavy metal concentration was found in Fe > Zn > Cd > Pb > Ni > Cu in irrigated water and Fe > Ni > Zn > Cu > Cd > Pb was observed in industrial contaminated sites of soils.

Parshar and Fazal (2013) assess impact of sewage irrigation on heavy metal contamination of Spinach, Cabbage, Beetroot, Reddish, Okra, Tomato, and Cucumber cultivated and consumed in urban India, particularly by the poor. In the edible portion of spinach, the Cd concentration was higher than the permissible limits of the Indian standard during summer, whereas Pb concentrations were higher in winter seasons. The study concludes that the use of treated and untreated wastewater for irrigation has increased the contamination of Cd, Pb in edible portion of vegetables causing potential health risk in the long term from this practice. Fe was measured abundant in soil whereas Pb and Cd were found more in untreated sites as compared to treated site.

Salakinop *et al.* (2014) conducted field experiment which laid out in split-split plot design with 3 replication. Higher wheat grain yield (4370 kg ha^{-1}), protein (12.88%) and dry glutein (9.22%) were obtained in field irrigated with sewage water compared to bore well-irrigated land. Concentration of heavy metal was higher in root followed by stem and lower in grain.

Akhtar *et al.* (2014) study four peri-urban agricultural areas (Multan, Kasur, Lahore and Gujranwala) were selected and surveyed. Total 138 Soil samples, 131 plants and 52 wastewater samples.

Accumulation of metals in crops was also estimated with major problem of Cd in crops and fodder plants and incase of Kasur Cr was found maximum. Exceeded concentration of Pb, Cd and Cr was also observed in Lahore and Gujranwala.

Khan *et al.* (2016) conducted experiment for the comparison of the heavy metal concentrations in soil, sewage water and in *Raphanus sativus L.* at three different growth stages, irrigated with municipal wastewater of Rawalpindi city. The collected samples were analyzed following the standard procedures for heavy metals like, Copper (Cu), Chromium (Cr), Lead (Pb), Cadmium (Cd), Nickel (Ni), Zinc (Zn), Cobalt (Co), Arsenic (As), Manganese (Mn), Iron (Fe), Magnesium (Mg) and Molybdenum (Mo). The survey data showed significant variations between heavy metals concentrations in water, soil and vegetable *(Raphanus sativus L*.) samples at three different growth stages.

Alghobar and Suresha (2016) studied effect of irrigation with untreated and treated wastewater from Vidyaranyapuram sewage treatment plant station on growth and yield of rice in Vidyaranyapuram area in the South West of Mysore, Karnataka. The growth and yield characters of rice crop were not improved by irrigation with UWW and TWW; however the high concentration of trace metals affected by lowering the growth and yield (number of grains/panicle, weight of 1000 seeds and yield/plant) attributing factors when irrigated by UWW and TWW as compared to GW control. These effects could be attributed to higher accumulation of micronutrients and macronutrients in soil and plant, when the mean values were highly significant as indicated by the present study.

Roy and Gupta (2016) conducted study in sub – urban region of Asansol, where wastewater from that Nunia nala is widely being used by poor farmers for irrigating vegetable on long–term basis. As a result elevated levels of heavy metals were found to accumulate in wastewater irrigated soil and vegetables, compared to well water

irrigated soil and vegetables. Higher enrichment factor of Cd was found in spinach, Cu in brinjal, Mn in cauliflower and Mn and Zn in carrot and pea respectively.

Kumar *et al*. (2017) investigate the concentration of different metals in agricultural soil and also in plants grown on those soils to notice the possible health risks to human body through food chain transfer. Results showed that concentration of Zn, Cu, Fe, Mn, Pb, Ni, Co and Cd in soil is lower than the WHO/FAO value. The Health Risk Index (HRI), on the basis of metals (Zn, Cu, Fe, Mn, Pb, Ni and Co) concentration in all edible plant parts were found < 1.0 except mustard can be considered safe with no risk to human health, while in mustard HRI value of Mn (1.0593) was found slightly higher to 1.0 and this value for Pb and Ni were observed 2.5969 and 1.6720 indicates matter of concern and need comprehensive study on soil plant relationship in plateau areas of Jharkhand having a sheath of mines and industries.

Hassan (2018) measure concentrations of some heavy metals in various imported and locally produced vegetable crops, including root crops (Turnips ''*Brassica rapa*'' and Carrots *''Daucus carrota''*), stem crops (Potatoes *''Solanum tuberosum''* and Onion *''Allium sativa''*), leaves (Lettuce *''Lactuca sativa''*), and fruits (Tomatoes *''Lycopersicon esculentum''*). In the imported vegetables, heavy metal mean concentrations were arranged in the following increasing order: Fe>Zn> Cu>Ni>Co>Cd>Cr>Pb, whereas higher levels of Cr, Fe, Cu, Zn, Cd and Pb (1.2075, 165.995, 37.2275, 43.775, 6.0375, 1.48) mg kg^{-1}, respectively, were found within the locally produced vegetables. High level of Co 3.09625 mg kg^{-1} was also detected in onion, while, increased concentrations of Ni 7.8675 mg kg^{-1} were found in lettuce collected from local market. Overall significant differences in the heavy metals concentration between imported and locally produced vegetables were observed. The daily intake of four main heavy metals (Cd, Cu, Zn and Pb) had been estimated which revealed highly

consumption of Cd (310 and 372 µg per day) for imported and locally vegetables respectively.

Saleem and Soundhirarajan (2018) analyzed the effects of irrigation with reclaimed water through field trials on the content and distribution of heavy metals in both okra and the soil. Accumulation of heavy metals, and the index for the heavy metal content is far below the critical value of the national standard, which indicates that the vegetables irrigated with reclaimed water during their growth turn out to be free of pollutants.

Safana *et al.* (2018) analyzed some heavy metals in vegetables and irrigation water of Ginzo waste channel in Katsina. Mean levels of heavy metals in lettuce were; Cadmium (ND), Chromium (0.09 mg kg^{-1}), Iron (2.36 mg kg^{-1}), Lead (0.12 mg kg^{-1}) and Zinc (0.16 mg kg^{-1}); those of Cabbage were Cadmium (ND), Chromium (0.06 mg kg^{-1}), Iron (3.1 mg kg^{-1}), Lead (0.09 mg kg^{-1}) and Zinc (0.07 mg kg^{-1}). Cadmium was absent, Chromium (0.16 mg kg^{-1}), Iron (0.77 mg kg^{-1}), Lead (0.07 mg kg^{-1}) and Zinc (0.07 mg kg^{-1}).

Rani *et al.* (2018) observed mean concentrations of Cadmium (Cd) in plant samples of Palak, Amaranthus, Spinach, Coriander, Green chillies and Paragrass under sewage irrigated condition were 2.08, 2.61, 2.28, 0.93, 2.11 and 1.80 mg kg^{-1} respectively. However, with ground water irrigation, the corresponding values were 1.31, 1.53, 1.06, 0.53, 1.34 and 1.22 mg kg^{-1} which were relatively lower. Under no irrigation (control), the corresponding values were 0.31, 0.15, 0.15, 0.17, 0.11 and 0.20 mg kg^{-1} which were quite lower.

Chapter III

MATERIAL AND METHODS

The present investigation “Impact of sewage irrigation water on soil pollution and uptake of heavy metal by crops in peri-urban area of Nagpur” was undertaken during the year 2018-2019 to assess the quality of soil, plant and sewage water samples collected from the peri-urban area of Nagpur, Kuhi and Kamathi taluka in vicinity of the Nag river at the time of maturity of the cereals and vegetable crops.

The sewage water of Nagpur city which is discharge into Nag river and is under long-term use for irrigating vegetables and other agricultural crops. The Nag river is taped at different locations and pumped through electric motors for irrigation purpose. Agricultural crops like wheat, brinjal, tomato and cauliflower are being irrigated with sewage water of Nag river by flooding the land, without judging the loading rate or actual requirements. Although majority of the farmers expressed probability of the use of effluent for irrigation, some of the respondents reported that, the yields are retarded since last few years while weeds and pests infestation became serve for some specific crops and vegetables. The farm produce from these areas sold in Nagpur and near villages, which are either consumed by human beings or animals. If the practice of effluent irrigation continue for longer period, without knowing pollutant load, this may lead to chemical degradation of lands and possible entry of pollutants in the food chain of people and animal consuming the farm produce on these lands. Thus an attempt to study the impact of sewage irrigation on soil and crops under the following heads and subheads.

3.1 General characteristics of area

3.1.3 Location

Three farmers from each village who are using sewage water for irrigation was selected for sampling from three talukas, viz Nagpur, Kamathi and Kuhi are as under.

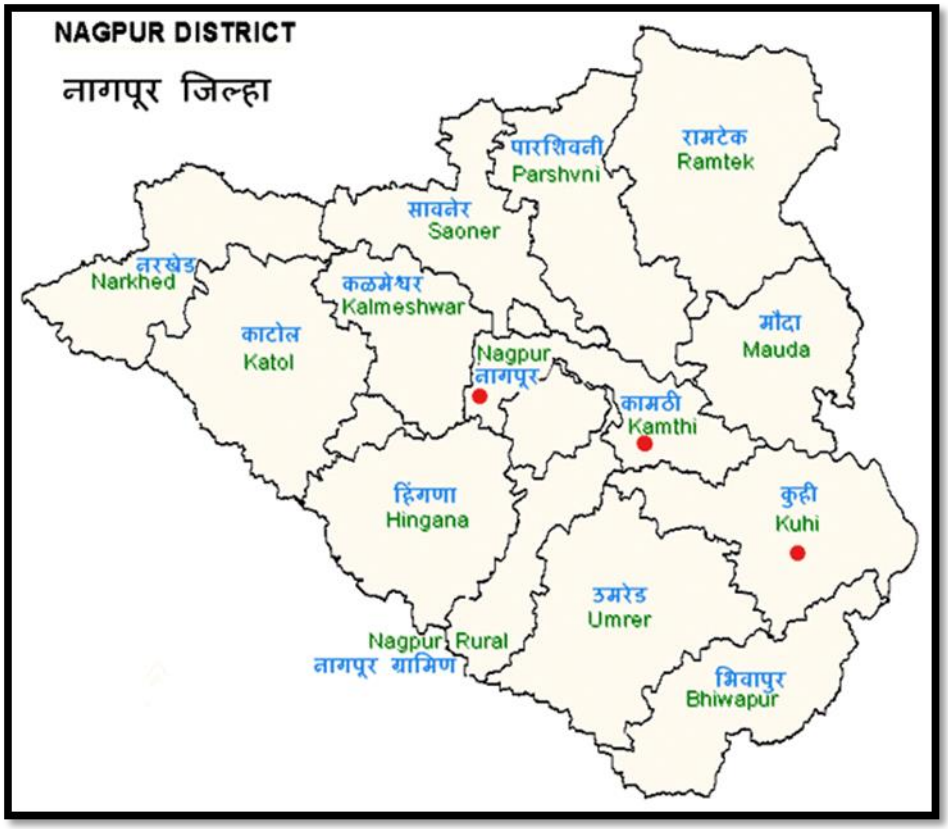

Figure No. 1: Location showing selected taluka of Nagpur district

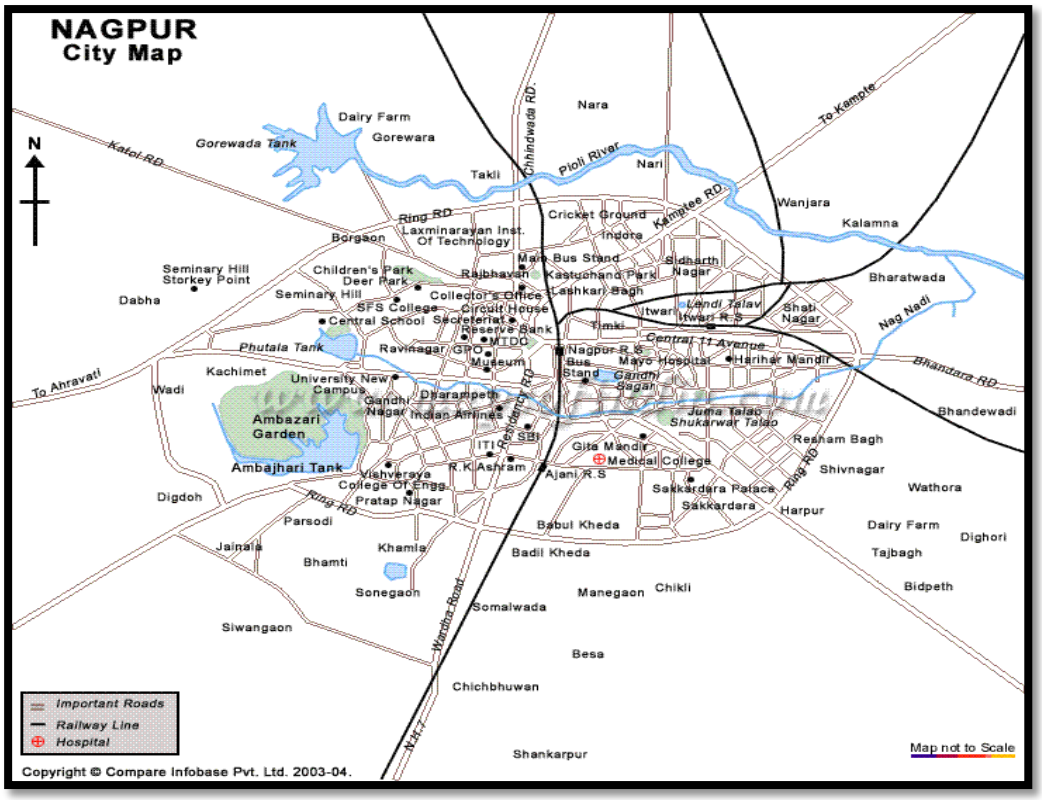

Figure No. 2 Location showing origin of Nag river

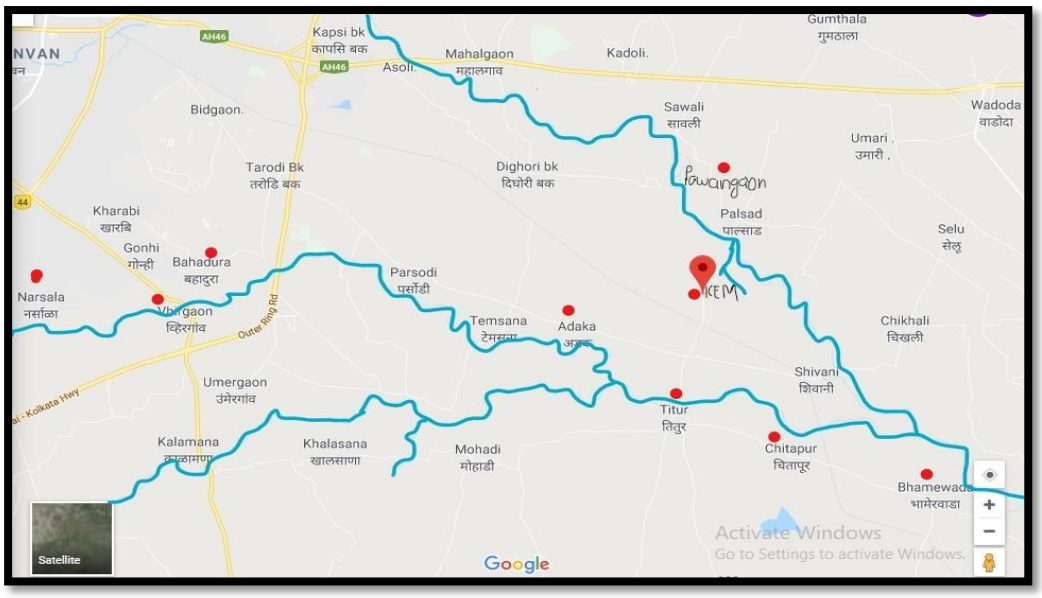

Figure No. 3: Location showing movement of Nag river from selected villages

The Nag river originates from Ambazari lake, moving through the city, finally reach to the Kanhan river. Constant pouring untreated sewage and industrial effluent in river, water quality deteriorated and the river give bad odour.

