RESEARCHERID
THOMSON REUTERS

[Martis* 5(6): June, 2018] ISSN 2349-4506
Impact Factor: 3.799

Global Journal of Engineering Science and Research Management

INVESTIGATION ON GROUND WATER, SOIL AND VEGETATION QUALITY WITH SPECIAL REFERENCE TO HEAVY METALS AROUND BELLANDUR LAKE AREA, BENGALURU

Sharal Martis*, C. R. Ramakrishnaiah
* M.Tech, Environmental engineering, Department of Civil Engineering, BMS College of Engineering, Bangalore, Karnataka, India
Department of Civil Engineering, BMS College of Engineering, Bangalore, Karnataka, India

DOI: 10.5281/zenodo.1293331

KEYWORDS: Heavy metals, distribution, migration, Bellandur lake, vegetables.

ABSTRACT
In recent years, environmental pollution is a major problem in most of the cities and it is also one of the causes for human health issues. Heavy metal pollution have arisen the interest in researchers, because of its potential health hazards to the humans even at low concentration. This project work provides an insight about the level of contamination in the ground water, soil and also in vegetation around the Bellandur Lake, Bengaluru. Bellandur Lake was once upon a time, major source of water to the localities, now it stands as one of most highly polluted lakes in Bengaluru. The elevated concentration of pollutants in the lake is mainly because of the direct discharge of effluents into the lake water from the surrounding areas. This lake water is being used for irrigation of crops cultivated around the lake. Usage of contaminated water for irrigation of crops is a main cause for accumulation of heavy metals in the soil pores. Therefore in this project work, the distribution and migration of heavy metals in soil is studied along with the impact of contaminated soil on vegetation around Bellandur Lake, where the lake water is used for the cultivation of vegetables.

INTRODUCTION
Heavy metals are ill-defined subset of chemical elements that exhibit metallic properties. Since heavy metals are stable and cannot be degraded or destroyed, so they tend to accumulate in the soil sediments. However, these days human activities are altering the biochemical and geochemical cycles and balance of heavy metals. Nowadays the environmental pollution due to toxic metals is of major concern in most of the metropolitan cities. The heavy metals entering the ecosystem leading bioaccumulation, bio-magnification and also leads to geo-accumulation. The heavy metals once it enters the soil system, it causes a major problem by polluting the underground water by leaching. The migration of soil is different for different types of soil. The accumulation of heavy metals in the ground water is directly related to soil characteristics. Food chain contamination is also a major issue these days since its ability to accumulate heavy metals through contaminated water, soil and air. The vegetable crops consume heavy metals mainly by their growth media that is soil, nutrients, water and air. Heavy metal contamination of soil resulting from wastewater irrigation is of major concern due to the potential health impacts of consuming contaminated produce. Therefore, detailed knowledge of heavy metal sources, their presence and effects in water, their accumulation in soil and plant system is studied. Bellandur lake is the largest lake in Bengaluru city attracting many people by the formation of froth and fire. It is the highly polluted lake with sewage effluents. Nearby areas have been discharging untreated sewage and industrial waste into the lake without checking. The combination of all these factors has led to an imbalance in the ecosystem of the lake which now resembles a stinking cesspool. This lake water is being used for the irrigation purposes and thereby toxic substances, particularly heavy metals, enter the ecosystem in large amounts.

STUDY AREA
Bengaluru is located at a latitude 12.58’N and longitude of 77.35’E at an altitude of 921 m above mean sea level. Bellandur lake is located in the suburb of Bellandur in the southeast of the city of Bengaluru. It is one of the largest lake in the Bengaluru city. The lake has a catchment area of about 148km^2. The lake is located at latitude 12^{0}56'3″N and longitude of 77^{0}39'46″E. Lake drains the southern and south-east parts of the city. Further the lake water flows to the east to the Varthur lake, from there it flows down the plateau and finally into the Pinakani river. This lake is currently the highly polluted lake with sewage. The foam covering water surface caught fire in and burned for hours in May 2015 and January 2018. One of the bountiful lake has now been turned into a sewage

tank. The problem began in late 1980s. Bellandur lake was the lifeline for surrounding 18 villages a few years ago. People used to cultivate crops, paddy, grow vegetables and also do fishing. According to the Lake Development Authority (LDA) Bellandur lake is over 891.9 acre and its water storage capacity is 17.66 million cubic feet. Now the lake size is not more than 726 acre. Now the lake has become more or less a sewage tank because of the untreated sewage entering into it. Improper sewage treatment of the STP's overflows and joins storm water, which in turn flows to Bellandur lake and also the insufficient treatment plants in industries leading to direct discharge of industrial waste to the lake. There are 17 inlet points to the lake upon which 4 major inlets from where sewage enters the lake are Koramangala, Challagatta, Agaram and Iblur. Bellandur lake receives about 40 % (400- 500 million liters of sewage) of treated or untreated sewage water of Bengaluru city especially from HAL, K R Puram, K R Market, Jayanagar, Bommanahalli, Byatarayanapura etc and also 110 villages largely contribute sewage to the Bellandur lake.

Groundwater and Soil sampling is carried out around the Bellandur lake area to study the distribution and migration of heavy metals in soil. In this background, the present study was made an attempt to investigate the distribution and migration of heavy metals around Bellandur lake and also to know the concentration of heavy metals in vegetables grown using sewage fed lake water. Study area is shown in map 1.

Map 1: Study area

MATERIALS AND METHODS
Grab sampling has been embraced to collect groundwater samples. 21 groundwater samples were collected in polythene containers of 1L volume for chemical examination after drawing out sufficient amount of water from the source such that, the sample gathered served as a representative sample. The analysis of several chemical parameters such as pH, Alkalinity, Total dissolved solids, Total Hardness, Nitrates, chlorides, Calcium and Magnesium were carried out to assess ground water quality. In the present work, 4 soil samples were collected to study the distribution of heavy metals in the soil around Bellandur lake from surface soil. Collection of sample is accomplished by using shovels, trowels, spades and scoops. Up to the required depth, the surface material is removed and using a trowel soil specimen is collected in the clean plastic bag. 12 soil specimens were collected to study the migration of heavy metals in soil around Bellandur lake from 0 to 60 cm depth. Initially a triangular cut is made up to the required depth and 2-3 cm thick slice from each of the cut is made using a shovel and using a clean trowel soil specimen is collected in a polythene bag. The soil specimen collected is examined for heavy metals using Mehlich-I extraction method. Representative soil sample is oven dried for 24 hours at 101-105^{0}C in a hot air oven. Then using a mortar pestle dried sample is grinded and sieved through 1mm sieve. Take five grams of sieved sample in a conical (Erlenmeyer) flask. 20ml of extracting solution i.e. (0.05N HCl+0.025N H_2SO_4) is

