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## Heavy metal contamination in soils and crops irrigated with lakes of Bengaluru

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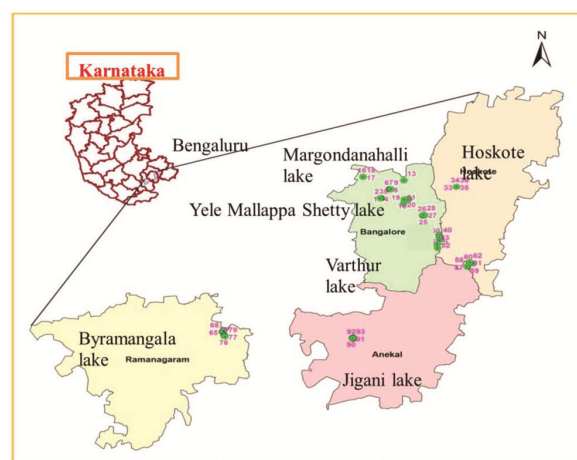
**Soils and vegetable crops being irrigated with water from six lakes in Bengaluru, India were analysed using ICP-OES for heavy metals and characterized based on the permissible limits of the European Union (EU) and the Indian Standards (IS). Chromium, nickel and lead content in the soils ranged from 89.36 to 145.21, 0.90 to 19.17 and below detection limit to 0.31 mg kg<sup>-1</sup> respectively. Among the total soil samples collected, 15%, 22%, 20%, 23%, 15% and 33% of the samples exceeded permissible limits of EU and IS for cadmium under Margondanahalli, Yele Mallappa Shetty, Hoskote, Varthur, Byramangala and Jigani lake respectively. All the crop samples analysed exceeded the EU standards for Cr, 25% for Ni, and none for Cd and Pb.**

**Keywords:** Heavy metals, lake water, soil contamination, standard permissible limits, vegetable crops.

LAKES were once important water resources for household needs, animal husbandry and agriculture. Bengaluru, Karnataka, South India had 280–285 lakes, many of which have been encroached by slums and private parties, dried up, leased out by Government organizations; today only 17 lakes exist. Unlike other cities, lakes in and

around Bengaluru have become part of the city drainage system that drains untreated and partially treated domestic sewage and industrial effluents from a number of small-scale units like garment factories, electroplating industries, distilleries, etc. The unscientific disposal of wastewater has caused immense environmental problems not only to the aquatic environment but also to humans worldwide<sup>1</sup>. This problem has intensified during the last few decades and the situation has become alarming in India<sup>2</sup>. The farmers in and around Bangalore use water from the lakes for cultivation of crops and in particular, vegetables. Soils receiving water from these lakes accumulate heavy metals to varying degrees depending on their concentration in water and the frequency of irrigation. The contamination of lake water with heavy metals leads to their accumulation in the sediments. When farmers use the sediments in agricultural fields as a common practice, the heavy metals accumulate in agriculture soils and pose serious problems. Wastewater irrigation may lead to the accumulation of heavy metals in agriculture soils and plants<sup>3</sup>. The heavy metals are absorbed by crops along with other essential plant nutrients. Heavy metals are non-biodegradable and thermostable, and thus readily accumulate to toxic levels<sup>4</sup>. Contamination of soils and crops with these metals may have adverse effects on soils, plants, animals and humans. Food safety issues and potential health risks make this one of the serious environmental concerns<sup>5</sup>. Ultimately different crops grown in these sites irrigated with contaminated lakes have shown uptake of heavy metals that make them unfit for consumption<sup>6</sup>. The present study aims to assess the extent of heavy-metal contamination of soils irrigated with lake water in Bengaluru urban and peri-urban areas.

Bengaluru is located in the southern part of Karnataka. Out of 17 lakes in Bengaluru, six were selected for the present study – Margondanahalli, Yele Mallappa Shetty (YMS), Hoskote Doddakere, Varthur, Byramangala and Jigani (Figures 1 and 2).



**Figure 1.** Soil and crop sampling sites irrigated with water from different lakes in Bengaluru, India.

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## RESEARCH COMMUNICATIONS

**Table 1.** Total elemental composition of soils irrigated with water from different lake of urban and peri-urban areas in Bengaluru, India