City of Nagpur is named after the Nag river. It has always been believed that the river starts as an outflows from the western weir of Ambazari Lake in west Nagpur. Forming a part of the Kanhan-Pench river system, the Nag river originates in Lava hills near wadi and the confluence point of Nag and Pili river is Pawangaon, and the confluence point of Nag and Kanhan river is near Sawangi village.

Nag river acts as storm water drainage for west, south, central and east Nagpur. Total length of Nag river is 17.00 Km upto the city limit. Its width ranges from 12 to 40 m and depth varies from 2 to 4.5 m. Total length of Nag river up to the confluence with Kanhan river at about 68 Km.

Nag river flowing through following selected villages and there distance from origin of Nag river are as follows:

Table No.1 Showing the distance of flowing of Nag river from selected village

Sr. No.	Name of Taluka	Name of villages	Distance (Km)
1	Nagpur	Vihirgaon	16
2		Bahadura	13
3		Narsala	9
4	Kuhi	Bhamewad	34
5		Titur	28
6		Chitapur	31
7	Kamathi	Pawangaon	15
8		Kem	29
9		Adak	26

Plate No. 1 Source of irrigation of farmer at Narsala village

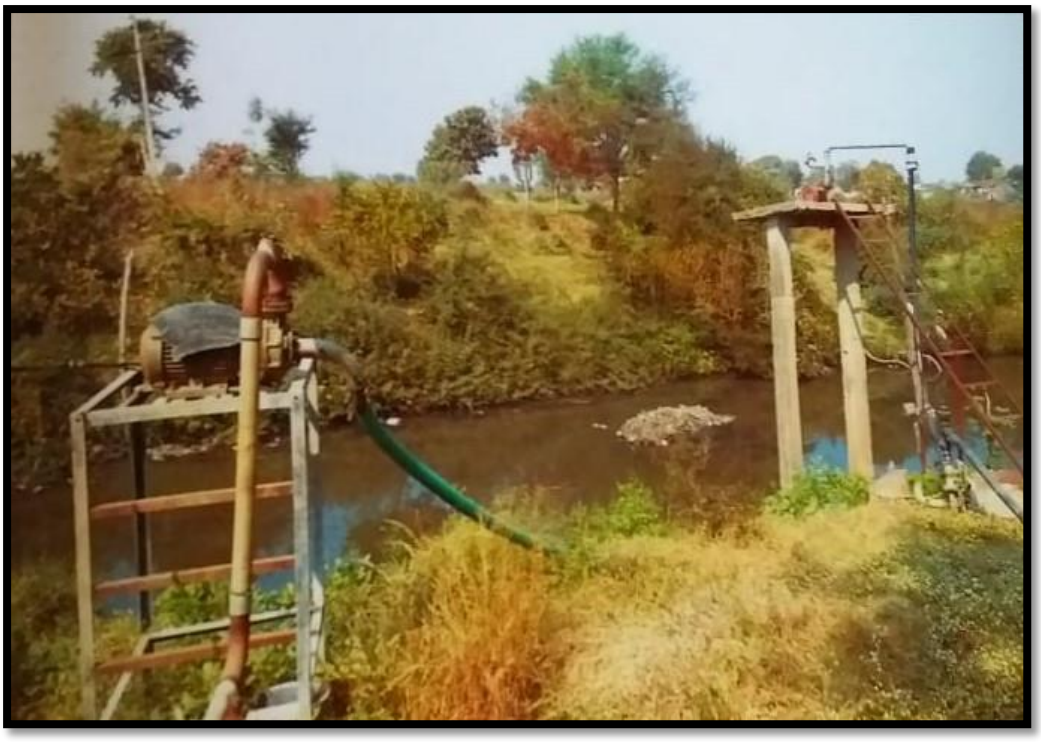

Plate No. 2 Source of irrigation of farmer at Chitapur village

Plate No. 3 Soil sampling at Vihirgaon village

3.1.2 Climate and weather condition

Nagpur is situated at $21^0$10' North latitude and $79^0$19' East longitude at the elevation of the 321.26 m above mean sea level and lies under subtropical zone. Nagpur is characterized by hot and dry summer and fairly cold winter. This area shows wide diurnal fluctuation in temperature. The maximum and minimum temperature ranged from 26.5 to 33.3^0 C and 9.6 to 18.2^0 C, respectively. Whereas, the relative humidity ranges from 28 to 69 per cent during morning hours and 16 to 34 per cent evening hours during the crop growth period. The mean annual precipitation on the basis of last fifteen years is about 1250 mm, which is received almost from the south-west monsoon. The meteorological data in respect of rainfall, relative humidity maximum and minimum temperature recorded at Meteorological Observatory, Department of Agronomy, College of Agriculture, Nagpur during course of investigation for the period of Sep 2018 - Dec 2018.

3.2 COLLECTION OF SAMPLES

3.2.1 Sewage water:

The directly lifted sewage water for irrigation to different crops were collected from 27 selected sites. The sewage water samples were collected in plastic bottles. The collected water samples were stored in the dark at laboratory conditions for future use.

3.2.2 Soli sample

In order to study the trace elements accumulation in soils samples were collected from the sewage water irrigated fields from peri-urban areas of Nagpur, Kuhi and Kamathi Tahsil of Nagpur district. Total 27 soil samples were collected from farmer's field using sewage water for irrigation.

The soil samples were first air dried ground with wooden pestle and mortar and passed through 2 mm stainless steel sieve. After mixing thoroughly the processed soil samples were stored in cloth bags

Plate No.4 Analysis of heavy metals and micronutrient of sewage water, soil and plant sample

and used for various physico-chemical properties, micronutrients and toxic metal analysis.

3.2.3 Plant sample

Samples of vegetables like Brinjal, Tomato and Cauflower and cereal like Wheat crops at maturity stage were collected from the same sites from which soil samples were collected. The plant samples collected were first washed with tap water to remove the adhering soil particles, followed by acidified deionized water and then with double distilled water. The excess water was removed by gentle shaking and pressing against the filter paper. The washed plant samples were first air dried and then put in the paper bags and placed it in an air draft oven at $65\pm2^{0}C$ to a constant weight. The oven dried samples were ground in mortar and sieve it and stored in small paper bags for laboratory analysis.

3.4 Method of analysis

3.4.1 Sewage water analysis:

The sewage waters were analyzed for the following parameters by using standard methods as outlined below:

a) pH:

It was determined by using glass electrode (Electrometric method) pH meter (APHA, 2012).

b) Electrical conductivity:

It was determined by using conductivity meter (APHA, 2012).

c) Total hardness and calcium hardness:

It were determined by the procedure mentioned in APHA, (2012).

d) Magnesium:

It was estimated by titrating with 0.01 N EDTA by buffering the solution to pH 10 with NH_4 $ClNH_4OH$ by using Erichrome black T indicator (The end point was indicated by the change of initial wine red to final sky blue colour).

e) Carbonate and bicarbonate:

Estimated by titrating a known volume of the sewage water with standard H_2SO_4 first in the presence of phenolphthalein indicator and then with methyl red indicator.

f) Chloride:

It was determined by titrating with standard (0.02 N) $AgNO_3$ solution by using potassium chromate as an indicator. The end point was obtained when white precipitates of AgCl change to brick red colour suggesting complete precipitation of chloride with Ag.

g) Sulphate:

It was determined by EDTA-titration method APHA, (2012).

h) Sodium and Potassium:

It was determined by flame photometer APHA, (2012).

i) Total suspended solids:

It was determined directly by flame photometer method APHA, (2012).

j) COD:

COD was determined by method APHA, (2012).

k) Ammonia:

Ammonia was determined by method APHA, (2012).

l) Micronutrients and toxic metal ions:

Water samples were analyzed for Zn, Cu, Mn, Fe, Cd, Pb, As, Hg and Cr on atomic absorption spectrometer (APHA, 2012).

3.4.2 Soil sample analysis

a) Soil pH:

The soil pH was determined by digital pH meter using glass electrodes and 1:2.5 Soil : Water ratio as described by Jackson, (1973).

b) Electrical conductivity:

It was determined with conductivity meter using 1:2.5 soil water suspension as described by Jackson. (1973).

c) Available nitrogen:

It was determined by alkaline potassium permanganate method as described by Subbiah and Asija, (1956). The 0.32 percent $KMnO_4$ and 2.5 percent NaoH solutions were used for distillation.

d) Available phosphorous:

The soil was extracted with Olsen's reagent 0.5M $NaHCO_3$ of pH 8.5 and from the extract available P was estimated calorimetrically as per Jackson, (1973).

e) Available potassium:

The available K (exchangeable and water soluble forms) was determined by flame photometer method using neutral ammonium acetate as an extractant (Jackson, 1973).

f) Hydraulic conductivity:

It was determined by Constant water head method as described by Richard, (1954).

g) Bulk density:

The bulk density of soil was determined by core method as described by Blake and Hartz, (1954). Insert cylindrical metal core sampler in field to desired depth and take it out from field as core sample. Dry the soil core sample in a oven at 105^0 C to 110^0 C and note the oven dry weight of the core.

h) Infiltration rate:

It was determined by double ring infiltrometer method as described by Parr and Bertrand, (1960).

i) Available micronutrient:

These micronutrients were estimated by the method described by Lindsey and Norvell, (1978). Total 10g soil was shaken in 20ml 0.005 M DTPA buffer solution (Diethyene triamine penta acetic acid) containing 0.1M calcium chloride adjusted to pH 7.3 with HCl solution for two hours and then filtered was subjected to measurement on Atomic Absorption Spectrophotometer (AAS) at different wave length for Fe, Mn, Zn and Cu.

j) Heavy metals:

The heavy metal content in soil (Cr, Co, Pb and Cd) were determined by acid digestion. Representative of soil samples were taken for heavy metal analysis. Exactly 0.2 g of sieved sample (<2mm) was taken for digestion with digestion mixture of nitric acid and perchloric acid in 1:4 ratios. The digestion takes place on hot plate in digestion chamber. The samples were collected to get digested until

the soil particle become white in color. After cooling it, the digested contents were filtered using Whatmann filter paper no. 42 and subsequently make up the volume to 100 ml using deionized water. The solution of the aliquot were subjected to heavy metal analysis using Atomic Absorption Spectrophotometer (AAS) (Lindsay and Norvell, 1978).

3.4.3 Plant sample analysis

Digestion of plant materials for chemical analysis

In order to determine the micronutrients and heavy metals viz. Cu, Zn, Fe, Mn, Cd, Pb, Co and Cr in plant parts (shoot and root) 0.5 g of ground and well mixed material was digested in a di-acid mixture of nitric acid and per chloric acid (4:1). After digestion the volume was made to 50 ml with distilled water, filtered and stored in well washed plastic bottles. The Cu, Zn, Fe, Mn, Cd, Pb, Co and Cr were estimated from the aliquot by using the Atomic Absorption Spectrophotometer (AOAC method, 1988).

Chapter IV

RESULTS AND DISCUSSION

The results of the present investigation on **"IMPACT OF SEWAGE IRRIGATION WATER ON SOIL POLLUTION AND UPTAKE OF HEAVY METALS BY CROPS IN PERI-URBAN AREA OF NAGPUR".** The crops grown in peri-urban area of Nag-river (Vegetables like Cauliflower, Brinjal, Tomato, Fenugreek, Palak, and cereal like Wheat) were collected at maturity for sale and analyzed for nutrient and heavy metal content in it. The collected data are tabulated and discussed under the following heads.

4.1 Chemical composition of sewage water

4.1.1 Characteristics of sewage water of Nag river

4.1.2 Micronutrients and heavy metals content in sewage water of Nag river

4.2 Effect of sewage irrigation water on soil

4.2.1 Effect of sewage irrigation water on physico-chemical properties of soil

4.2.2 Effect of sewage irrigation water on DTPA-extractable micronutrients content of soil

4.2.3 Effect of sewage irrigation water on DTPA-extractable heavy metals content of soil

4.3 Effect of sewage irrigation water on micronutrients and heavy metals content of plant

4.1 Chemical composition of sewage water

4.1.1 Characteristics of sewage water of Nag river

The physico-chemical characteristics of sewage water are given in table 3. The data revealed that the mean value of pH and EC of sewage water ranged from 6.17 to 6.94 and 1.25 to 2.06 dS m^{-1},

respectively. The pH of all site was observed below 7.0, therefore pH of sewage water is slightly acidic to neutral. Similar finding were reported by Dash, (2009) who found that pH of sewage water sample ranged from 6.5 to 6.89 which was acidic. The reason for decrease in soil pH may be decomposition of organic matter and production of organic acids in soils irrigated with wastewater. The WHO normal range for pH are 6.5 to 8.5.The pH of all collected water sample was recorded within the normal range.

The EC of Narsala sewage water is 2.06 dS m^{-1} which is higher than the other water sample because this is the sewage water release point of Nagpur city. Similar finding were reported by Narain *et. al*. (2013) who found that EC of sewage water of Allipur block of Delhi state ranged from 0.46 to 5.89 dS m^{-1}. They further reported that EC was found to fluctuate which indicate the significant amount of precipitation or erosion that may have an impact on water quality.

The basic cation and anion Na^{+}, Mg^{2+}, CO^{3-}, HCO^{3-}, SO_4^{2-} and Cl^{-} ranged from 127 to 189, 1.08 to 2.71, 5 to 50, 646.13 to 843.32, 14.82 to 49.60 and 44.5 to 102.89 mg L^{-1}, respectively and followed the order to $Na^{+} > Mg^{2+}$ for cation and $HCO^{3-} > Cl^{-} > CO^{3-} > SO_4^{2-}$ for anions. It observed that quantity of both cation and anion maximum in sewage water of Narsala village and minimum in sewage water of Bhamewada village this is due to sewage water of Nag river first flowing through Narsala village and lastly through Bhamewad village where the water from other Nalas mixed with this river water having less concentration of this cation and anion which reduced the concentration from Narsala to Bhamewad village. However, the concentration of Na^{+}, Mg^{2+} and SO_4^{2-} in sewage water of Nag river less than WHO, (1993) standard which was 200, 150 and 250 mg L^{-1} respectively. The result found similar with the result given by Selem, et. al. (2000) in case of CO^{3-}, HCO^{3-} and Cl^{-1} of sewage water.