added. Shake it for 15 minutes using mechanical shaker. Filter through whatman (no.42) filter paper into 50ml volumetric flask and then dilute it to 50ml with Mehlich-I extracting solution and analyze the sample for heavy metal concentration using Atomic Absorption Spectrophotometer (AAS). In the present study vegetables such as Brinjal, Coriander leaf, Spinach, Mint, Beans, Radish, Radish leaf, Tomato, Amaranth leaves, Drumstick, Ladies finger, Cattle feed, Millet leaf, Broad beans are collected to check the heavy metal concentration in particular vegetables. The vegetable samples collected near Bellandur lake area are cut into small pieces and kept for air drying for two successive days. Again it is dried for 3 hours at 100+/-1^{0}C in hot air oven. Using mortar pestle the samples were ground in warm condition. And it is sieved using 1mm sieve. 2 gram of the sieved sample is taken for digestion process that is carried out using 10 ml of Nitric acid. Filtered sample is then diluted to 50ml using distilled water. Spatial representation of ground water sampling points is represented in the fig 1.

Fig 1: Spatial representation of ground water sampling points around Bellandur lake

RESULTS AND DISCUSSIONS
To evaluate the ground water quality, ground water samples collected from the study area were analyzed for 8 physic-chemical parameters. Within the 24 hours of sample collection, all the physic-chemical characteristics were evaluated. The outcomes of all the physic-chemical parameters in the ground water samples collected from the existing 21 bore wells are presented in the table 1. By adopting the standard methods, the ground water samples were analyzed in the Environmental Laboratory, Department of Civil Engineering, BMS College of Engineering, Bengaluru.

Also the spatial variations of ground water parameters are represented pictorially using Geographic Information System(GIS). The results shows that pH ranges from 6.9-7.9, TDS 1060- 2350 mg/l, chlorides 72-335 mg/l, nitrates 0-92 mg/l, total hardness 264-508 mg/l of $CaCO_3$, alkalinity 304-708mg/l, calcium 75-152 mg/l, magnesium 2.9- 75 mg/l. The outcomes of heavy metals concentration in the ground water samples collected from

RESEARCHERID
THOMSON REUTERS

[Martis* 5(6): June, 2018] ISSN 2349-4506
Impact Factor: 3.799

Global Journal of Engineering Science and Research Management

the existing 21 bore wells are presented in the table 3. The concentration of nickel and chromium in few samples exceed the limit prescribed by BIS. The variation of nickel and chromium concentration in groundwater is shown in fig 2. The iron concentration in mg/l is varies from 0 to 0.05, nickel 0-0.36 mg/l, copper 0 to 0.1 mg/l, zinc 0-0.13 mg/l, Chromium 0-0.11mg/l. The spatial distribution of TDS, chlorides, nickel and copper are shown in fig 3 to fig 6.The variation in top soil sample is shown in table 2. It can be concluded from the table 2 and figure 7 that the concentration of copper, nickel and chromium are quite high location number 3. This is because the pollution sources are near to the sample location 3. The concentration of copper is low in location 2, chromium concentration is low in location 1, and nickel concentration is low in location 2. The concentration in the soil is in the order of chromium(Cr) > copper(Cu) > nickel(Ni). The concentration of chromium varies between 11.1-12.3 mg/kg, distribution of copper is between 8.8- 10.5 mg/kg and distribution of nickel is between 1.5- 3.2 mg/kg.
For migration study the concentration of heavy metals from the top soil to the 60cm depth is carried out. The variation of heavy metals concentration is represented in the table 4. The variation of heavy metals at different depths at different locations is shown in fig 8 to fig 11. It can be conclude that the concentration of heavy metals varies from high concentration at the surface to low at 60 cm depth, in all the sampling stations from 1 to 4. This concludes that surface is relatively rich in heavy metal concentration due to continuous use of contaminated water for irrigation in the study area. The concentration of chromium in mg/kg is higher in all the samples, whereas nickel is in low concentration. Chromium concentration indicates that the surface water is polluted mainly by industrial effluents, which in turn used for irrigation of crops.

The concentration of heavy metals in the vegetable sample is represented in the table 5. The variation of copper, chromium and nickel concentrations in various vegetables are shown in the fig 12 to fig 14.The concentration of copper in the vegetable samples varies from 182-1650 µg/g, chromium 4.5-911 µg/g, nickel 370-670 µg/g. It can be concluded from results that the leafy vegetables are highly contaminated.

Tables:

Table 1: Results of physic-chemical characteristics in the study area

sl no	latitude	longitude	pH	TDS	Chlorides	Total Hardness	Calcium	Magnesium	Alkalinity	Nitrate
1	N12^{0}55′22.9″	E77^{0}39′52.1″	6.99	1160	164.71	392	99.38	34.9	424	0
2	N12^{0}55′22.9″	E77^{0}39′44.7″	7.09	1241	143.75	324	125.03	2.9	352	16
3	N12^{0}55′21.9″	E77^{0}40′05.5″	6.77	1570	198.65	468	198	48.1	316	18
4	N12^{0}55′39.4″	E77^{0}39′45.5″	6.76	1300	89.84	360	75.34	41.79	304	16
5	N12^{0}55′46.4″	E77^{0}39′39.1″	7.08	1612	266.54	340	181.14	43.74	528	12
6	N12^{0}55′40.8″	E77^{0}39′57.2″	6.83	1700	153.7	460	200.38	38.88	424	0
7	N12^{0}55′23.5″	E77^{0}40′05.2″	7.79	1150	243.5	448	136.26	26.24	348	92
8	N12^{0}55′48.7″	E77^{0}40′07.7″	7.33	1250	168.7	432	109	17.5	524	26
9	N12^{0}55′48.3″	E77^{0}40′02.2″	7.01	1315	335.42	380	144.27	4.8	492	12
10	N12^{0}55′47.3″	E77^{0}40′18.5″	7.61	1125	193.6	344	117.17	12.6	468	28
11	N12^{0}55′47.1″	E77^{0}40′20.4″	7.43	1060	313.45	484	80.15	69	604	20
12	N12^{0}55′51.6″	E77^{0}40′30.4″	7.89	1187	72.87	264	81.75	14.6	312	24
13	N12^{0}56′16.9″	E77^{0}40′39.2″	7.01	2350	320.4	480	175	48.6	708	0
14	N12^{0}56′29.7″	E77^{0}40′46.4″	7.16	1348	235.6	508	118.6	51.5	460	18
15	N12^{0}56′39.6″	E77^{0}40′48.4″	7.29	1720	194.6	460	157	16.5	472	20
16	N12^{0}56′40.6″	E77^{0}40′40.8″	7.02	1150	204.6	408	150	21.62	468	22
17	N12°56'38.17"	E77°40'58.59"	6.84	1481	204.6	520	83.36	75.81	380	18
18	N12^{0}56′39.8″	E77^{0}39′08.2″	7.4	1618	305.5	404	81.75	48.6	496	22
19	N12°56'27.43″	E77°39'27.44"	6.94	1124	241.5	484	152.29	25.3	400	14
20	N12^{0}56′42.4″	E77^{0}39′01.2″	7.29	1222	225.6	384	137.86	9.72	524	26
21	N12^{0}56′45.7″	E77^{0}38′56.7″	7.35	1350	171.7	276	102.6	4.86	520	28
	All parameters except pH are in mg/l									