Lake		Cr (mg kg <sup>-1</sup> )	Cd (mg kg <sup>-1</sup> )	Ni (mg kg <sup>-1</sup> )	Pb (mg kg <sup>-1</sup> )
Margondanahalli ( <i>n</i> = 14)	Range	55.64–136.57	BDL –6.2	20.96–63.95	0.0–25.57
	Mean ± SD	89.36 ± 22.36	2.87 ± 1.74	42.22 ± 11.94	7.54 ± 7.24
YMS ( <i>n</i> = 6)	Range	78.12–111.71	2.41–5.43	29.64–53.81	BDL –6.07
	Mean ± SD	96.92 ± 14.07	3.74 ± 1.20	42.08 ± 8.16	1.73 ± 2.58
Hoskote ( <i>n</i> = 3)	Range	114.25–129.97	2.92–3.48	41.97–59.9	BDL –5.16
	Mean ± SD	119.76 ± 8.85	3.25 ± 0.29	50.51 ± 8.99	1.72 ± 2.98
Varthur ( <i>n</i> = 23)	Range	21.34–217.25	BDL –10.9	13.44–53.63	BDL –7.39
	Mean ± SD	105.09 ± 42.89	3.77 ± 2.23	30.38 ± 10.92	2.17 ± 2.55
Byramangala ( <i>n</i> = 15)	Range	43.96–348.37	BDL –9.22	8.1–90.95	BDL –20.48
	Mean ± SD	145.21 ± 101.85	4.38 ± 3.72	46.67 ± 28.87	7.89 ± 7.12
Jigani ( <i>n</i> = 13)	Range	81.67–113.85	3.22–8.08	34.46–62.91	BDL –13.63
	Mean ± SD	90.99 ± 10.24	5.33 ± 1.53	46.33 ± 7.72	2.50 ± 3.85
Permissible limits	EU	150	3.0	75	300
	IS	100	3.0	50	300

*n* the number of samples. EU, European Union; IS, Indian Standards; YMS, Yele Mallappa Shetty lake; BDL, Below detection limit.



**Figure 2.** General view of agricultural fields irrigated with water from different lakes in Bengaluru.

Surface soil samples from major vegetable cultivated fields irrigated with water from different lakes were collected at 0–15 cm depth. Soil samples were air-dried under shade. Next, 1 g of soil was ground and sieved through 0.2 mm sieve and stored in polythene bags till further analysis.

The use of closed-vessel microwave-assisted digestion systems under high temperature and pressure for acid digestion has now become routine. For the analysis of total heavy metals in the soil, 0.05 g of 0.2 mm sieved soil was taken in Teflon digestion vessels and predigested with 8 ml HNO<sub>3</sub> (70%), 2 ml H<sub>2</sub>O<sub>2</sub> (30%). Then the samples were digested using a microwave digester (Milestone-START D) at 150°C as follows: 1200 W for 15 min, 1200 W for 10 min and venting for 10 min. The digested samples were stored in clean plastic tubes of 50 ml capacity, after making up the volume using double-distilled water. The samples were analysed for heavy metal content using Inductively Coupled Plasma-Optical Emission Spectrophotometer (ICP-OES) (ThermoFisher-model ICAP 7000 series).

For the analysis of Diethylene Triamine Penta Acetate (DTPA) extractable heavy metals 10 g of 2 mm sieved soil was taken in a 50 ml centrifuge tube and 20 ml of DTPA extractant was added. After continuous end-to-end shaking in a mechanical shaker for 2 h, the solution was filtered through micro-syringe filters. Heavy metals in the

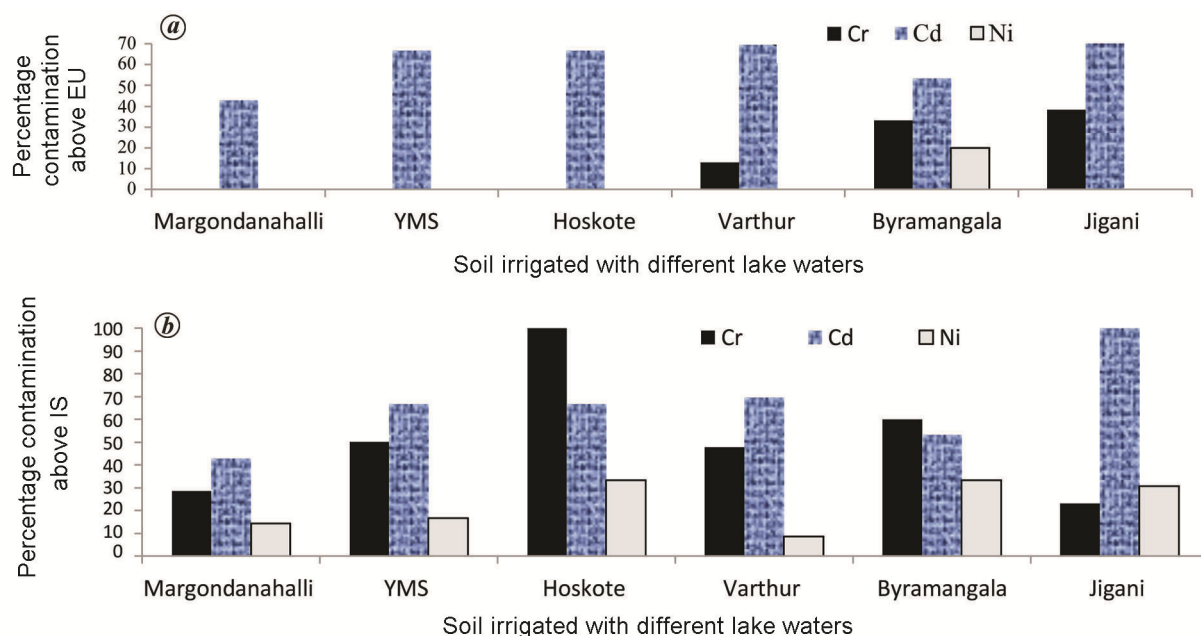
extracted filtered solution were determined using ICP-OES.