Table 3: Characteristic of sewage water of selected villages

Location	pH	EC dS m^{-1}	Total Hardness mg L^{-1}	Ca-hardness mg L^{-1}	CO_3 mg L^{-1}	HCO_3 mg L^{-1}	Cl mg L^{-1}	SO_4 mg L^{-1}	TSS mg L^{-1}	Mg^{2+} mg L^{-1}	Na^{+} mg L^{-1}	K^{+} mg L^{-1}	COD mg L^{-1}	NH3 mg L^{-1}
Narsala	6.17	2.06	273.6	197.0	50	873.32	102.89	49.60	252	2.71	189	9	456.01	4.2
Vihirgaon	6.26	1.96	261.1	152.8	32	855.78	83.93	34.70	243	2.55	172	8	408.18	3.7
Bahadura	6.35	1.92	253.3	140.9	32	847.88	82.73	30.92	244	2.38	172	6	320.67	3.3
Adaka	6.47	1.88	246.8	140.6	31	750.02	77.14	27.18	208	2.00	146	5	280.13	3.4
Titur	6.74	1.79	246.9	141.2	22	725.93	73.37	19.26	188	1.73	138	4	247.36	3.0
Chitapur	6.83	1.42	224.1	126.4	18	724.88	54.42	17.10	175	1.60	138	3	179.70	3.2
Bhamewada	6.94	1.25	170.8	117.4	15	646.13	44.50	14.82	157	1.08	127	3	152.64	2.9
Kem	6.56	1.82	201.2	133.7	32	873.32	49.42	15.70	242	1.72	146	5	260.07	2.6
Pawangaon	6.36	1.85	217.3	136.4	43	752.33	66.28	19.70	251	2.30	155	6	376.73	3.1
Overall mean	**6.52**	**1.77**	**232.7**	**142.9**	**30.55**	**783.29**	**70.52**	**27.09**	**218**	**2.01**	**154**	**5.4**	**297.94**	**3.3**

The total hardness and Ca-hardness of sewage water of Nag river was observed in the range of 170.78 to 273.6 mg L^{-1} and 117.4 to 197 mg L^{-1}, respectively. Similar finding were reported by Khurana and Singh, (2012) in case of hardness of sewage water which was having in the range of 200 to 250. The hardness of sample was found below ISI standard ranged from 300-500 mg L^{-1}.

The COD is the amount of oxygen consumed to chemically oxidize organic water contaminates to inorganic end products. The COD of sewage water sample of Nag river was observed in the range of 152.64 to 456.01 mg L^{-1} which is less than ISI (1991) standard reading which is 250 mg L^{-1}.

The total suspended solids are the portion of solids that usually consist of silt, clay, fine particle of organic and inorganic matter, which is regarded as a type of pollution because water high in concentration of suspended solids may adversely affect the growth and reproduction rates of aquatic fauna and flora. The TSS of sewage water of Nag river ranged from 157 to 252 mg L^{-1}. Similar results were reported by Shring and Chaterjee (2014) observed TSS of sewage water was 250 mg L^{-1}.

The content of ammonia of sewage water of Nag river ranged from 2.9 to 4.2 mg L^{-1}. Hussain (2014) also reported that ammonia of sewage water ranged from 0.4 to 3 mg L^{-1} for stagnant water, 0.1 to 0.8 mg L^{-1} for running water and 2.1 to 2.4 mg L^{-1} for waste water. The highest values were found to be in summer season for all the water bodies studied. The NH_4-N values were enhanced by warm temperature in stagnant and waste water bodies while there was no temperature effect on NH_4-N of running water. Ammonia is basic source of microalgae growth.

All these parameters have their own importance as they are part of environment necessary for conductance of life processes. For example pH is a measure of acid-base equilibrium achieved by water dissolved compounds as well as extent of flocculation and coagulation

process of chemicals. Electrical conductivity (EC) which is a measure of water's ability to conduct an electric current is related to the amount of dissolved minerals in water, but it does not give an indication of which element is present but higher value of EC is a good indicator of the presence of contaminants such as sodium, potassium, chloride or sulphate while hardness of water is defined as the measure of concentration of dissolved calcium and magnesium ions in water. Hardness of water is very important property of water and is very important for life processes. Analysis of all these parameters is very necessary because their knowledge is very important for fish and human health.

4.1.2 Micronutrients and heavy metals content in sewage water of Nag river

The results obtained on micronutrient content (Fe, Zn, Cu and Mn) in sewage water of Nag river at selected location are depicted in table 4. The result showed that micronutrient content Fe, Zn, Cu and Mn in sewage water ranged from 0.6 to 0.25, 0.11 to 0.24, 1.78 to 1.87 and 0.55 to 3.81 mg L^{-1}, respectively and followed the order Mn > Cu > Zn > Fe. Similar results shown by Dash (2009).

Cu concentration was observed highest in water of Narsala (1.87 mg L^{-1}) where as it was minimum at Bhamewada (1.78 mg L^{-1}). The concentration of Zn and Fe were observed more in Narsala which is 0.24 and 0.25 mg L^{-1}. Lowest Mn value was recorded in sewage water of Bhamewada (0.55 mg L^{-1}). The distance between origin of Nag river and Bhamewad village is more and in between that two Nala meet to Nag river and then finally flowing through Bhamewad village so that concentration of micronutrient and heavy metals is reduced.

Table 4. Micronutrient content of sewage water of Nag river at selected villages (mg L^{-1})

Villages	Micronutrient content of sewage water (mg L^{-1})			
	Fe	**Zn**	**Cu**	**Mn**
Narsala	0.25	0.24	1.87	3.81
Vihirgaon	0.23	0.21	1.86	2.64
Bahadura	0.18	0.18	1.83	2.55
Adak	0.55	0.14	1.82	2.35
Titur	0.14	0.15	1.83	1.37
Chitapur	0.12	0.13	1.82	1.24
Bhamewad	0.6	0.11	1.78	0.55
Kem	0.18	0.17	1.82	2.27
Pawangaon	0.18	0.23	1.78	3.31
Mean	**0.27**	**0.17**	**1.83**	**2.23**

The results obtained on heavy metals content Co, Cd, Cr, Pb, As and Hg in sewage water of Nag river in selected location are presented in table 5 and figure 5. The results showed that the mean value of heavy metal Co, Cd, Cr, Pb, As and Hg in sewage water of Nag river was observed 0.31, 0.05, 0.18, 0.75, 0.07 and 0.06 mg L^{-1}, respectively and followed the order Pb > Co > Cr > As > Hg > Cd. The data showed that, the sewage water of Narsala and Pawangaon contain more amount of micronutrient and heavy metals because these are the sewage water release point of Nagpur city. However concentration of Cd was found highest in Narsala water (0.09 mg L^{-1}) whereas highest concentration of Cr was observed in swage water of Adak village. Similar results observed by Dash et al., (2009) who found that sewage water contained low to medium quantities of Pb, Cd, Cr and As. The Cd is the primary toxic element in most of the municipal waste applied to agricultural lands.

The reason for this extremity in values is might be due to the addition of civic wastes and industrial effluents as the sewage of the city is directly discharged into the river along with the industries which are also discharging their effluents directly into the river. This is in

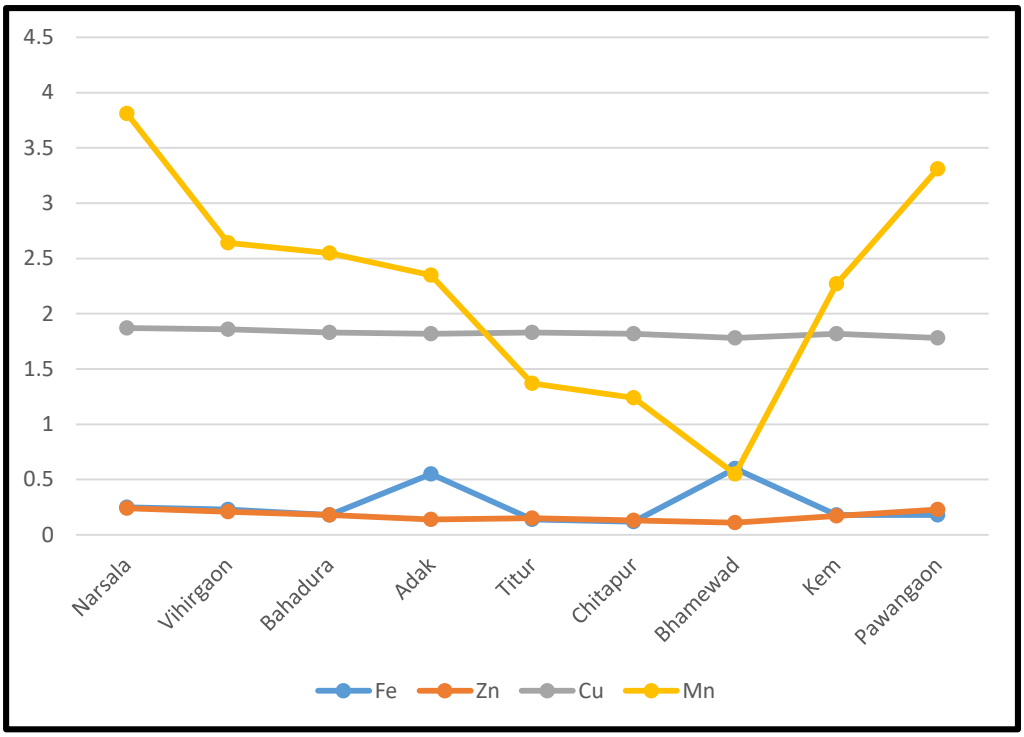

Figure No.4 Average concentration of micronutrients of sewage water of selected villages

agreement with the studies of Hassan et al., (2012) who reported that, the level of heavy metals increasing in the rivers due to discharge of industrial effluents and civic pollution of various kinds. This is in turn deteriorating the water quality making it unsuitable for both aquatic and human life.

Table 5. Heavy metal (mg L^{-1}) content of sewage water of Nag river at selected villages

Villages	Heavy metal content of sewage water (mg L^{-1})					
	Co	Cd	Cr	Pb	As	Hg
Narsala	0.46	0.09	0.14	1.04	0.1	0.1
Vihirgaon	0.4	0.07	0.11	0.98	0.1	0.09
Bahadura	0.35	0.07	0.12	0.86	0.1	0.07
Adak	0.24	0.05	0.11	0.60	0.01	0.04
Titur	0.29	0.04	0.09	0.60	0.01	0.04
Chitapur	0.23	0.04	0.08	0.62	0.01	0.04
Bhamewad	0.13	0.03	0.05	0.43	0.01	0.01
Kem	0.24	0.04	0.15	0.65	0.1	0.06
Pawangaon	0.43	0.05	0.14	0.87	0.1	0.08
Mean	**0.31**	**0.05**	**0.18**	**0.75**	**0.07**	**0.06**

4.2 Effect of sewage irrigation water on soil

4.2.1 Effect of sewage irrigation water on physico-chemical properties of soil

The data presented in table 6 showed the physico-chemical properties of sewage water irrigated soils of Kuhi, Kamathi and Nagpur taluka of Nagpur district. The pH of soil irrigated with sewage water ranged from 7.49 to 7.95. The pH of soil tending to alkaline. Similar results were reported by Das *et al*., (2002) who found that pH varied within the range of 7.8 to 8.4 of soil irrigated with raw sewage sample. The low pH observed in Bhamewada soil sample (7.49) this is because of last discharge pont of Nag river where 2 Nalas having good water source meet at this village.

The EC of soil ranged from 0.515 to 0.939 dS m^{-1}. Ramesh (2003) reported that soils irrigated with sewage water recorded higher

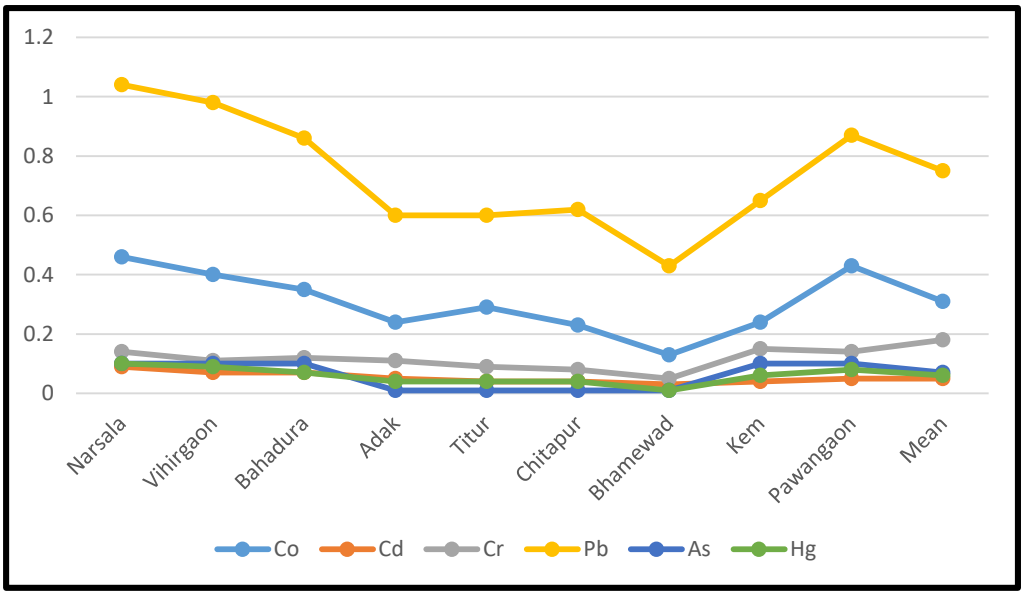

Figure No. 5. Average concentration of heavy metals present in sewage water of selected village

pH and EC as compared to soils irrigated with normal water. Tiwari *et al.,* (1996) observed that, soils irrigated with sewage water had relatively higher pH (8.0) and EC (0.8 dS m^{-1}) as compared to soil irrigated with tube well water (7.5) at Banaras Hindu University, Varanasi.

The data depicted in table 6 showed that the infiltration rate of soil irrigated with sewage water ranged from 1.55 to 2.25. Bhamewada shows high infiltration rate about 2.25 mg L^{-1} and minimum infiltration rate of soil was at Narsala (1.55 mg L^{-1}). This might be due to high TSS at discharge point of Narsala and that sewage water directly used for irrigation. Kaupai *et al.,* (2006) reported that the average infiltration rate at the beginning and end of growing season were 2.1 and 2.9 mg L^{-1} respectively. Therefore the application of waste water caused decrease in the infiltration rate.