Table 2: Variation of heavy metals concentration in the soil of distribution study

Location	Latitude	longitude	copper	chromium	nickel
1	12°55′46.34″	77°39′43.54″	9.8	11.1	2.9
2	12°55′47.54″	77°39′41.33″	8.8	11.7	1.5
3	12°55′44.82″	77°39′49.39″	10.5	12.3	3.2
4	12°55′47.21″	77°39′45.79″	10.2	11.9	2.3

Table 3: Heavy metal concentration in groundwater samples

Sl no	latitude	longitude	Iron	Zinc	Nickel	chromium	copper
1	N12°55′22.9″	E77°39′52.1″	0.03	0.05	0	0	0
2	N12°55′22.9″	E77°39′44.7″	0	0.043	0	0	0
3	N12°55′21.9″	E77°40′05.5″	0	0.038	0.11	0	0.09
4	N12°55′39.4″	E77°39′45.5″	0	0.053	0.07	0.01	0.1
5	N12°55′46.4″	E77°39′39.1″	0	0.067	0.12	0	0.04
6	N12°55′40.8″	E77°39′57.2″	0.05	0	0	0.11	0.04
7	N12°55′23.5″	E77°40′05.2″	0	0	0.05	0	0
8	N12°55′48.7″	E77°40′07.7″	0.03	0.13	0	0	0.06
9	N12°55′48.3″	E77°40′02.2″	0.027	0.04	0	0	0.05
10	N12°55′47.3″	E77°40′18.5″	0.014	0	0	0	0
11	N12°55′47.1″	E77°40′20.4″	0	0	0.36	0	0
12	N12°55′51.6″	E77°40′30.4″	0.036	0	0	0	0.06
13	N12°56′16.9″	E77°40′39.2″	0	0.056	0.15	0.09	0
14	N12°56′29.7″	E77°40′46.4″	0	0	0.17	0.02	0.05
15	N12°56′39.6″	E77°40′48.4″	0	0	0	0	0.03
16	N12°56′40.6″	E77°40′40.8″	0	0	0.02	0	0
17	N12°56'38.17"	E77°40'58.59"	0	0.04	0.12	0.02	0.02
18	N12°56′39.8″	E77°39′08.2″	0.015	0	0.26	0	0
19	N12°56'27.43	E77°39'27.44"	0.028	0.033	0	0	0
20	N12°56′42.4″	E77°39′01.2″	0	0.024	0.03	0	0.01
21	N12°56′45.7″	E77°38′56.7″	0	0	0.22	0	0.01
	all the values are in mg/l						

Table 4: Variation of heavy metals concentration in soil from 0 to 60 cm depth in study area

sample no.	depth in cm	Copper	Chromium	nickel
1	0	9.8	11.1	2.9
	20	9.6	11.7	0
	40	8.9	10.1	0.7
	60	8	9.4	0.7
2	0	8.8	11.7	1.5
	20	8.3	10	0.3
	40	8.1	9.8	0.1
	60	7.8	9.7	0.1
3	0	10.5	12.3	3.2
	20	10	11.5	1.5
	40	9.9	10.2	0.8
	60	9.5	9.3	0.1
4	0	10.2	11.9	2.3
	20	9.4	11.7	1.2
	40	9	9.6	0.5
	60	8.9	9.3	0.4
All the values are in mg/kg				

Global Journal of Engineering Science and Research Management

Table 5: concentration of heavy metals in the vegetables

Vegetables	Copper	Chromium	Nickel
Brinjal	1073	816	492
Coriander leaf	1112.5	122	490
Spinach	1195	911.3	492.5
Mint	183.7	907.5	490
Beans	1675.8	25.5	370
Raddish	1635	857.5	650
Raddish leaf	1635	872	600
Tomato	1652	867	480
Amaranth leaves	1613	11.5	550
Drum stick	1607.5	7.75	448
Ladies finger	1027	9.25	389
cattle feed	1603	918	590
Millet leaf	1595	4.5	670
broad beans	1528	29.5	445

All the units in µg/g

Figures:

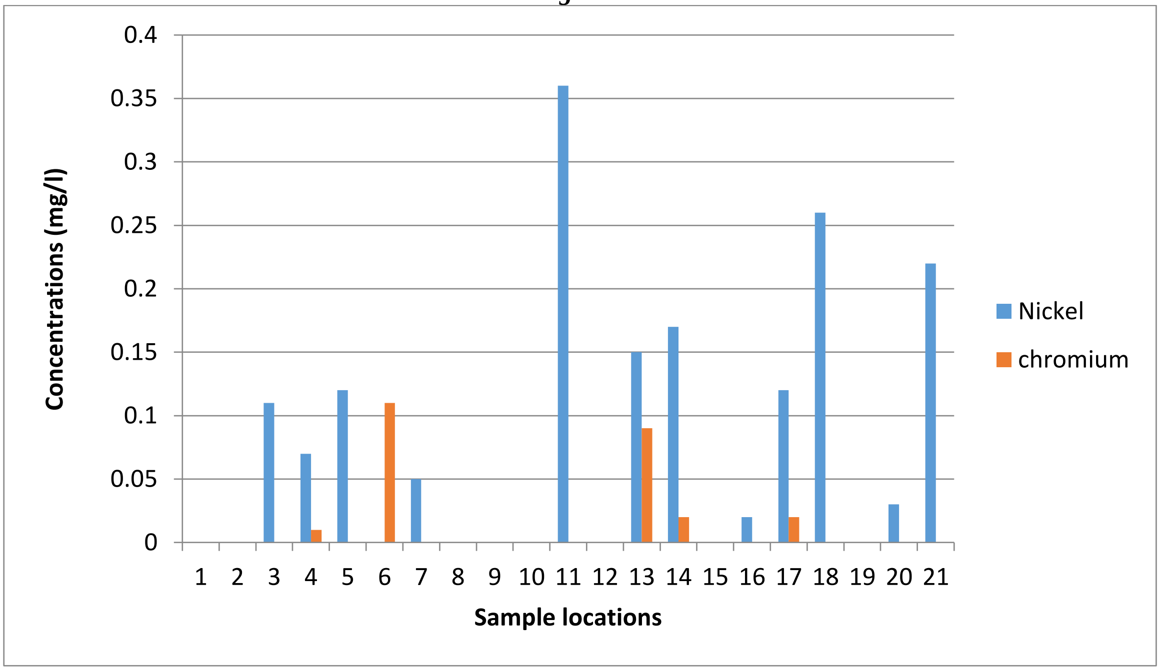

Fig 2: Variation of nickel and chromium concentration in groundwater

ISSN 2349-4506
Impact Factor: 3.799

Global Journal of Engineering Science and Research Management

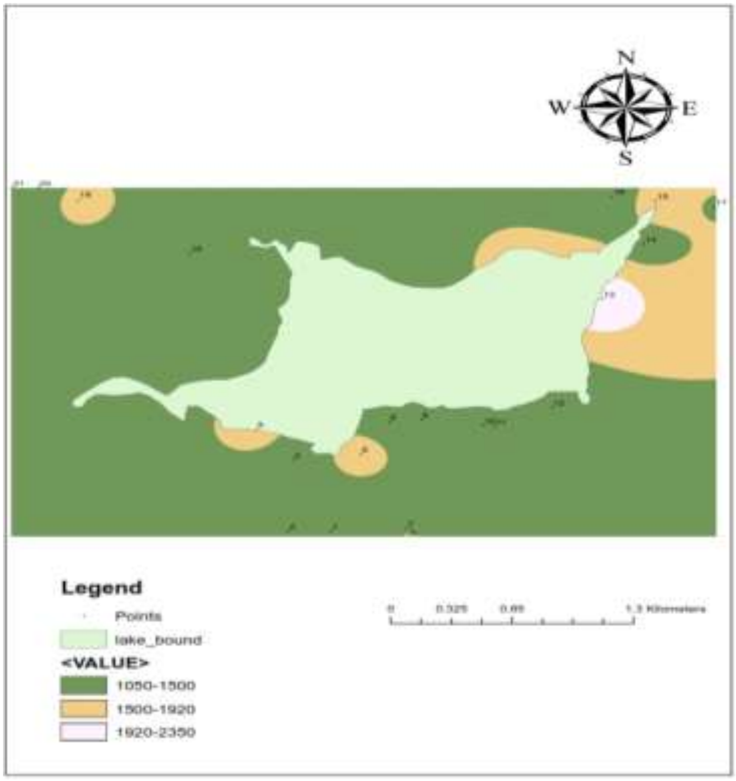

Fig 3: Spatial distribution of TDS in groundwater

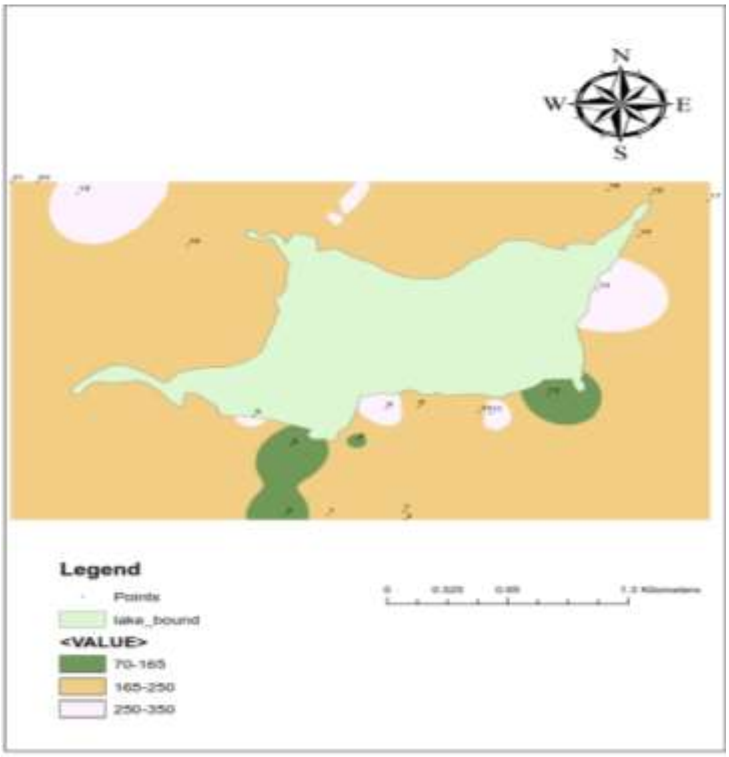

Fig 4: Spatial distribution of Chlorides in groundwater

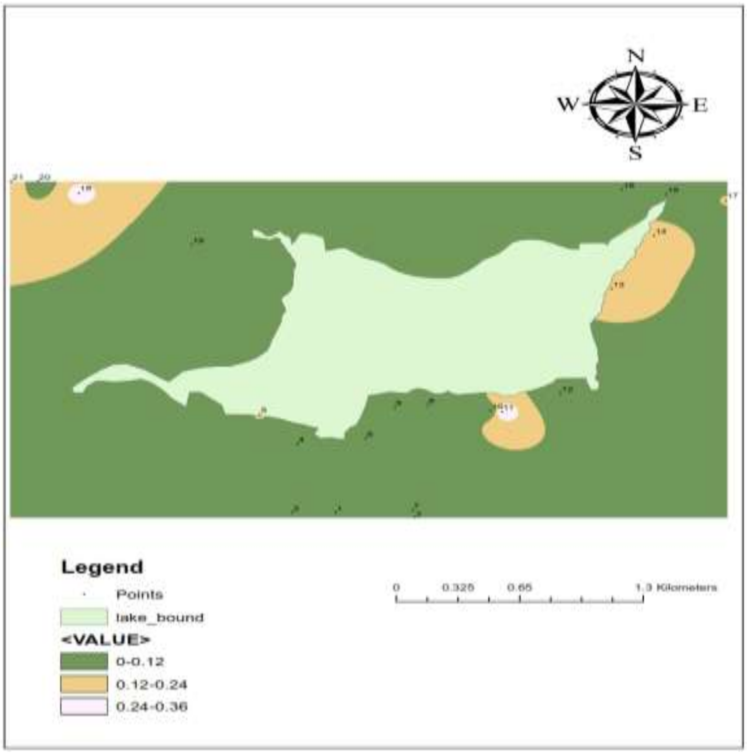