Edible parts of the crops, preferably vegetables grown in the sites irrigated with water from the selected lakes were sampled. A total of 93 plant samples at maturity were collected during post-monsoon of 2017 and soil samples were also collected from the same plots.

The plant samples were washed with running tap water followed by double-distilled water to remove adhered dirt particles. They were dried in the hot-air oven at 70°C, powdered and used for analysing heavy metal content following the same procedure as for soil total metal content.

To assess the heavy metal contamination of soils and crops irrigated with lake water, a survey was conducted to select the farmer's fields being irrigated with lake water, soil and crop samples were collected. The number of samples varied with the area depending on the crops grown with lake water irrigation and preferably cultivation of vegetable crops. The soil samples were analysed for heavy metal content.

Total chromium (Cr), cadmium (Cd), nickel (Ni) and lead (Pb) in the soils irrespective of lake water irrigation ranged from 89.36 to 145.21, 2.87 to 5.33, 30.38 to 50.51 and 1.72 to 7.54 mg kg<sup>-1</sup> respectively (Table 1). The permissible limits in soils according to the European Union (EU) standards for Cr, Cd, Ni and Pb are 150, 3.0, 75 and 300 mg kg<sup>-1</sup> respectively and Indian Standards (IS) are 100, 3.0, 50 and 100 mg kg<sup>-1</sup> respectively. The highest average concentration of 5.33 and 50.51 mg kg<sup>-1</sup> for Cd and Ni respectively was recorded in soils irrigated with water from Jigani and Hoskote lakes, 145.21 and 7.89 mg kg<sup>-1</sup> for Cr and Pb respectively in case of Byramangala lake. The lowest concentration of 89.36 and 2.87 mg kg<sup>-1</sup> for Cr and Cd respectively, was recorded in soils irrigated with water from Margondanahalli lake, 30.38 and 1.72 mg kg<sup>-1</sup> for Ni and Pb respectively for Varthur and Hoskote lakes. The average total heavy metal



**Figure 3.** Percentage of samples above permissible limits according to (a) European Union (EU) standards and (b) Indian Standards (IS) for heavy metals in soils irrigated with water from different lakes.

content in the soils was 0.261, 0.086, 0.129 and 0.515 mg kg<sup>-1</sup> for Cr, Cd, Ni and Pb respectively.

Chromium is mostly used in a variety of applications such as leather tanning, chromium plating, timber preservation, corrosion protection, textiles, etc. Around 90% of leather is tanned using chromium salts. All these industries let wastewater into nearby water bodies and contaminate them<sup>7</sup>.

From the present study we found that none of the samples exceeded EU limits for soil Cr and 33% of the samples were above IS in soils irrigated with water from Margondanahalli lake. All the samples were below permissible limits for Cr in case for YMS lake water; 67% and 100% of the total samples exceeded permissible limits for Cr of EU and IS respectively in case of Hoskote lake water, 14.29% and 52.38% above EU limits and IS respectively, for Cr in soils irrigated with water from Varthur lake. All the samples collected from Byramangala lake water irrigation were below EU limits (75 mg kg<sup>-1</sup>) and 9.52% recorded higher than IS permissible limits (50 mg kg<sup>-1</sup>) for soil Cr (Figure 3).

Higher concentration of Cr was observed in soils irrigated with Byramangala lake water than other lakes. Similarly, soils exceeded the Prevention of Food Adulteration (PFA) limits for Cr under irrigation using water from various lakes of peri urban Bengaluru, viz. Belandur, Varthur, Byramangala and Nagavara<sup>6</sup>. Other studies showed that the soil samples irrigated with Byramangala lake water recorded 76.88 mg kg<sup>-1</sup> of Cr while irrigation with other lake waters soil Cr ranged from below detection level to 116.94 mg kg<sup>-1</sup> (ref. 4). We found that the soils irrigated with Byramangala lake water recorded

higher values for DTPA-extractable Cr similar to total Cr content.