The bulk density and hydraulic conductivity of soil irrigated with sewage water ranged with 1.31 to 1.58 mg m^3 and 1.92 to 3.21 cm h^{-1} respectively. Maximum hydraulic conductivity observed at Narsala and low at Bhamewad. The results were conformity with those reported by Mathan *et al*., (1994) who recorded significantly lower bulk density and hydraulic conductivity in soil with sewage water irrigation for 15 years. This can be attributed to improvement in total porosity and aggregates stability in the sewage irrigated soils due to addition of organic matter which play an important role in improving soil physical environment. Koupai *et al*., (2006) also reported that the application of waste water caused a decreased in the hydraulic conductivity at depth of 0-15 and 15-30 cm. Suspended solids including organic matter in waste water may have filled up some of the soil voids decreasing hydraulic

Table No. 6 Physico-chemical properties of soil irrigated with sewage water

Location	pH	EC dS m^{-1}	Infiltration rate cm h^{-1}	Hydraullic conductivity cm h^{-1}	Bulk Density mg m^3	Available nitrogen kg ha^{-1}	Available phosphorous kg ha^{-1}	Available potassium kg ha^{-1}
Narsala	7.49	0.939	1.55	3.21	1.58	324.95	15.63	686.6
Vihirgaon	7.63	0.760	1.57	2.67	1.57	259.13	15.53	675.7
Bahadura	7.78	0.724	1.60	2.41	1.52	252.53	12.93	649.9
Adaka	8.03	0.515	1.97	2.79	1.49	200.71	12.05	659.7
Titur	7.90	0.595	1.73	2.34	1.44	196.50	12.44	645.2
Chitapur	7.69	0.560	1.91	2.09	1.39	192.55	10.10	636.5
Bhamewada	7.95	0.553	2.25	1.92	1.31	190.04	6.57	592.1
Kem	7.83	0.633	1.63	2.26	1.53	251.09	12.77	690.1
Pawangaon	7.55	0.785	1.65	2.20	1.50	225.79	14.26	682.4
Overall mean	**7.76**	**0.674**	**1.76**	**2.43**	**1.42**	**231.50**	**12.47**	**657.3**

conductivity of the soils. Also, in the waste water treated plots, growth of micro-organism in the soil pore may results in the reduction of hydraulic conductivity.

Available N, P and K in effluents irrigated soil ranged from 190.55 to 324.95, 6.57 to 15.63 and 592.07 to 686.6 kg ha^{-1}, respectively. The higher available N in sewage irrigated soil is associated with buildup of organic matter due to continuous application of sewage water (Azad *et al*., 1987). The higher content of available P in sewage water irrigated soil might be due to the fact that considerable amount of P present in sewage effluent containing sufficient detergent used for washing (Azad *et al*., 1987, Reddy and Rao, 2000). These finding were in conformity with work of Sahare et al., (2014) who reported that there was an increase in available N and K content of soil in treatment receiving effluents.

The sewage water have a high nutrient load, suspended solids, dissolved nitrates. It adds available N, P, K, Fe, Mn, Zn and Cu to soil, indicating their significant addition through sewage suggesting use of sewage water as a low grade cheap fertilizer in agriculture which can markedly reduce the cost due to substitution of chemical fertilizers.

4.2.2 Effect of sewage irrigation water on DTPA-extractable micronutrients in soil

The data on DTPA extractable micronutrients Fe, Mn, Zn and Cu in the soil irrigated with sewage water are presented in the table 7. The DTPA extractable micronutrients Fe, Mn, Zn and Cu in effluent irrigated soil ranged between 2.71 to 6.07, 4.45 to 8.23, 0.64 to 2.97 and 2.54 to 5.04 mg kg^{-1}, respectively. The mean concentration of micronutrients viz. Fe, Mn, Zn and Cu is 4.57, 6.37, 1.69 and 3.75 mg kg^{-1} respectively and followed the order Mn > Cu > Fe > Zn. The concentration of DTPA-extractable micronutrient was found maximum in soil irrigated with sewage water at Narsala village and minimum in soil at Bhamewad village.

Similar finding were reported by Rattan et al., (2005) who reported that the sewage irrigation for 20 years resulted into significant buildup of DTPA extractable Zn, Cu, Fe and Mn in sewage irrigated soils over adjacent tube well water irrigated soils. Micronutrients persists in soils and can be adsorbed in soil particles or leached into ground water. Antil and Narwal (2008) also found that, the application of sewage water on agricultural land for long period increased the total content of Zn, Mn, Cu and Fe in Haryana soils.

Table 7: Micronutrient concentration in sewage water irrigated soil of selected villages (mg kg^{-1})

Villages	Micronutrient content of sewage irrigated soil (mg kg^{-1})			
	Fe	Mn	Zn	Cu
Narsala	6.07	8.23	2.97	5.04
Vihirgaon	5.62	7.20	2.13	4.20
Bahadura	4.68	6.46	2.04	3.98
Adaka	4.62	6.08	1.50	3.43
Titur	4.18	5.67	1.37	3.37
Chitapur	3.10	5.00	1.33	3.06
Bhamewada	2.71	4.45	0.64	2.54
Kem	4.63	6.80	0.82	4.21
Pawangaon	5.39	7.59	2.38	3.91
Mean	**4.57**	**6.37**	**1.69**	**3.75**
Safe limit	**7000-55000**	**20-300**	**10-300**	**2-100**

4.2.3 Effect of sewage irrigation water on DTPA-extractable heavy metals content of soil

The data on heavy metals Cd, Cr, Pb and Co in the soils irrigated with sewage water of Nag river are presented in table 8. The heavy metals Cd, Cr, Pb and Co in effluent irrigated soils ranged between 0.14 to 0.21, 0.39 to 0.83, 9.74 to 22.17 and 0.35 to 0.95 mg kg^{-1}, respectively. The mean concentration of Cd, Cr, Pb and Co is 0.15, 0.65, 16.39 and 0.67 mg kg^{-1} respectively and followed the order Pb > Co > Cr > Cd. The concentration of Cr, Pb and Co was observed more in soil irrigated with sewage water at Narsala village (0.83, 22.17

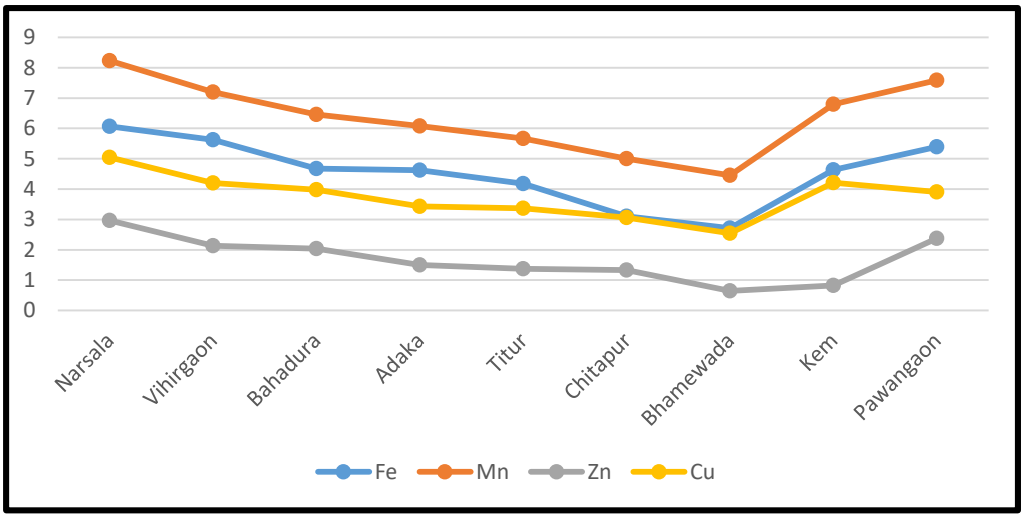

Figure No.6 Average concentration of micronutrients in sewage irrigated soil of selected villages

and 0.953 mg kg^{-1}) and less in Bhamewada village (0.39, 9.74 and 0.35 mg kg^{-1}) where as in case of Cd was found more in Narsala village (0.21 mg kg^{-1}) and less in Chitapur village (0.14 mg kg^{-1}). Similar findings were reported by Akhtar *et al*., (2014) and Yadav *et al*., (2013).

The higher concentration of heavy metals in irrigated soils may be due to practice of intensive farming or long term use of heavy metals contaminated water for irrigation. The intensive farming on peri-urban lands leads to contaminate the soils and crops with pollutants including heavy metals such as copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), lead (Pb), cadmium (Cd), nickel (Ni) and mercury (Hg) by different sources (Smit, 1996). This loading of heavy metals often leads to degradation of soil health and contamination of food chain mainly through the vegetables grown on such soils (Rattan et al. 2002).

Table 8. Heavy metal concentration in sewage water irrigated soil of selected villages (mg kg^{-1})

Villages	Heavy metal concentration of sewage irrigated soil (mg kg^{-1})			
	Cd	Cr	Pb	Co
Narsala	0.21	0.83	22.17	0.95
Vihirgaon	0.18	0.81	21.35	0.89
Bahadura	0.18	0.74	16.61	0.78
Adaka	0.17	0.68	15.37	0.66
Titur	0.16	0.67	14.48	0.55
Chitapur	0.14	0.54	12.85	0.44
Bhamewada	0.14	0.39	9.74	0.35
Kem	0.17	0.53	16.12	0.64
Pawangaon	0.19	0.74	18.85	0.94
Mean	**0.15**	**0.65**	**16.39**	**0.67**
Safe limit	**0.01-0.0.7**	**1-1000**	**2-200**	**-**

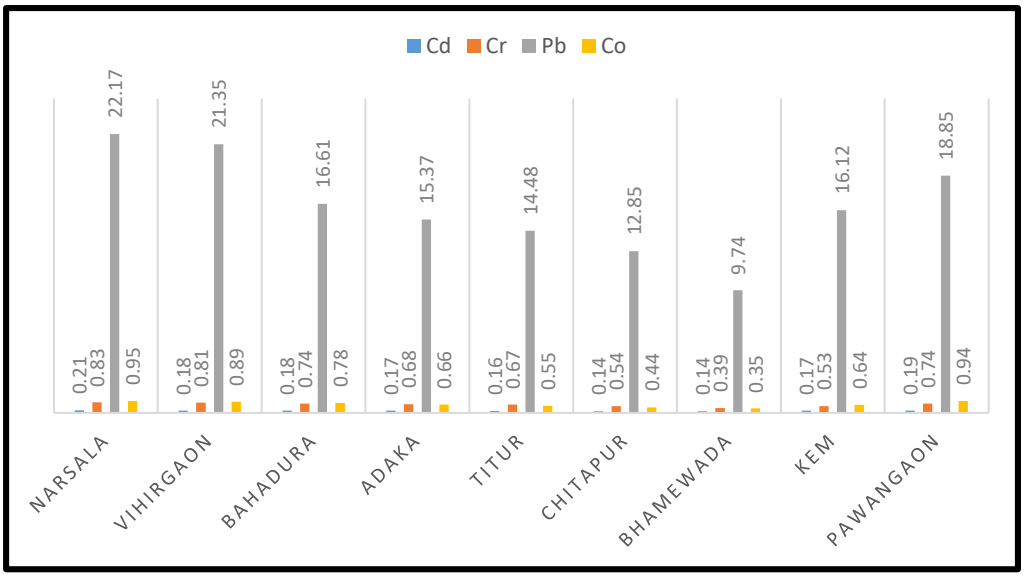

Figure No.7 Average concentration of heavy metals in sewage water irrigated soil of selected villages

4.3 Effect of sewage irrigation water on micronutrients and heavy metals content on plant sample

The average per capita consumption of leafy and non-leafy vegetables is 130gm/person/day (Alam et al. 2003). The micronutrients are as important as primary and secondary nutrients in plant nutrition. Plant analysis is excellent diagnostic tools to monitor the adverse effect of heavy metals and micronutrients. Micronutrient content in Wheat, Brinjal, Tomato and Cauliflower crop as influenced by sewage water of Nag river are presented in table 9.

The mean concentration of Fe, Mn, Zn and Cu in Brinjal is 438.91, 33.06, 53.26 and 22.34 mg kg^{-1}. The concentration of micronutrient observed more at Narsala and less at Bhamewad. The concentration of micronutrient (Fe, Mn, Zn and Cu) in Tomato range from 172.06 to 641.73, 58.23 to 97.11, 18 to 43.99 and 13.61 to 50.76 mg kg^{-1}. In case of Cauliflower mean concentration of Fe, Mn, Zn and Cu is 8.66, 20.96, 19.08 and 5.74 mg kg^{-1}. The concentration of Fe was observed more in Tomato followed by Cauliflower and Brinjal. The concentration of Fe, Mn, Zn and Cu in Wheat crop ranged from 113.14 to 293.82, 142.69 to 238.57, 4.24 to 39.97 and 6.52 to 23.82 mg kg^{-1}. The table 9 shows that concentration micronutrient (Fe, Mn, Zn and Cu) in all crop (Brinjal, Tomato, Cauliflower and Wheat) was observed more at Narsala and less at Bhamewad because Narsala is nearer to origin of Nag river so concentrated sewage water discharge into Narsala whereas toward Bhamewad one clean Nala meet so concentration of micronutrient reduced at Bhamewad. Similar finding were reported by Yadav *et al.,* (2013).

Table No.9 Micronutrient (mg kg^{-1}) concentration in sewage water irrigated crop plant at selected village

Name of crop	Micronutrient content (mg kg^{-1})	Name of villages									
		Narsala	Vihirgaon	Bahadura	Adak	Titur	Chitapur	Bhamewad	Kem	Pawangaon	Mean
Brinjal	Fe	681.45	641.22	559.43	541.32	345.23	267.55	222.66	255.88	435.44	**438.91**
	Mn	43.6	43.16	39.4	35.48	30.38	23.73	21.55	28.02	32.23	**33.06**
	Zn	60.08	59.15	55.73	52.6	49.68	47.66	47.44	52.22	54.8	**53.26**
	Cu	31.15	29.49	26.37	22.9	19.56	17.78	14.63	17.57	21.58	**22.34**
Tomato	Fe	641.73	611.46	579.72	511.41	447.03	353.54	172.06	215.48	455.84	**443.14**
	Mn	97.11	85	82.62	78.13	73.9	67.56	58.23	66.11	73.58	**75.80**
	Zn	43.99	42.14	38.64	31.8	25.4	20.54	18	22.76	30.15	**30.38**
	Cu	50.76	48.55	40.67	33.63	28.81	18.01	13.61	25.98	29.43	**32.10**
Cauliflower	Fe	13.84	11.98	9.89	8.43	7.32	6.8	4.86	5.96	8.88	**8.66**
	Mn	35.44	31.57	29.61	23.28	18.65	10.98	6.35	11.54	21.16	**20.96**
	Zn	39.41	32.44	22.69	16.46	11.09	8.37	4.13	14.77	22.45	**19.08**
	Cu	1.36	1.29	1.24	1.19	1.16	1.12	1.05	1.13	42.16	**5.74**
Wheat	Fe	293.82	268.77	238.58	205.01	187.06	141.69	113.14	150.98	207.26	**200.7**
	Mn	238.57	231.53	277.81	215.55	209.25	157	142.86	182.54	197.81	**197.81**
	Zn	39.97	37.53	31.5	25.08	18.66	10.85	4.24	17.37	22.951	**22.95**
	Cu	23.82	21.58	17.68	13.61	12.3	8.36	6.52	15.61	16.24	**16.24**
Guideline for safe limit (WHO/FAO)											
Fe		**Mn**				**Zn**			**Cu**		
500		**5-20**				**1-400**			**20-1000**		