Fig 5: Spatial distribution of Nickel in groundwater

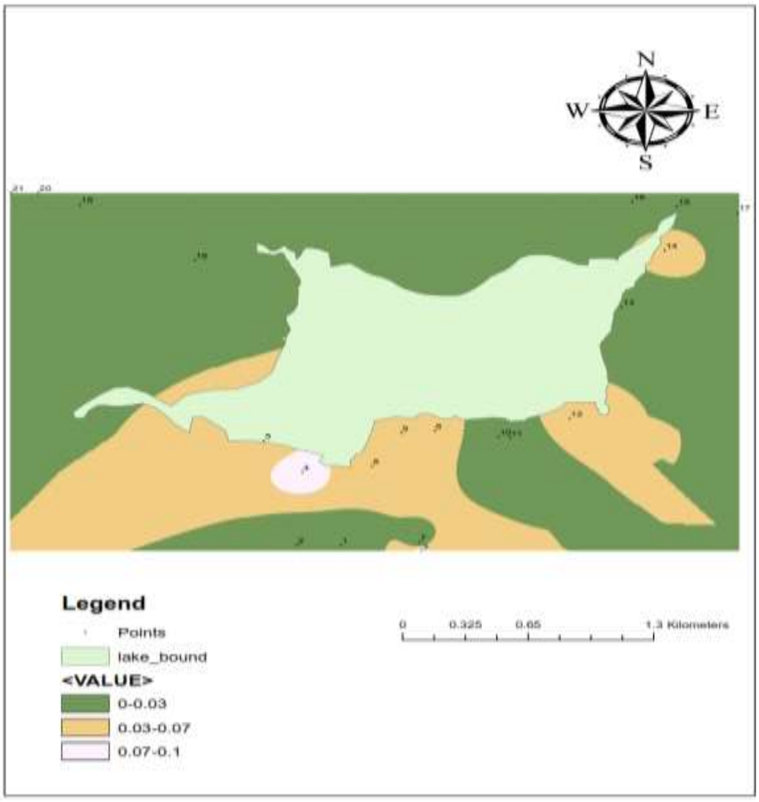

Fig 6: Spatial distribution of Copper in groundwater

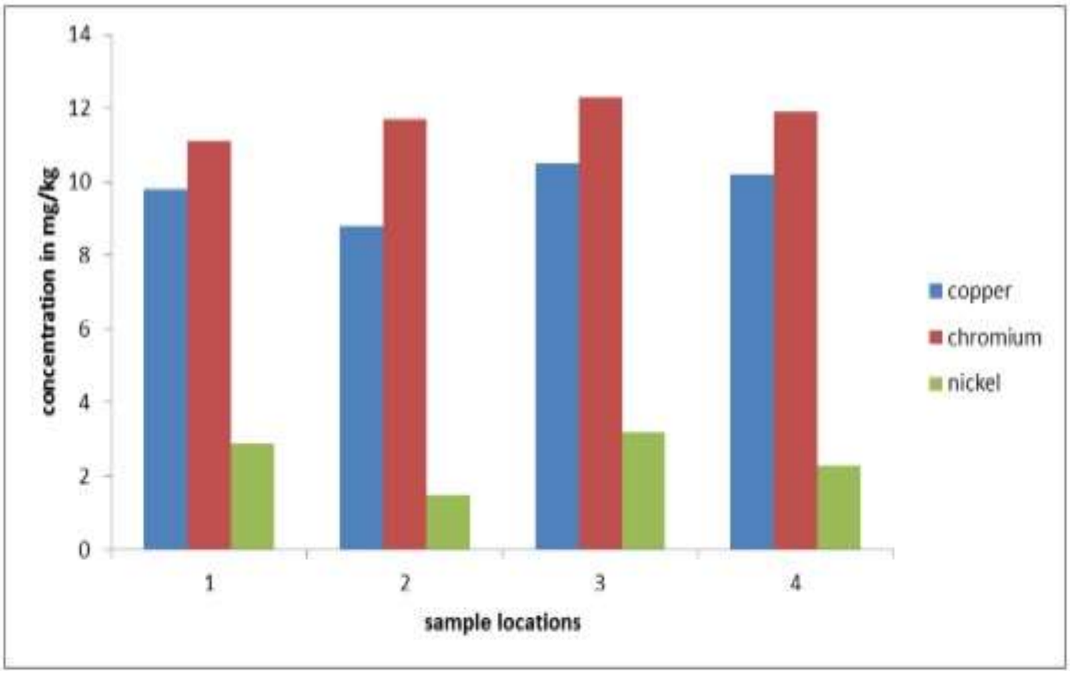

Fig 7: Concentration of various heavy metals in soil

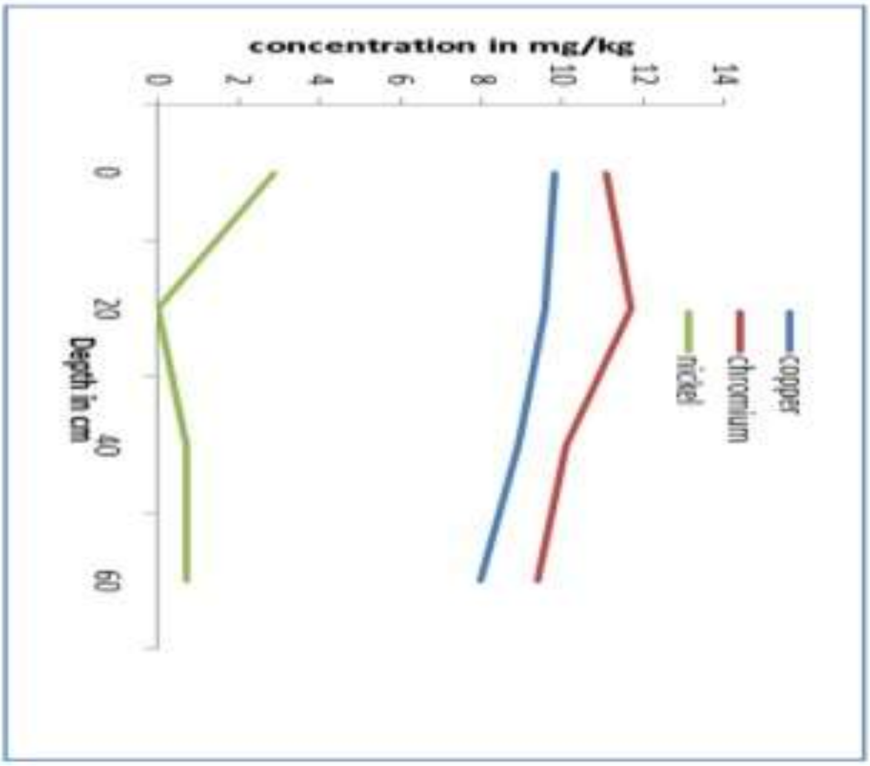

Fig 8: Variation of heavy metals at location 1

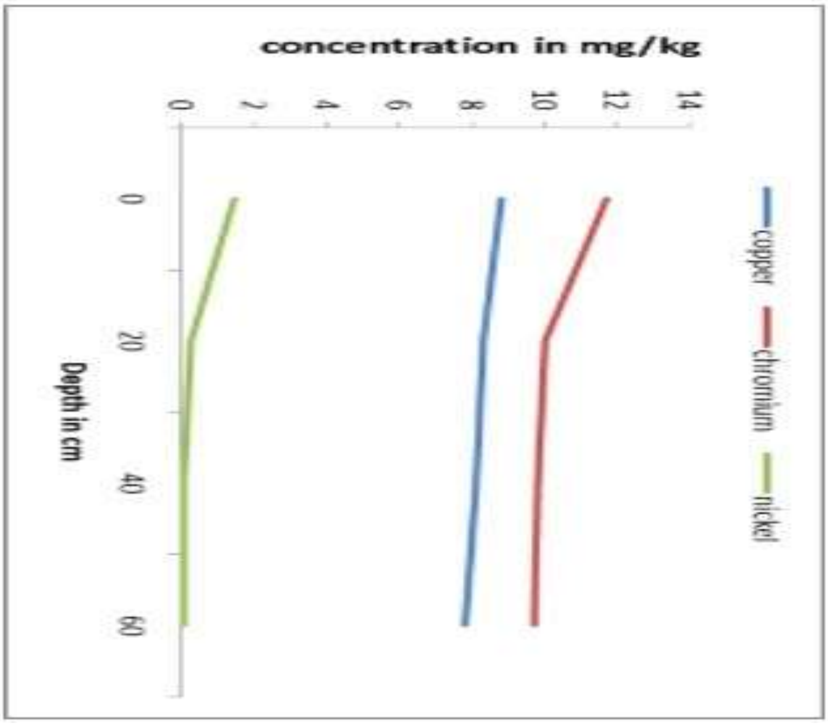

Fig 9: Variation of heavy metals at location 2

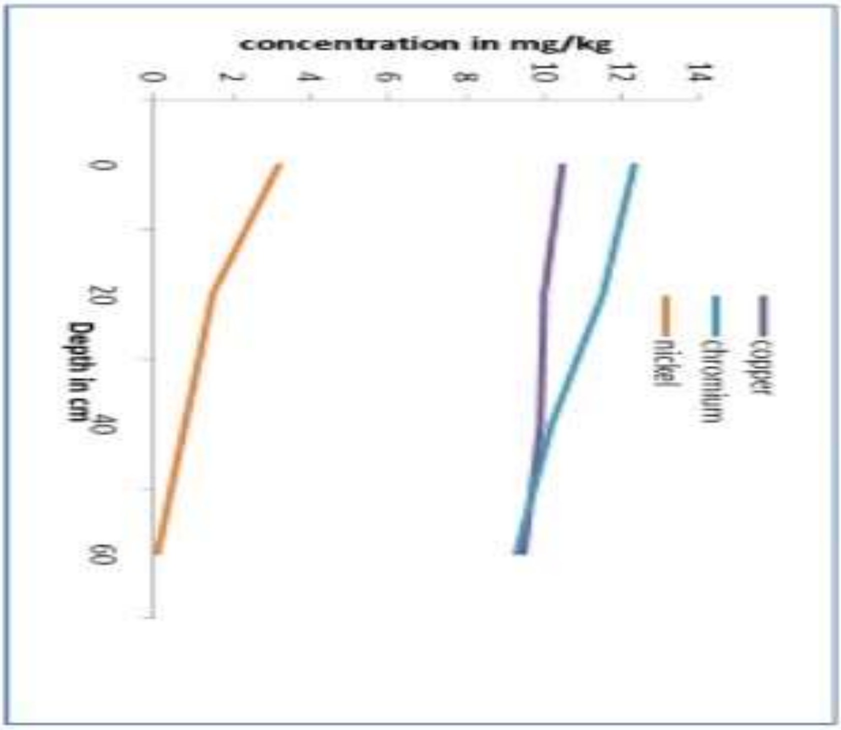

Fig 10: Variation of heavy metals at location 3

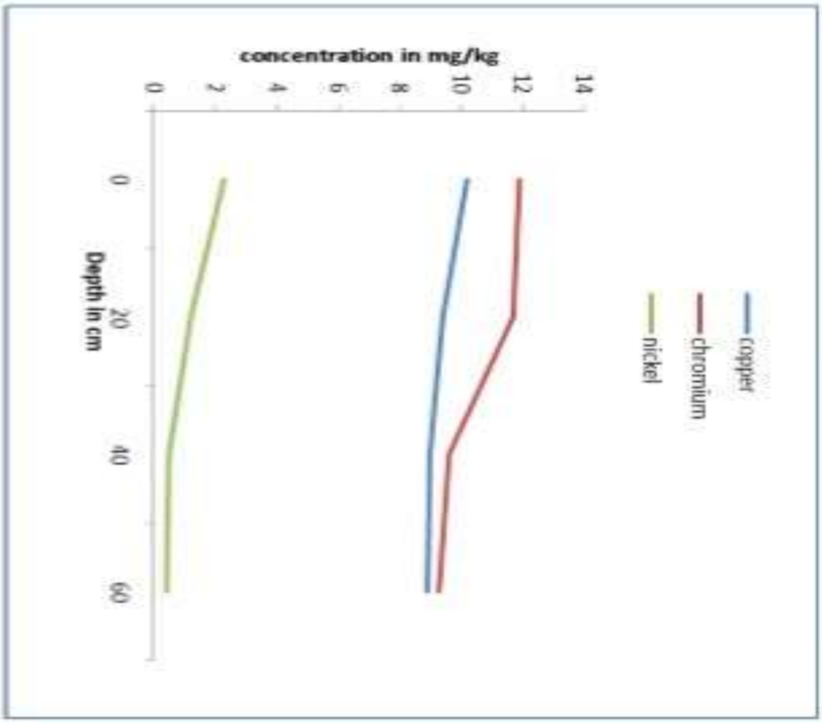

Fig 11: Variation of heavy metals at location 4

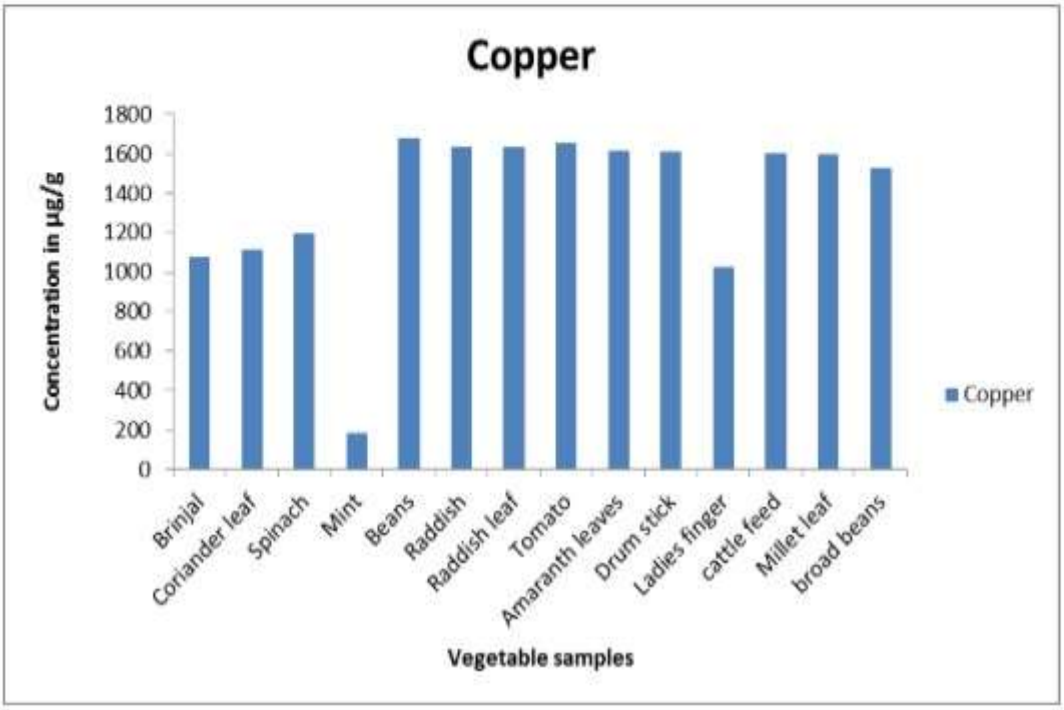

Fig 12: Variation of copper in vegetables

RESEARCHERID
THOMSON REUTERS
[Martis* 5(6): June, 2018] ISSN 2349-4506
Impact Factor: 3.799
Global Journal of Engineering Science and Research Management

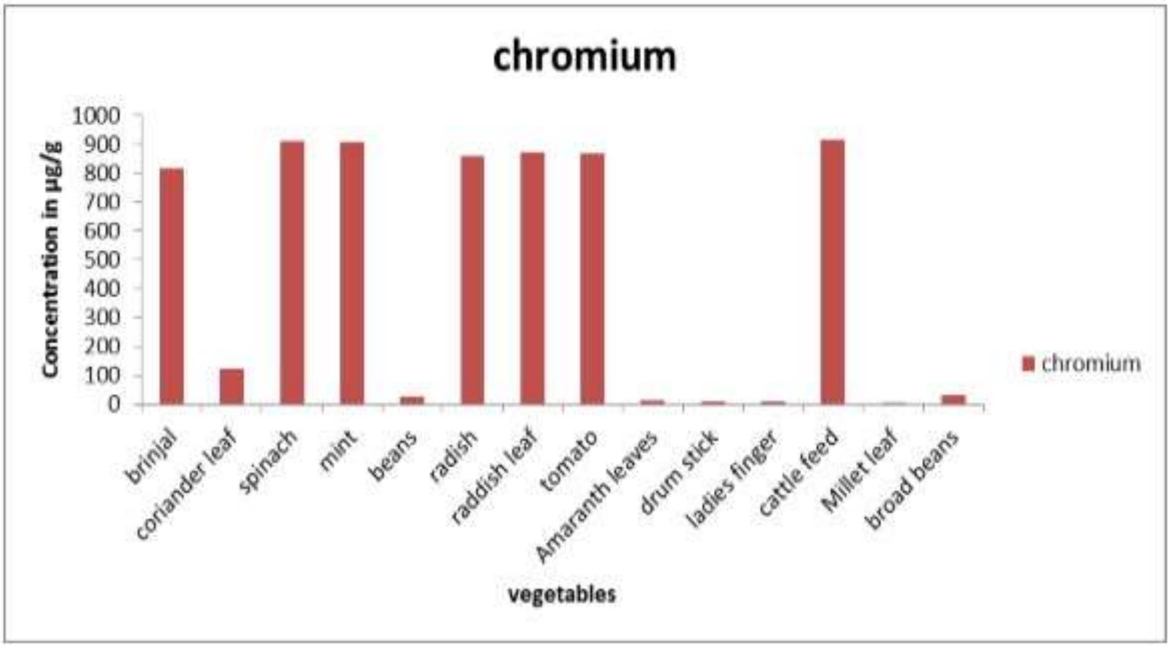

Fig13: Variation of chromium in vegetables

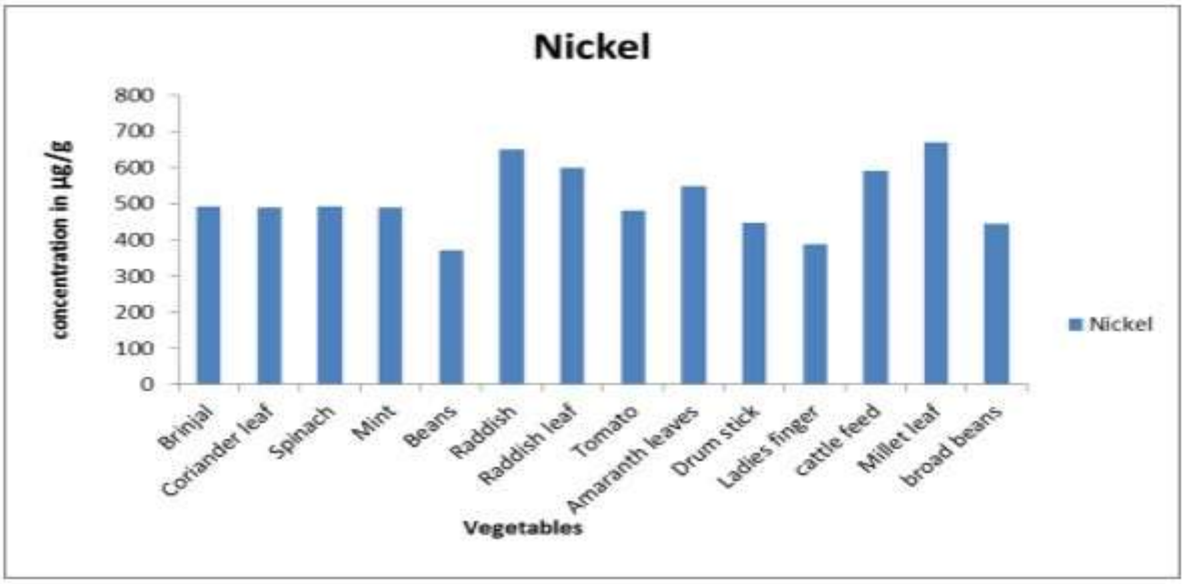

Fig 14: Variation of nickel in vegetables

CONCLUSION

The work was carried out to know the ground water quality and soil quality and level of contamination in vegetables near Bellandur Lake, Bengaluru. The physic-chemical analysis of ground water samples and heavy metal concentration in ground water samples, also the distribution study of the soil and migration study of the soil were carried out. Concentration of heavy metals in the vegetation was also found out.