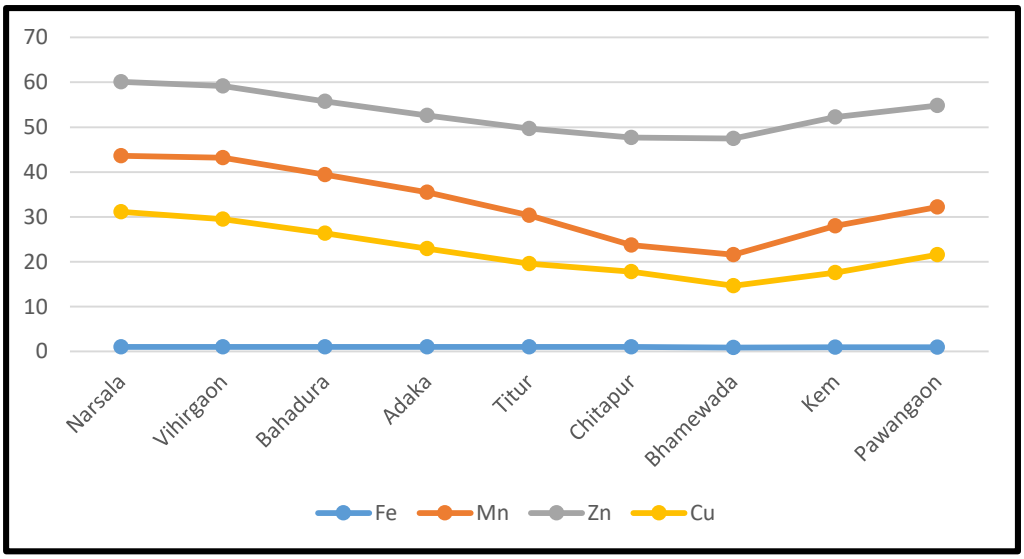

Figure No. 8 Average concentration of micronutrient (mg kg^{-1}) in sewage irrigated Brinjal crop

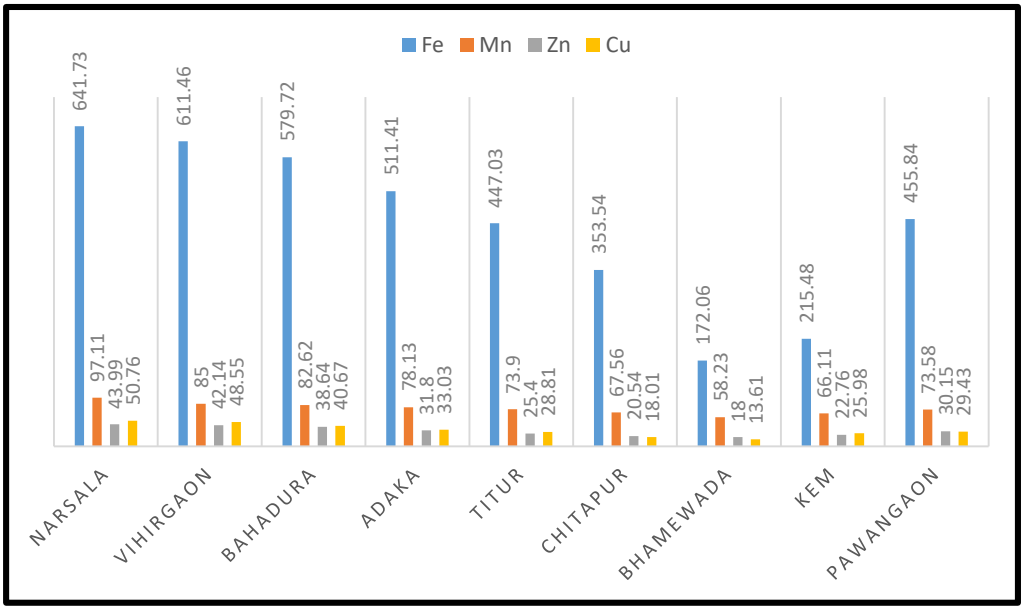

Figure No. 9 Average concentration of micronutrient (mg kg^{-1}) in sewage irrigated Tomato crop

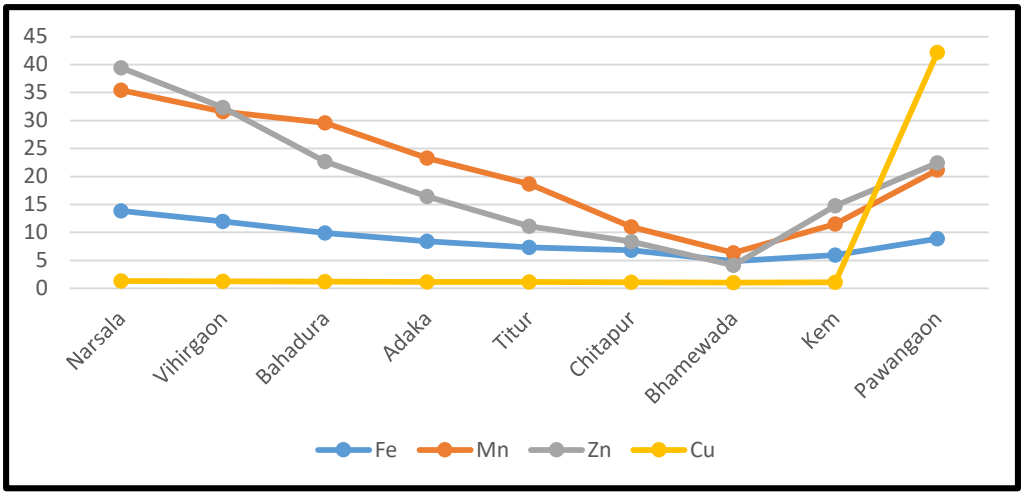

Figure No. 10 Average concentration of micronutrient (mg kg^{-1}) in sewage irrigated Cauliflower crop

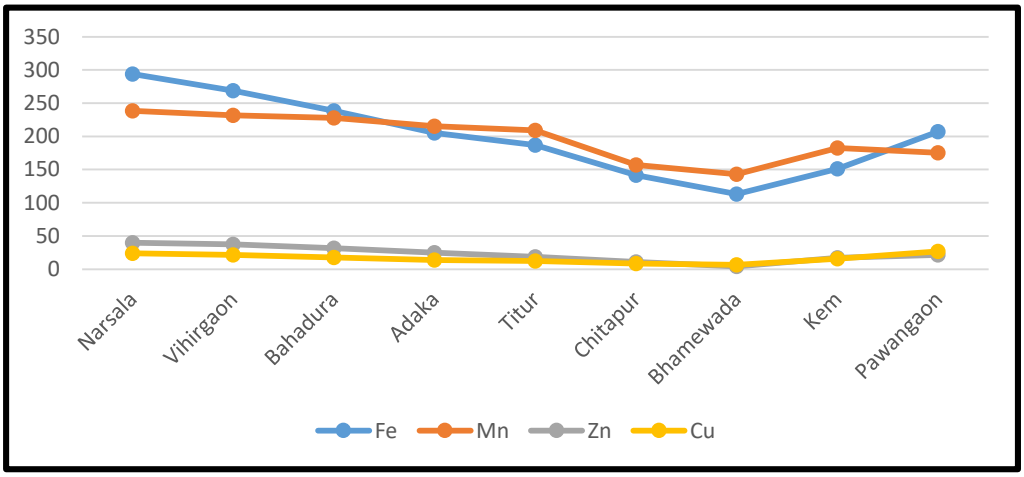

Figure No. 11 Average concentration of micronutrient (mg kg^{-1}) in sewage irrigated Wheat crop

The heavy metal (Pb, Co, Cr and Cd) content in sewage water irrigated crop (Brinjal, Tomato, Cauliflower and Wheat) are presented in table 10. The mean concentration of Pb, Co, Cr and Cd in Brinjal are 23.22, 3.44, 9.95 and 0.74 mg kg^{-1} . The concentration of Pb, Co, Cr and Cd in Tomato ranged from 12.54 to 30.09, 2.7 to 10.69, 0.83 to 5.1 and 0.32 to 0.98 mg kg^{-1}. In case of Cauliflower mean concentration of Pb, Co, Cr and Cd is 0.78, 0.9, 9.53 and 1.09 mg kg^{-1}. The concentration of Fe was observed more in Tomato followed by Brinjal and Cauliflower. The concentration of Pb, Co, Cr and Cd in Wheat ranged from 2.5 to 6.9, 2.1 to 7.9, 3.49 to 16.9 and 0.4 to 2.2 mg kg^{-1}. The concentration of Pb, Co, Cr and Cd was found maximum at Narsala village because of due to waste from some dyeing industry which are located in Nagpur city directly pour waste into Nag river. The compounds used for these dyeing processes include copper, chromium, nickel and lead which is very toxic and carcinogenic (Begum et al., 2011). Similar findings were reported by Malhi et al., (2010) who reported that mean concentration of Pb, Cr, Cd and Co in crop plants growing on soils irrigated with sewage contaminated water were 1.2, 2.1, 8.7 and 1.9 times higher than in plants irrigated with deep tube-well water, respectively. The amount of potentially toxic metals were significantly and positively correlated with cation exchange capacity and organic carbon content and negatively correlated with soil pH. In conclusion, long-term accumulation of toxic metals in soils and their uptake by crop plants has a high potential for phytotoxicity as well as for entering into the food chain.

Property of heavy metals is to dissolve in water make them harmful and cause damaging effects to all living organisms including plants, animals and humans even at low concentration (Uzu et al., 2011). Heavy metals accumulation was known to increase in plants due to sewage irrigation but extent of accumulation varies among varieties and crops depending on concentration of heavy metals in effluent and frequency of application.

Table No.10 Heavy metal (mg kg-^{1}) concentration in swage water irrigated crop plant at selected village

Name of crop	Heavy metal content (mg kg^{-1})	Name of villages									
		Narsala	Vihirgaon	Bahadura	Adak	Titur	Chitapur	Bhamewad	Kem	Pawangaon	Mean
Brinjal	Pb	31.31	29.82	26.62	23.64	19.65	16.97	13.73	21.42	25.66	**23.22**
	Co	5.2	5.1	4.1	3.8	3.2	2.2	1.3	2.7	3.4	**3.44**
	Cr	16.9	14.1	11.53	9.13	8.5	7.5	4.3	7.6	10.06	**9.95**
	Cd	0.98	0.93	0.88	0.75	0.63	0.55	0.32	0.5	0.85	**0.74**
Tomato	Pb	30.09	28.43	26.63	22.67	19.44	14.35	12.54	19.32	27.52	**22.33**
	Co	5.1	4.6	4.43	3.7	3	2.23	0.83	1.63	3.37	**3.21**
	Cr	10.69	9.34	7.96	7.02	6.43	3.53	2.7	7.6	10.06	**7.26**
	Cd	0.98	0.93	0.88	0.75	0.63	0.56	0.32	0.5	0.85	**0.71**
Cauliflower	Pb	0.97	0.94	0.93	0.9	0.75	0.61	0.43	0.63	0.86	**0.78**
	Co	1.47	1.43	1.03	0.8	0.5	0.37	0.17	0.8	1.57	**0.90**
	Cr	14.2	13.82	13.17	10	7	5.05	3.57	6.52	12.41	**9.53**
	Cd	1.21	1.17	1.09	1.07	1.07	1.04	0.97	1.15	1.04	**1.09**
Wheat	Pb	6.9	6.3	5.7	4.1	4.13	3.3	2.5	2.9	3.8	**4.4**
	Co	7.9	7.0	6.7	5.8	5.4	3.7	2.1	4.0	6.8	**5.49**
	Cr	16.9	14.56	11.66	10.01	7.54	5.65	3.49	11.87	16.74	**10.94**
	Cd	2.2	1.9	1.7	1.4	1.0	0.9	0.4	0.8	1.0	**1.25**
Guideline for safe limit (WHO/FAO)											
Pb		**Co**				**Cr**			**Cd**		
0.2-20		**0.02-1**				**0.03-1.4**			**0.1-2.4**		

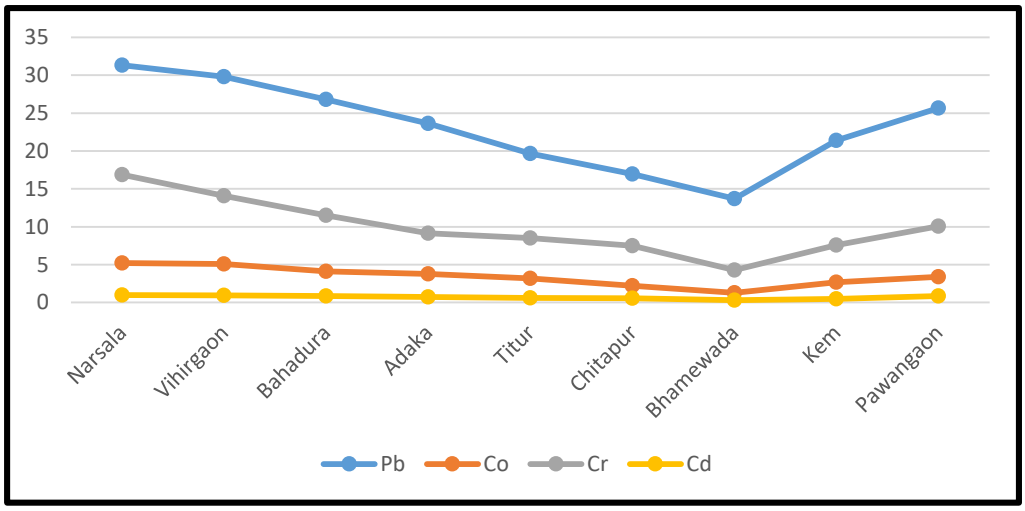

Figure No. 12 Average concentration of heavy metal (mg kg^{-1}) in sewage irrigated Brinjal crop

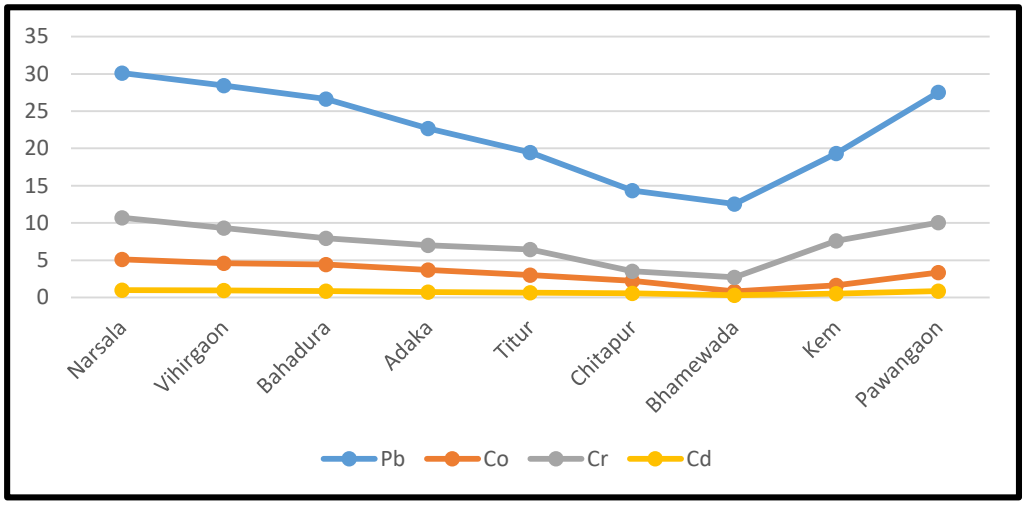

Figure No. 13 Average concentration of heavy metal (mg kg^{-1}) in sewage irrigated Tomato crop