The results obtained were,

I. The pH, magnesium, potassium, sodium are well within the permissible limits. Total dissolved solids are not within the desirable limits but well within the permissible limit except for 13th sample. Chlorides in the samples 5, 9,11,13,14,18 are not within the permissible limit. Nitrate in the sample number 7 is exceeding the permissible limit prescribed by BIS. Total hardness in the water sample is within the permissible limit but few samples are not within the desirable limit. The water around Bellandur lake area falls under the category of hard water. Alkalinity in sample 11 and 13 are not within permissible limit and most of the samples exceed desirable limit. Calcium in all the sample is within the permissible limit.

II. The concentration of nickel in the ground water sample location 3, 5, 7, 11, 13, 14, 17, 18, 20, 21 are not within the permissible limits, hence unfit for drinking. Concentration of copper, iron, and zinc in mg/l are well within the permissible limit prescribed by BIS. The concentration of chromium in the 6 and 13th sample are not within the prescribed limit, other samples are within the limit.

III. The distribution study of the soil exposes that the heavy metal Concentration in (mg/kg) is quite high in sampling location 3 and low in sampling location 1. The distribution of chromium concentration in soil in mg/kg is very high and nickel concentration in mg/kg is low. The soil in the study area is highly contaminated with heavy metals.

IV. From the migration study it is concluded that the surface of the soil is highly contaminated with heavy metals that is at 0 cm and it decreases as it moves deeper that is at 60 cm depth, the concentration is low. The concentration of chromium content in mg/kg is found to be higher and the concentration of nickel content in mg/kg is found to be less in all the sampling stations in the study area.

V. The concentration of heavy metals vegetable samples of the study area are highly contaminated with chromium, nickel and copper. The leafy vegetables like spinach, mint, cattle feed, coriander leaf, amaranthus were found to be more contaminated. The order of concentration of heavy metals in vegetables can be expressed as copper> chromium > nickel.

It is concluded from the results that the ground water has to be treated prior to consumption also assessment is required periodically to prevent further contamination. The irrigation by sewage-fed water for the cultivation of crops has increased the concentration of heavy metals in soil and also in the vegetables. It is necessary to supply good quality vegetables to the consumers, hence care must be taken to protect vegetables from the heavy metal contamination.

ACKNOWLEDGEMENT
It is a great honour for me to express my sincere thanks to my guide Dr. C.R Ramakrishnaiah for his valuable guidance. I take this opportunity to thank Principal Dr.Mallikarjuna Babu for the constant support. I wish to thank the Head of the Department Dr. Maya Naik, Civil Engineering Department, BMSCE, Bengaluru for providing me the required permission to conduct this research work.

REFERENCES
1. H. Lokeshwari and G. T. Chandrappa Department of Chemistry, Bangalore University, “Impact of heavy metal contamination of Bellandur Lake on soil and cultivated vegetation”, current science,vol.91, no.5 , 2006
2. S. Gupta S. Nayek R. N. Saha S. Satpati, west bengal “Assessment of heavy metal accumulation in macrophyte, agricultural soil, and crop plants adjacent to discharge zone of sponge iron factory”, Eniron Geol 55:731-739,2007
3. A. Ramesh, B.S. Nagendra Prakash, P.V. Sivapullaiaih, A.S. Sadhashivaiah, “Assessment of Ground Water Quality in Designated Peenya Industrial Area and Estate, Bangalore, India – A Case Study”, International Journal of Environmental Protection, 2012
4. L. R. Varalakshmi and A. N. Ganeshamurthy, “Heavy metal contamination of water bodies, soils and vegetables in peri urban areas of Bangalore city of India” ,© 2010 19th World Congress of Soil Science, Soil Solutions for a Changing World 39, 1 – 6 August 2010, Brisbane, Australia
5. Jayadev and E.T. Puttaih “Assessment of heavy metals uptake in leafy vegetables grown on long term wastewater irrigated soil across Vrishabhavathi River, Bangalore, Karnataka” IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT), Vol 7, (Nov. - Dec. 2013), pp 52-55

6. I.V.Galitskayaa, Rama Mohan K.b, Keshav Krishna A.b, G.I.Batraka, O.N.Ereminaa, V.S.Putilinaa, T.I.Yuganovaa, "Assessment of soil and groundwater contamination by heavy metals and metalloids in Russian and Indian megacities", Procedia Earth and Planetary Science 17 (2017) 674 – 677
7. Abida Begum, M. Ramaiah, Harikrishna, Irfanulla Khan And K.Veena., "Analysis of Heavy Metals Concentration in Soil and Litchens from Various Localities of Hosur Road, Bangalore, India", E-Journalof Chemistry ,6(1), 13-22, 2009
8. A. Keshav Krishna, K. Rama Mohan, N. N. Murthy , V. Periasamy , G. Bipinkumar , K. Manohar, S. Srinivas Rao "Assessment of heavy metal contamination in soils around chromite mining areas, Nuggihalli, Karnataka, India", Environ Earth Science, 2013.
9. C.VIJAYA BHASKAR, KIRAN KUMAR and G. NAGENDRAPPA, "Assessment of Heavy Metals in Water Samples of Certain Locations Situated Around Tumkur, Karnataka, India", E-Journal of Chemistry, 2010, 7(2), 349-352.
10. C. Y. Chang & H. Y. Yu & J. J. Chen & F. B. Li & H. H. Zhang & C. P. Liu, "Accumulation of heavy metals in leaf vegetables from agricultural soils and associated potential health risks in the Pearl River Delta, South China", Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, Environ Monit Assess,2013
11. Krishna A K , "Soil contamination due to heavy metals from an industrial area of Surat, Gujarat and Western India" , 2007
12. Jintao Liang, Cuicui Chen, Xiuli Song, Yulan Han, Zhenhai Liang "Assessment of Heavy Metal Pollution in Soil and Plants from Dunhua Sewage Irrigation Area" International Journal of electrochemical science, 2011
13. H.Chandrashekar, K.V.Lokesh, H.Pushpa and G.Ranganna "Studies on the Assessment of Tropic Status of Lakes" International Journals on Microbiology and Applied Science, Vol 3, 2014, pp. 245-254
14. Nusrat Jan, N.Nandini, Aboud S Jumbe, Anupama B.S. " Impact of Municipal and Industrial pollutant on Byramangala Lake, Bangalore Rural District, India" World Lake Conference, 2008
15. Dr. C. R. Ramakrishnaiah and N. Manasa ,"Distribution and Migration of Heavy Metals in Peenya Industrial Area, Bangalore, Karnataka, India- A Case Study", Science domain international, 2016
16. H.S. Govardhana Swamy, H. Uma Devi, Dr. K. Venugopal "GIS and Remote Sensing Applications" Research Paper