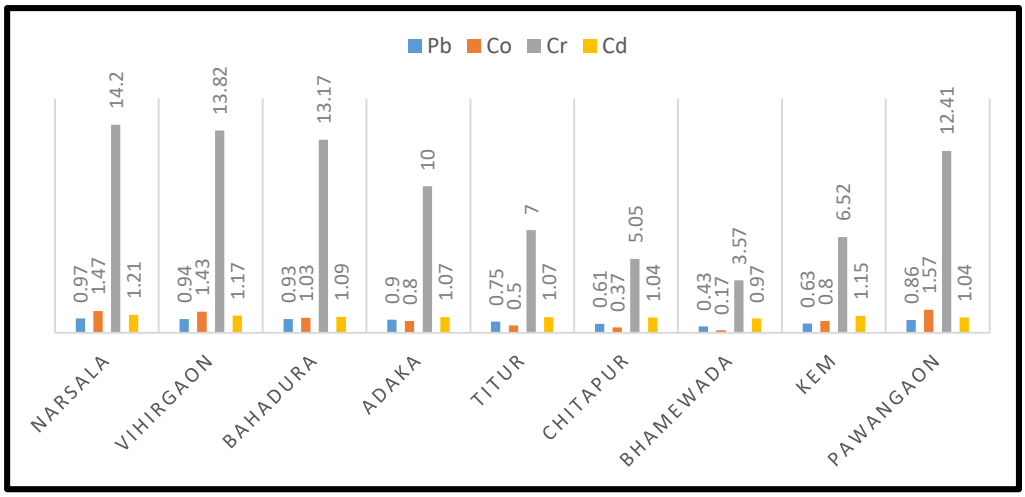

Figure No. 14 Average concentration of heavy metal (mg kg^{-1}) in sewage irrigated Cauliflower crop

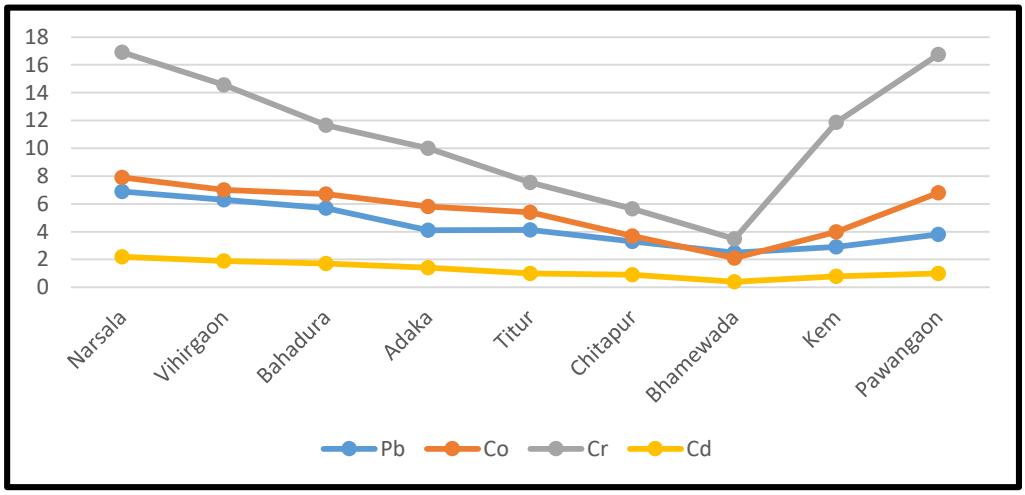

Figure No. 15 Average concentration of heavy metal (mg kg^{-1}) in sewage irrigated Wheat crop

Chapter V

SUMMARY AND CONCLUSION

The present investigation **"IMPACT OF SEWAGE IRRIGATION WATER ON SOIL POLLUTION AND UPTAKE OF HEAVY METALS BY CROPS IN PERI-URBAN AREA OF NAGPUR"** was undertaken during 2018-2019 to assess the quality of sewage water of Nag-river from Nagpur, Kuhi and Kamathi taluka of Nagpur district where the sewage water directly lifted by the farmers, for the irrigation with the electric pump adjacent to the Nag river.

The data obtained were compiled and the results of the study are summarized below:

1) The characteristic of effluent varied with the location. The pH of the sewage water of Nag river in various location ranged from 6.17 to 6.94 which were found slightly acidic to neutral in reaction. The EC of sewage water ranged from 1.25 to 2.06 dS m^{-1}.
2) The basic cation and anion Na^{+}, Mg^{2+}, CO^{3-}, HCO^{3-}, SO_4^{2-} and Cl^{-} ranged from 127 to 189, 1.08 to 2.71, 15 to 50, 646.13 to 873.32, 14.82 to 49.6 and 44.5 to 102.89 mg L^{-1} respectively and followed the order to $Na^{+} > Mg^{2+}$ and $HCO^{3-} > Cl^{-} > CO^{3-} > SO_4^{2-}$.
3) Total hardness and Ca-hardness of sewage water of Nag river ranged from 170 to 273.3 mg L^{-1} and 117.4 to 197 mg L^{-1} respectively. Hardness of given water sample is lower than ISI standard (1991) which ranged between 300 to 500 mg L^{-1}.
4) COD of sewage water sample of Nag river ranged from 152.64 to 456.01 mg L^{-1} which was less than ISI (1991) standard (250 mg L^{-1}) at Titur (247.36 mg L^{-1}), Chitapur (179.70 mg L^{-1}) and at Bhamewad (152.64 mg L^{-1}).
5) The TSS of sewage water of Nag river ranged from 157 to 252 mg L^{-1} and ammonia of sewage water ranged from 2.9 to 4.2 mg L^{-1}.

6) Micronutrient content Fe, Zn, Cu and Mn in sewage water ranged from 0.06 to 0.25, 0.11 to 0.24, 1.78 to 1.87 and 0.55 to 3.81 mg L^{-1}, respectively and followed the order Mn > Cu > Fe> Zn.

7) The mean value of heavy metal Co, Cd, Cr, Pb, As and Hg in sewage water of Nag river was observed 0.31, 0.05, 0.18, 0.75, 0.07 and 0.06 mg L^{-1}, respectively and followed the order Pb > Co > Cr > As > Hg > Cd.

8) The pH of soil irrigated with sewage water ranged from 7.49 to 7.95 and electrical conductivity ranged from 0.515 to 0.939 dS m^{-1}. Infiltration rate of soil irrigated with sewage water ranged from 1.55 to 2.91 (mg L^{-1}).

9) The bulk density and hydraulic conductivity of soil irrigated with sewage water ranged with 1.31 to 1.58 mg m^3 and 1.21 to 1.52 cm h^{-1} respectively.

10) Available N, P and K in effluents irrigated soil ranged from 280.04 to 324.95, 15.63 to 15.73 and 592.07 to 686.6 kg ha^{-1}, respectively.

11) The DTPA extractable micronutrients Fe, Mn, Zn and Cu in effluent irrigated soil ranged between 22.71 to 26.07, 4.45 to 8.23, 0.94 to 2.97 and 2.54 to 5.04 mg kg^{-1}, respectively and followed the order Fe > Mn > Cu > Zn.

12) The mean concentration of Cd, Cr, Pb and Co is 0.15, 0.65, 16.39 and 0.67 mg kg^{-1} respectively and followed the order Pb > Co > Cr > Cd. The concentration of Cr, Pb and Co was observed more in soil irrigated with sewage water at Narsala village (0.83, 22.17 and 0.953 mg kg^{-1}) and less in Bhamewada village (0.39, 9.74 and 0.35 mg kg^{-1}) where as in case of Cd was found more in Narsala village (0.21 mg kg^{-1}) and less in Chitapur village (0.14 mg kg^{-1}).

13) The micronutrients (Fe, Mn, Zn and Cu) content in sewage irrigated Brinjal ranged between 435.44 to 681.44, 21.55 to 43.6, 47.44 to 60.08 and 14.63 to 31.15 mg kg^{-1} respectively.

14) The micronutrients (Fe, Mn, Zn and Cu) content in sewage irrigated Tomato ranged between 172.06 to 641.73, 58.23 to 97.11, 18 to 43.99 and 13.61 to 50.76 mg kg^{-1} respectively. In tomato content of Fe and Mn was above permissible limit at Narsala, Vihirgaon, Bahadura, and Adak.
15) The micronutrients Fe, Mn, Zn and Cu content in sewage irrigated Cauliflower ranged between 4.86 to 13.84, 6.35 to 35.44, 4.13 to 39.41 and 1.05 to 1.36 mg kg^{-1}, respectively.
16) The mean value of micronutrient content in wheat was observed more amount of Fe (293.82 mg kg^{-1}) and Mn (238.57 mg kg^{-1}) as compared to Brinjal, Tomato and Cauliflower but below the permissible limit.
17) The mean concentration of heavy metal (Pb, Co, Cr and Cd) in sewage water irrigated Brinjal crop is 23.22, 3.44, 9.96 and 0.71 mg kg^{-1}.
18) The mean concentration of heavy metal (Pb, Co, Cr and Cd) in sewage water irrigated Tomato crop is 22.33, 3.21, 7.26 and 0.71 mg kg^{-1} whereas, in Cauliflower it ranged from 0.43 to 0.97, 1.17 to 0.47, 2.57 to 14.2 and 0.97 to 1.21 mg kg^{-1}.
19) The mean concentration of heavy metal (Pb, Co, Cr and Cd) in sewage water irrigated Wheat crop was 4.4, 5.49, 10.82 and 1.25 mg kg^{-1}.
20) The heavy metal content in vegetables and cereal crop were above the permissible limit.

Conclusions

- On the basis of above data, the continuous irrigation with sewage water increased the micronutrients and heavy metals content in vegetables and cereal..
- The more concentration of micronutrients and heavy metals observed in the locations of Narsala, Vihirgaon and Bahadura region where as Bhamewada location

have less concentration of micronutrients and heavy metals in soil and plant sample.

- The vegetables grown at Narsala, Vihirgaon Bahadura and Adak village are not safe for eating as the concentration of micronutrients and heavy metals observed over permissible limit. Whereas, Bhamewada location is safe as one clean water Nala meet with Nag river so dilution occur and reduced the concentration of heavy metals.
- Sewage water of Nag river should be collected and give secondary treatment to it and treated sewage water should be use for protective irrigation to crops and the development of gardens for the beautification to Nagpur city.

Chapter VI

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APPENDIX I

Table A: List of farmers from selected villages who use sewage water for irrigation

Sr. No.	Name of Taluka	Name of Villages	Name of farmers
1	Nagpur	Vihirgaon	Vishwanath Kapse
			Harishchandra Kapse
			Sheshrao Shinde
		Bahadura	Damodhar Khadave
			Ramchandra Nandurkar
			Tulsiram Khandave
		Narsala	Rushikesh Raut
			Panjabrao Nagpure
			Ajabrao Nagpure
2	Kuhi	Bhamewad	Pappu Lende
			Bandu Matkar
			Kabir Sakharkar
		Titur	Vasanta Meshram
			Umesh Lande
			Bahar Thakre
		Chitapur	Kawadu Narnarwe
			Gajanan Narnarwe
			Ashok Ghate
3	Kamathi	Pawangaon	Padmakar Chaudhary
			Vasantrao Chaudhary
			Kiran Raut
		Kem	Padmakar Chaudhary
			Vasantrao Chaudhary
			Kiran Raut
		Adak	Vinayak Bhoyar
			Gangadhar Sambhare
			Gajanan Sambhare

APPENDIX II

Table A: Characteristic of sewage water

Location	pH	EC dS m^{-1}	Total Hardness mg L^{-1}	Ca-hardness mg L^{-1}	CO_3 mg L^{-1}	HCO_3 mg L^{-1}	Cl mg L^{-1}	SO_4 mg L^{-1}	TSS mg L^{-1}	Mg^{2+} mg L^{-1}	Na^+ mg L^{-1}	K^+ mg L^{-1}	COD mg L^{-1}	NH_3 mg L^{-1}
Narsala	6.15	2.16	272.2	197.0	54	1030.90	103.07	49.53	250	2.65	198	12	88.00	4.1
	6.18	2.02	274.4	197.2	47	567.30	102.59	49.82	253	2.60	182	12	87.98	4.2
	6.19	1.99	274.3	196.8	48	1021.75	103.02	49.43	254	2.89	186	6	88.05	4.1
Mean	**6.17**	**2.06**	**273.6**	**197.0**	**50**	**873.32**	**102.89**	**49.60**	**252**	**2.71**	**189**	**9**	**88.01**	**4.2**
Vihirgaon	6.28	1.99	260.0	153.0	36	924.15	86.00	24.93	244	2.60	171	7	58.23	3.7
	6.26	1.93	261.8	152.8	30	549.00	85.20	24.63	242	2.56	180	9	58.32	3.6
	6.25	1.95	261.5	152.6	30	1049.20	80.60	24.53	243	2.50	165	7	57.98	3.9
Mean	**6.26**	**1.96**	**261.1**	**152.8**	**32**	**855.78**	**83.93**	**24.70**	**243**	**2.55**	**172**	**8**	**58.18**	**3.7**
Bahadura	6.31	1.95	256.8	140.0	30	1055.25	86.50	20.82	246	2.40	124	6	52.00	3.1
	6.39	1.92	250.7	141.8	30	893.65	81.50	21.02	244	2.30	162	6	51.00	3.2
	6.36	1.89	252.4	140.9	36	594.75	80.20	20.94	243	2.45	168	6	49.00	3.5
Mean	**6.35**	**1.92**	**253.3**	**140.9**	**32**	**847.88**	**82.73**	**20.92**	**244**	**2.38**	**172**	**6**	**50.67**	**3.3**
Titur	6.75	1.82	248.0	141.3	21	1000.00	75.03	17.55	189	1.70	135	4	37.33	2.8
	6.68	1.77	246.7	141.6	15	564.75	72.04	16.98	182	1.80	142	5	37.48	3.2
	6.78	1.78	246.0	140.8	31	613.05	73.05	17.24	192	1.70	137	4	37.28	2.9
Mean	**6.74**	**1.79**	**246.9**	**141.2**	**22**	**725.93**	**73.37**	**17.26**	**188**	**1.73**	**138**	**4**	**37.36**	**3.0**
Chitapur	6.89	1.30	224.3	129.3	29	570.35	55.93	17.23	180	1.70	133	3	40.00	2.8
	6.75	1.31	224.3	129.6	24	518.50	52.62	16.59	179	1.50	135	4	39.00	2.7
	6.84	1.65	223.8	130.0	ND	1085.80	54.72	17.48	165	1.60	142	3	40.10	2.8
Mean	**6.83**	**1.42**	**224.1**	**126.4**	**18**	**724.88**	**54.42**	**17.10**	**175**	**1.60**	**138**	**3**	**39.7**	**3.2**
Bhamewada	7.02	1.24	170.7	107.5	15	530.70	34.83	14.62	148	0.40	128	4	22.00	2.2

	6.89	1.29	171.8	107.9	ND	542.95	35.61	14.82	160	1.23	130	3	22.92	2.4
	6.91	1.21	169.8	106.9	ND	564.75	33.05	15.02	162	1.60	122	3	23.00	2.3
Mean	**6.94**	**1.25**	**170.8**	**107.4**	**5**	**546.13**	**34.50**	**14.82**	**157**	**1.08**	**127**	**3**	**22.64**	**2.9**
Adaka	6.52	1.88	248.5	140.0	28	552.05	78.93	21.34	195	2.30	145	5	40.00	3.5
	6.42	1.88	245.8	141.6	38	854.00	75.82	20.98	190	1.90	152	5	40.20	3.2
	6.48	1.88	246.2	140.2	27	844.00	76.68	21.23	240	1.80	140	4	40.19	3.5
Mean	**6.47**	**1.88**	**246.8**	**140.6**	**31**	**750.02**	**77.14**	**21.18**	**208**	**2.00**	**146**	**5**	**40.13**	**3.4**
Kem	6.58	1.81	200.7	136.5	30	1006.50	49.53	15.37	243	1.80	138	5	60.00	2.6
	6.52	1.80	201.2	132.0	30	576.45	50.02	15.69	240	1.80	147	5	60.23	2.7
	6.58	1.85	201.8	132.5	35	1037.00	48.72	16.02	242	1.56	152	6	59.98	2.5
Mean	**6.56**	**1.82**	**201.2**	**133.7**	**32**	**873.32**	**49.42**	**15.70**	**242**	**1.72**	**146**	**5**	**60.07**	**2.6**
Pawangaon	6.35	1.83	217.3	136.2	45	591.70	69.90	19.58	252	2.45	157	6	76.00	2.8
	6.45	1.86	216.5	136.8	42	594.75	60.52	19.53	249	2.35	146	6	76.20	3.2
	6.28	1.87	218.2	136.5	42	1070.55	68.42	20.00	253	2.10	162	6	77.98	3.3
Mean	**6.36**	**1.85**	**217.3**	**136.4**	**43**	**752.33**	**66.28**	**19.70**	**251**	**2.30**	**155**	**6**	**76.73**	**3.1**
Overall mean	**6.52**	**1.77**	**232.7**	**142.9**	**29**	**783.29**	**70.52**	**27.09**	**218**	**2.01**	**154**	**5.4**	**297.94**	**3.3**

Table B : Micronutrient and heavy metal (mg L^{-1}) content of sewage water of Nag-river at selected villages

Villages	**Fe**	**Zn**	**Cu**	**Mn**	Co	Cd	Cr	As	Pb	Hg
Narsala	0.25	0.25	1.86	3.95	0.46	0.09	0.15	0.10	0.91	0.1
	0.25	0.24	1.87	3.59	0.46	0.08	0.14	0.10	1.11	0.1
	0.26	0.22	1.89	3.89	0.46	0.09	0.13	0.10	1.11	0.09
Mean	**0.25**	**0.24**	**1.87**	**3.81**	**0.46**	**0.09**	**0.14**	**0.1**	**1.04**	**0.1**
Vihirgaon	0.24	0.23	1.89	3.40	0.42	0.05	0.12	0.10	0.99	0.09
	0.23	0.21	1.87	2.29	0.40	0.08	0.09	0.10	0.98	0.08
	0.21	0.2	1.82	2.22	0.39	0.07	0.12	0.10	0.96	0.09
Mean	**0.23**	**0.21**	**1.86**	**2.64**	**0.4**	**0.07**	**0.11**	**0.1**	**0.98**	**0.09**
Bahadura	0.2	0.18	1.83	2.28	0.34	0.05	0.10	0.10	0.88	0.07
	0.18	0.19	1.81	2.25	0.35	0.04	0.09	0.10	0.89	0.08
	0.16	0.17	1.85	2.51	0.36	0.05	0.08	0.10	0.80	0.06
Mean	**0.18**	**0.18**	**1.83**	**2.35**	**0.35**	**0.06**	**0.09**	**0.1**	**0.86**	**0.07**
Titur	0.15	0.16	1.83	2.25	0.32	0.10	0.10	0.01	0.73	0.05
	0.12	0.15	1.84	2.45	0.28	0.05	0.10	0.01	0.63	0.08
	0.14	0.14	1.82	2.95	0.27	0.06	0.8	0.01	0.73	0.07
Mean	**0.14**	**0.15**	**1.83**	**2.55**	**0.29**	**0.07**	**0.33**	**0.01**	**0.70**	**0.07**
Chitapur	0.12	0.12	1.84	1.25	0.24	0.04	0.10	0.01	0.60	0.04
	0.11	0.11	1.80	1.22	0.24	0.04	0.10	0.01	0.60	0.02
	0.14	0.15	1.82	1.26	0.20	0.03	0.10	0.01	0.65	0.06
Mean	**0.12**	**0.13**	**1.82**	**1.24**	**0.23**	**0.04**	**0.10**	**0.01**	**0.62**	**0.04**
Bhamewada	0.11	0.1	1.81	0.98	0.15	0.04	0.5	0.01	0.54	0.01
	0.9	0.11	1.72	0.52	0.14	0.02	0.6	0.01	0.32	0.01
	0.8	0.12	1.81	0.16	0.11	0.03	0.4	0.01	0.42	0.01
Mean	**0.6**	**0.11**	**1.78**	**0.55**	**0.13**	**0.03**	**0.5**	**0.01**	**0.43**	**0.01**
Adaka	0.7	0.15	1.79	1.23	0.24	0.05	0.10	0.10	0.70	0.04
	0.8	0.14	1.86	1.25	0.24	0.05	0.10	0.10	0.60	0.04
	0.14	0.12	1.82	1.63	0.24	0.03	0.12	0.10	0.50	0.01
Mean	**0.55**	**0.14**	**1.82**	**1.37**	**0.24**	**0.04**	**0.11**	**0.01**	**0.60**	**0.04**
Kem	0.18	0.14	1.82	2.52	0.24	0.05	0.14	0.10	0.74	0.07
	0.18	0.18	1.82	2.12	0.23	0.05	0.15	0.10	0.65	0.08
	0.19	0.2	1.82	2.16	0.24	0.03	0.16	0.10	0.56	0.04
Mean	**0.18**	**0.17**	**1.82**	**2.27**	**0.24**	**0.04**	**0.15**	**0.1**	**0.65**	**0.06**
Pawangaon	0.18	0.2	1.82	3.45	0.42	0.05	0.14	0.10	0.84	0.08
	0.17	0.24	1.87	3.19	0.46	0.06	0.16	0.10	0.86	0.07
	0.19	0.26	1.83	3.29	0.40	0.05	0.12	0.10	0.92	0.09
Mean	**0.18**	**0.23**	**1.78**	**3.31**	**0.43**	**0.05**	**0.14**	**0.1**	**0.87**	**0.08**
Overall mean	**0.27**	**0.17**	**1.83**	**2.23**	**0.31**	**0.05**	**0.18**	**0.07**	**0.75**	**0.06**

APPENDIX III

Table A: Physico-chemical properties of soil

Location	pH	EC dS m^{-1}	Infiltration rate cm h^{-1}	Hydraullic conductivity cm h^{-1}	Bulk Density mg m^3	Available nitrogen kg ha^{-1}	Available phosphorous kg ha^{-1}	Available potassium kg ha^{-1}
Narsala	7.43	0.980	1.50	3.22	1.57	326.14	14.11	682.9
	7.61	0.892	1.52	3.20	1.60	326.14	13.44	698.3
	7.43	0.944	1.62	3.21	1.58	322.56	16.35	678.5
Mean	**7.49**	**0.939**	**1.55**	**3.21**	**1.58**	**324.95**	**15.63**	**686.6**
Vihirgaon	7.62	0.741	1.52	2.58	1.58	225.79	16.8	652.3
	7.68	0.791	1.53	3.22	1.55	275.97	14.11	687.5
	7.58	0.749	1.68	2.23	1.57	275.62	15.68	687.5
Mean	**7.63**	**0.76**	**1.57**	**2.67**	**1.57**	**259.13**	**15.53**	**675.77**
Bahadura	7.74	0.710	1.54	2.42	1.57	258.63	12.84	652.2
	7.79	0.742	1.62	2.40	1.52	243.25	12.72	645.8
	7.81	0.720	1.63	2.40	1.50	255.70	13.23	642.8
Mean	**7.78**	**0.724**	**1.60**	**2.41**	**1.02**	**252.53**	**12.93**	**646.9**
Titur	7.97	0.498	1.69	2.58	1.49	240.53	14.03	652.8
	7.89	0.614	1.76	2.22	1.43	152.89	9.94	642.1
	7.85	0.672	1.75	2.23	1.40	193.07	13.36	640.8
Mean	**7.9**	**0.595**	**1.73**	**2.34**	**1.44**	**186.50**	**12.44**	**645.23**
Chitapur	7.74	0.555	1.86	2.12	1.40	150.53	13.36	632.8
	7.80	0.486	1.96	2.03	1.42	225.44	9.03	638.9
	7.52	0.638	1.92	2.11	1.36	195.69	7.91	637.9
Mean	**7.69**	**0.56**	**1.91**	**2.09**	**1.39**	**190.55**	**10.1**	**636.53**

Bhamewada	8.00	0.684	1.92	1.97	1.35	190.35	8.24	589.7
	8.05	0.521	1.86	1.88	1.34	192.89	6.24	598.6
	7.81	0.482	2.96	1.91	1.21	192.89	5.24	587.9
Mean	**7.95**	**0.553**	**2.25**	**1.92**	**1.31**	**192.04**	**6.57**	**592.07**
Adaka	8.07	0.568	1.94	2.12	1.43	175.62	12.27	658.7
	8.01	0.411	2.04	3.13	1.62	238.34	11.29	674.5
	8.01	0.565	1.94	3.11	1.43	188.16	12.60	645.8
Mean	**8.03**	**0.515**	**1.97**	**2.79**	**1.49**	**200.71**	**12.05**	**659.67**
Kem	7.73	0.725	1.63	2.16	1.58	225.79	15.68	698.7
	7.89	0.542	1.73	2.30	1.67	238.96	13.44	674.8
	7.86	0.632	1.53	2.32	1.35	288.51	9.18	698.7
Mean	**7.83**	**0.633**	**1.63**	**2.26**	**1.53**	**251.09**	**12.77**	**690.73**
Pawangaon	7.44	0.872	1.66	3.20	1.54	238.34	13.89	698.7
	7.60	0.742	1.78	1.21	1.50	200.70	14.56	648.8
	7.62	0.742	1.52	2.19	1.45	263.42	14.34	699.8
Mean	**7.55**	**0.785**	**1.65**	**2.20**	**1.5**	**225.79**	**14.26**	**682.43**
Overall mean	**7.76**	**0.675**	**1.76**	**2.43**	**1.42**	**231.5**	**12.47**	**657.32**

Table B: Micronutrient and heavy metal (mg L^{-1}) concentration in sewage water irrigated soil at selected villages

Villages	Fe	Mn	Zn	Cu	Cd	Cr	Pb	Co
Narsala	6.15	7.81	3.05	4.39	0.20	0.83	28.30	0.98
	6.03	8.00	3.02	6.16	0.201	0.84	15.65	0.97
	6.03	8.98	2.85	4.58	0.21	0.83	20.11	0.91
Mean	**6.07**	**8.23**	**2.97**	**5.04**	**0.21**	**0.83**	**21.35**	**0.95**
Vihirgaon	5.27	6.90	2.12	3.76	0.17	0.80	23.70	0.96
	5.86	7.17	1.43	4.13	0.18	0.85	25.50	0.97
	5.74	7.52	2.85	4.72	0.20	0.79	17.31	0.73
Mean	**5.62**	**7.20**	**2.13**	**4.20**	**0.18**	**0.81**	**22.17**	**0.89**
Bahadura	4.19	5.36	2.64	3.21	0.18	0.78	16.50	0.78
	4.12	6.17	1.91	5.16	0.18	0.71	16.61	0.68
	5.74	7.84	1.58	3.56	0.17	0.73	16.71	0.89
Mean	**4.68**	**6.46**	**2.04**	**3.98**	**0.18**	**0.74**	**16.61**	**0.78**
Titur	4.30	6.84	1.78	3.34	0.16	0.65	14.78	0.68
	3.90	5.93	1.98	3.46	0.15	0.71	13.68	0.55
	4.33	4.23	1.34	3.33	0.16	0.65	14.97	0.75
Mean	**4.18**	**5.67**	**1.37**	**3.37**	**0.16**	**0.67**	**14.48**	**0.66**
Chitapur	2.82	5.79	1.73	3.08	0.14	0.58	14.78	0.59
	2.77	6.73	1.55	3.05	0.14	0.59	12.91	0.31
	3.72	5.72	0.70	3.05	0.15	0.44	10.85	0.41
Mean	**3.10**	**6.08**	**1.33**	**3.06**	**0.14**	**0.54**	**12.85**	**0.44**
Bhamewada	2.68	4.59	1.20	1.82	0.13	0.37	9.60	0.21
	2.80	3.46	0.14	2.82	0.14	0.48	10.70	0.15
	2.65	5.29	0.58	2.99	0.15	0.33	8.91	0.10
Mean	**2.71**	**4.45**	**0.64**	**2.54**	**0.14**	**0.39**	**9.74**	**0.35**
Adaka	3.95	4.53	1.57	3.68	0.13	0.53	14.26	0.67
	4.29	5.12	1.36	3.56	0.14	0.67	14.26	0.39
	5.97	5.35	1.52	3.06	0.15	0.60	17.59	0.59
Mean	**4.74**	**5.00**	**1.50**	**3.43**	**0.14**	**0.6**	**15.37**	**0.55**
Kem	4.92	6.55	0.72	4.36	0.19	0.53	15.70	0.52
	4.50	6.88	0.94	4.12	0.17	0.51	17.89	0.75
	3.97	6.97	0.81	4.14	0.17	0.57	14.78	0.64
Mean	**4.63**	**6.80**	**0.82**	**4.21**	**0.17**	**0.53**	**16.12**	**0.64**
Pawangaon	6.98	7.56	2.37	3.94	0.19	0.72	22.11	0.91
	4.95	7.62	2.74	3.79	0.19	0.78	18.30	0.95
	4.24	7.61	2.01	4.00	0.20	0.72	16.13	0.97
Mean	**5.39**	**7.59**	**2.38**	**3.91**	**0.19**	**0.74**	**18.85**	**0.94**
Overall mean	**4.57**	**6.37**	**1.69**	**3.75**	**0.15**	**0.65**	**16.39**	**0.67**

APPENDIX IV

Table A: Micrunutrient and heavy metal content of sewage irrigated Brinjal crop (mg kg^{-1})

Villages	Fe	Mn	Zn	Cu	Pb	Co	Cr	Cd
Narsala	1.09	45.96	60.12	31.35	32.56	5	17	0.98
	1.05	42.58	60.12	31.25	30.52	5.2	16.85	1
	1.05	42.25	60.01	30.85	30.85	5.3	16.87	0.97
Mean	**1.06**	**43.59**	**60.08**	**31.15**	**31.31**	**5.17**	**16.91**	**0.98**
Vihirgaon	1.04	45.96	59.23	30.58	30.85	4.9	15.23	0.85
	1.04	42.26	60.02	28.25	29.85	4.2	14.85	0.95
	1.02	41.25	58.2	29.65	28.75	6	12.23	0.98
Mean	**1.03**	**43.16**	**59.15**	**29.49**	**29.82**	**5.03**	**14.10**	**0.93**
Bahadura	1.04	39.65	58.03	25.48	29.87	4.2	10.23	0.92
	1.03	40.25	57.26	28.97	25.85	4.1	12.52	0.89
	1.02	38.29	52.03	24.56	24.75	4	11.85	0.82
Mean	**1.03**	**39.39**	**55.77**	**26.34**	**26.82**	**4.1**	**11.53**	**0.88**
Adak	1.02	35.62	52.31	24.56	23.85	3.9	9.2	0.82
	1.04	38.25	54.23	21.58	24.23	4	9	0.7
	1.07	32.58	51.26	22.58	22.85	3.5	9.2	0.72
Mean	**1.04**	**35.48**	**52.6**	**22.91**	**23.64**	**3.8**	**9.13**	**0.75**
Titur	1.05	31.25	48.23	20.48	20.58	3.5	8.5	0.65
	1.06	29.05	49.56	19.65	19.85	3.2	8.9	0.62
	1.02	30.85	51.24	18.54	18.52	3	8.2	0.6
Mean	**1.04**	**30.38**	**49.68**	**19.56**	**19.65**	**3.23**	**8.53**	**0.62**
Chitapur	1.02	25.68	48.56	17.85	18.25	2.5	7.5	0.52
	1.05	24.25	48.21	18.65	17.42	2.1	7.2	0.58
	1.08	21.25	46.21	16.85	15.23	1.9	7.8	0.56
Mean	**1.05**	**23.73**	**47.66**	**17.78**	**16.97**	**2.17**	**7.5**	**0.55**
Bhamewad	0.85	21.25	45.02	15.38	12.52	1.5	4.5	0.42
	0.78	22.15	48.26	14.85	15.42	1.2	3.2	0.23
	0.98	21.25	49.05	13.65	13.25	1.2	5.2	0.32
Mean	**0.87**	**21.55**	**47.44**	**14.63**	**13.73**	**1.3**	**4.3**	**0.32**
Kem	0.98	30.25	52.16	18.95	18.52	2.5	8.5	0.52
	0.87	28.54	50.26	17.52	24.23	2.8	7.5	0.42
	1.08	25.26	54.23	16.23	21.52	2.7	6.8	0.58
Mean	**0.98**	**28.02**	**52.22**	**17.57**	**21.42**	**2.67**	**7.6**	**0.51**
Pawangaon	1.05	32.58	54.26	18.95	25.23	3.2	7.8	0.85
	0.78	31.25	52.89	20.54	24.52	3.5	9.8	0.84
	0.98	32.85	57.24	25.26	27.23	3.4	12.58	0.86
Mean	**0.94**	**32.27**	**54.77**	**21.58**	**25.66**	**3.37**	**10.06**	**0.85**
Ovearall mean	**1.0044**	**33.06**	**53.26**	**22.34**	**23.22**	**3.44**	**9.95**	**0.71**

Table B: Micrunutrient and heavy metal content of sewage irrigated Tomato crop (mg kg^{-1})

Villages	Fe	Mn	Zn	Cu	Pb	Co	Cr	Cd
Narsala	650.43	98.65	45.48	51.2	30.12	5	10.67	0.98
	649.23	97.45	45.23	50.23	30.14	5.2	10.55	1
	625.54	95.23	41.25	50.84	30.02	5.1	10.85	0.97
Mean	**641.73**	**97.11**	**43.99**	**50.76**	**30.09**	**5.1**	**10.69**	**0.98**
Vihirgaon	623.58	85.23	42.25	48.23	28.25	4.8	9.85	0.85
	612.54	87.54	40.58	47.85	29.52	4.9	9.65	0.95
	598.25	82.23	43.58	49.56	27.52	4.2	8.52	0.98
Mean	**611.46**	**85.00**	**42.14**	**48.55**	**28.43**	**4.63**	**9.34**	**0.93**
Bahadura	587.23	82.13	39.85	42.25	28.52	4.5	8.52	0.92
	589.62	79.52	38.54	40.12	26.52	4.6	7.52	0.89
	562.31	86.21	37.54	39.65	24.85	4.2	7.85	0.82
Mean	**579.72**	**82.62**	**38.64**	**40.67**	**26.63**	**4.43**	**7.96**	**0.88**
Adak	523.65	82.13	35.24	35.26	24.23	3.9	6.89	0.82
	512.02	80.25	30.58	32.58	22.25	3.8	6.75	0.7
	498.56	72	29.58	31.25	21.52	3.5	7.42	0.72
Mean	**511.41**	**78.13**	**31.8**	**33.03**	**22.67**	**3.73**	**7.02**	**0.75**
Titur	489.23	76.23	28.54	30.25	20.58	3.2	5.8	0.65
	456.23	74.23	25.32	28.58	18.23	2.8	6.8	0.62
	395.62	71.25	22.35	27.59	19.52	3	6.7	0.6
Mean	**447.03**	**73.90**	**25.40**	**28.81**	**19.44**	**3**	**6.43**	**0.62**
Chitapur	389.52	69.23	21.25	15.23	15.28	2.4	4.5	0.52
	372.56	65.23	19.52	18.23	14.52	2.5	3.6	0.58
	298.54	68.21	20.85	20.58	13.25	1.8	2.5	0.56
Mean	**353.54**	**67.56**	**20.54**	**18.01**	**14.35**	**2.23**	**3.53**	**0.55**
Bhamewad	215.32	58.23	19.35	15.23	11.52	1.2	2.1	0.42
	198.62	62.23	18.23	12.58	13.58	0.8	3.2	0.23
	102.23	54.24	16.52	13.02	12.52	0.5	2.8	0.32
Mean	**172.06**	**58.23**	**18.03**	**13.61**	**12.54**	**0.83**	**2.7**	**0.32**
Kem	152.87	62.25	20.58	20.58	17.58	1.8	8.5	0.52
	215.23	64.85	25.23	24.58	19.52	1.4	7.5	0.42
	278.35	71.23	22.48	32.78	20.85	1.7	6.8	0.58
Mean	**215.48**	**66.11**	**22.76**	**25.98**	**19.32**	**1.63**	**7.6**	**0.51**
Pawangaon	425.89	74.25	28.54	32.58	27.85	3.2	7.8	0.85
	356.98	75.23	32.58	28.59	26.85	3.5	9.8	0.84
	584.65	71.25	29.32	27.12	27.85	3.4	12.58	0.86
Mean	**455.84**	**73.58**	**30.15**	**29.43**	**27.52**	**3.37**	**10.06**	**0.85**
Ovearall mean	**443.14**	**75.8**	**30.38**	**32.1**	**22.33**	**3.21**	**7.25**	**0.85**

Table C: Micrunutrient and heavy metal content of sewage irrigated Cauliflower crop (mg kg^{-1})

Villages	Fe	Mn	Zn	Cu	Pb	Co	Cr	Cd
Narsala	12.12	35.59	39.41	1.32	1	1.5	14.51	1.15
	14.12	35.87	40.25	1.35	1	1.5	14.52	1.25
	15.28	34.85	38.58	1.42	0.9	1.4	13.58	1.23
Mean	**13.84**	**35.44**	**39.41**	**1.36**	**0.97**	**1.47**	**14.20**	**1.21**
Vihirgaon	14.12	32.87	35.58	1.25	0.9	1.2	13.85	1.25
	11.23	31.25	31.58	1.32	0.98	1.3	12.85	1.14
	10.58	30.58	29.85	1.3	0.95	1.8	14.75	1.11
Mean	**11.98**	**31.57**	**32.34**	**1.29**	**0.9**	**1.43**	**13.82**	**1.17**
Bahadura	10.28	30.85	25.47	1.25	0.95	1.2	10.85	1.1
	9.52	28.74	21.85	1.22	0.92	1	15.82	1.09
	9.87	29.23	20.74	1.24	0.93	0.9	12.85	1.08
Mean	**9.89**	**29.67**	**22.69**	**1.24**	**0.9**	**1.03**	**13.17**	**1.09**
Adak	8.6	25.23	18.57	1.2	0.92	0.9	10.85	1.05
	8.23	22.87	16.58	1.19	0.89	0.8	9.65	1.08
	8.45	21.74	14.23	1.18	0.9	0.7	9.52	1.07
Mean	**8.43**	**23.28**	**16.46**	**1.19**	**0.90**	**0.8**	**10.01**	**1.07**
Titur	7.25	20.87	12.85	1.17	0.65	0.6	8.52	1.05
	7.85	19.85	10.58	1.16	0.75	0.5	7.23	1.07
	6.85	15.23	9.85	1.15	0.85	0.4	5.23	1.08
Mean	**7.32**	**18.65**	**11.03**	**1.16**	**0.75**	**0.5**	**6.99**	**1.07**
Chitapur	5.85	12.85	9.06	1.14	0.72	0.2	5.32	1.03
	7.98	9.85	8.52	1.12	0.62	0.5	4.52	1.05
	6.58	10.23	7.58	1.11	0.5	0.4	5.32	1.04
Mean	**6.80**	**10.98**	**8.39**	**1.12**	**0.61**	**0.37**	**5.05**	**1.04**
Bhamewad	4.23	8.25	5.23	1.09	0.45	0.2	2.35	1.02
	5.58	4.52	4.58	1.05	0.52	0.1	4.85	1
	4.78	6.28	2.58	1.02	0.32	0.2	3.52	0.9
Mean	**4.87**	**6.35**	**4.13**	**1.05**	**0.43**	**0.17**	**3.57**	**0.97**
Kem	5.23	10.87	9.87	1.15	0.65	0.7	6.85	1.05
	5.79	6.28	14.58	1.02	0.62	0.8	4.85	1.08
	6.85	17.48	19.85	1.23	0.62	0.9	7.85	1.11
Mean	**5.97**	**11.54**	**14.77**	**1.13**	**0.63**	**0.8**	**6.52**	**1.15**
Pawangaon	7.85	19.85	21.85	1.23	0.85	1.5	9.85	1.12
	8.95	20.85	19.63	1.25	0.87	1.4	14.52	1.13
	9.85	22.85	25.87	124	0.86	1.8	12.85	0.86
Mean	**8.88**	**21.18**	**22.45**	**42.16**	**0.86**	**1.57**	**12.47**	**1.037**
Ovearall mean	**8.66**	**20.96**	**19.08**	**5.74**	**0.78**	**0.9**	**9.53**	**1.09**

Table D: Micrunutrient and heavy metal content of sewage irrigated Wheat crop (mg kg^{-1})

Villages	Fe	Mn	Zn	Cu	Pb	Co	Cr	Cd
Narsala	300	240	40	25	7	8	17	2
	285.85	239.85	39.65	25.23	6.9	7.9	17.52	2.5
	295.62	235.87	40.25	21.23	6.8	7.8	16.2	2.1
Mean	**293.82**	**238.57**	**39.97**	**23.82**	**6.9**	**7.9**	**16.91**	**2.2**
Vihirgaon	275.24	234.21	37.85	23.25	6.5	7.5	15.87	1.9
	265.23	230.85	39.52	21.25	6.2	7.4	14.23	1.8
	265.85	229.52	35.23	20.25	6.3	6	13.58	1.9
Mean	**268.77**	**231.53**	**37.53**	**21.58**	**6.3**	**6.97**	**14.56**	**1.87**
Bahadura	245.32	228.52	32.58	19.58	5.9	6.8	12.85	1.8
	240.21	229.58	31.41	15.23	5.4	6.9	11.25	1.7
	230.21	225.32	30.52	18.24	5.7	6.5	10.87	1.5
Mean	**238.58**	**227.81**	**31.50**	**17.68**	**5.7**	**6.73**	**11.66**	**1.67**
Adak	213.25	219.58	28.54	13.25	4.2	6.2	9.85	1.4
	203.52	215.74	25.12	12.85	4.1	5	10.58	1.5
	198.25	211.32	21.58	14.74	3.9	6.1	9.65	1.2
Mean	**205.07**	**215.55**	**25.08**	**13.61**	**4.1**	**5.77**	**10.03**	**1.37**
Titur	198.52	210.38	21.23	11.85	4	5.8	8.57	1.1
	187.42	209.85	19.52	14.52	4.8	5.2	7.52	1
	175.23	207.52	15.23	10.52	3.6	5.1	6.52	1
Mean	**187.06**	**209.25**	**18.66**	**12.29**	**4.1**	**5.37**	**7.54**	**1.03**
Chitapur	152.23	154.85	12.52	9.85	3.6	4.2	5.85	0.9
	142.58	153.28	10.52	8.72	3.2	3.2	4.58	0.8
	130.25	162.85	9.52	6.52	3	3.8	6.52	0.9
Mean	**141.69**	**156.99**	**10.85**	**8.36**	**3.3**	**3.73**	**5.65**	**0.87**
Bhamewad	124.52	152.85	5.23	5.23	2.9	2.8	3.65	0.5
	112.38	143.52	4.25	6.85	2.5	2.4	4.23	0.3
	102.52	132.2	3.25	7.48	2.1	1.2	2.58	0.4
Mean	**113.14**	**142.86**	**4.24**	**6.52**	**2.5**	**2.13**	**3.49**	**0.4**
Kem	135.85	184.58	15.28	12.85	2.5	3.5	9.85	0.8
	142.56	187.53	16.25	14.74	3.2	3.8	10.52	0.7
	174.52	175.52	20.58	19.23	3	4.7	15.23	0.8
Mean	**150.98**	**182.54**	**17.37**	**15.67**	**2.9**	**4**	**11.87**	**0.77**
Pawangaon	187.59	185.23	18.23	21.85	4.5	5.8	12.85	0.9
	198.53	174.52	20.58	28.93	3	6.7	17.85	1
	235.65	165.85	25.28	29.32	3.9	7.8	19.52	1
Mean	**207.26**	**175.2**	**21.36**	**26.7**	**3.8**	**6.77**	**16.74**	**1**
Ovearall mean	**200.7**	**197.81**	**22.95**	**16.24**	**4.4**	**5.5**	**10.94**	**1.25**

APPENDIX V

Statement showing the weekly meterological data for the year 2017-2018 (period from s, 2018 september december, 2018) recorded at agriculture college Nagpur.

Month		Met week	Temp ^{0} C		R.H.%		Total Rainfall (mm)	No. of rainy days	Evaporation (mm)
			Max	Min	Morn	Eve			
27-02	Sep 18	35	27.8	21.7	86	77	21.4	2	2.0
03-09		36	29.6	21.1	81	69	25.6	2	2.2
10-16		37	33.5	23.4	71	52	00.0	0	3.9
17-23		38	33.5	23.6	77	67	44.6	1	4.5
24-30		39	33.7	24.1	76	65	00.0	0	3.9
01-07	Oct 18	40	34.7	23.8	72	49	00.0	0	3.7
08-14		41	34.6	22.6	68	44	00.0	0	3.7
15-21		42	34.3	23.2	69	40	00.0	0	3.0
22-28		43	31.4	21.3	68	41	00.0	0	2.4
29-04	Nov 18	44	32.8	20.8	67	43	00.0	0	2.8
05-11		45	33.0	20.1	68	39	00.0	0	2.5
12-18		46	32.4	18.9	67	46	00.0	0	3.2
19-25		47	30.0	17.3	74	45	00.0	0	2.8
26-02	Dec 18	48	28.1	16.2	70	32	00.0	0	3.0
03-09		49	27.3	15.4	76	43	16.6	0	2.1
10-16		50	25.0	14.9	78	67	3.2	1	1.6
17-23		51	25.5	12.8	78	66	00.0	1	2.2
24-31		52	25.5	11.2	71	69	00.0	0	2.5