The common source of Cd contaminants is corrosion of galvanized pipes, erosion of natural deposits, discharge from metal refineries, run-off from waste batteries and paints<sup>8</sup>.

Out of 15 samples collected from Margondanahalli lake water irrigation sites, 15% exceeded permissible limits of EU and IS for Cd (3.0 mg kg<sup>-1</sup>) and 22%, 20%, 23%, 15% and 33% exceeded permissible limits of EU and IS for Cd under YMS, Hoskote, Varthur, Byramangala and Jigani, respectively (Figure 3). Soils irrigated with Varthur lake water exceeded the safe limits<sup>9</sup>, but Cd content in Belandur, Ramagondanahalli, Parappana Agrahara and Jigani and Byramangala lake was below detection level<sup>14</sup>. The DTPA-extractable Cd content in soils irrigated with water from Margondanahalli, Varthur and Jigani lakes was 0.01 mg kg<sup>-1</sup>, whereas for YMS and Hoskote it was below detection limits. The Byramangala soils recorded comparatively higher values of 0.02 mg kg<sup>-1</sup>. The total Cd content was higher in soil irrigated with Jigani lake water.

The presence of Ni in water bodies could be due to leaching from pipes and fittings in contact with water bodies or along with industrial effluents directly let into the lakes<sup>10</sup>.

Nickel concentration in soil samples collected from various lake water irrigation sites ranged from 0.90 to 14.14, 7.10 to 14.01, 6.28 to 9.15, 4.6 to 17.89, 5.86 to 19.17 and 2.09 to 9.58 mg kg<sup>-1</sup> for Margondanahalli, YMS, Hoskote, Varthur, Byramangala and Jigani respectively (Table 2). Figure 3 shows the percentage of

**Table 2.** Contents of Cr, Cd, Pb and Ni (mean, mg kg<sup>-1</sup>) in crops irrigated with water from different lakes in Bengaluru

Crop	Lake	Cr	Cd	Pb	Ni
Knol khol	Margondanahalli ( <i>n</i> = 4)	30.42	0.58	BDL	1.74
	Varthur ( <i>n</i> = 2)	9.06	0.35	BDL	0.52
	Byramangala ( <i>n</i> = 2)	14.57	0.28	0.28	BDL
Spinach	Margondanahalli ( <i>n</i> = 2)	13.22	0.22	BDL	0.42
	YMS ( <i>n</i> = 3)	21.06	BDL	BDL	1.42
	Hoskote ( <i>n</i> = 2)	13.17	1.69	BDL	1.91
	Varthur ( <i>n</i> = 6)	14.69	BDL	BDL	BDL
Tomato	Jigani ( <i>n</i> = 7)	22.67	0.07	BDL	0.71
	Margondanahalli ( <i>n</i> = 2)	20.07	0.21	BDL	0.01
	Byramangala ( <i>n</i> = 2)	19.81	0.04	BDL	BDL
Amaranthus	Margondanahalli ( <i>n</i> = 3)	27.72	0.43	BDL	0.53
	Hoskote ( <i>n</i> = 2)	13.95	0.03	BDL	0.49
	Varthur ( <i>n</i> = 2)	12.18	BDL	BDL	1.35
Paddy grain	Jigani ( <i>n</i> = 2)	20.66	BDL	BDL	0.46
	Margondanahalli ( <i>n</i> = 2)	30.69	BDL	BDL	0.75
	Varthur ( <i>n</i> = 4)	17.45	0.23	BDL	BDL
Paddy straw	Margondanahalli ( <i>n</i> = 2)	33.99	BDL	BDL	1.10
	Varthur ( <i>n</i> = 4)	17.03	BDL	BDL	BDL
Coriander	Margondanahalli ( <i>n</i> = 3)	15.71	0.10	BDL	1.20
	YMS ( <i>n</i> = 2)	14.55	BDL	BDL	0.63
	Hoskote ( <i>n</i> = 2)	13.78	0.04	BDL	1.10
	Varthur ( <i>n</i> = 2)	18.27	BDL	BDL	0.75
	Byramangala ( <i>n</i> = 5)	19.88	0.45	BDL	0.96
Beans	Jigani ( <i>n</i> = 3)	20.37	0.07	BDL	0.50
	Margondanahalli ( <i>n</i> = 3)	20.40	BDL	BDL	BDL
Beetroot	YMS ( <i>n</i> = 2)	22.15	BDL	BDL	2.48
	Hoskote ( <i>n</i> = 2)	3.21	0.01	BDL	BDL
Radish tuber	Varthur ( <i>n</i> = 4)	13.81	BDL	BDL	0.87
	Jigani ( <i>n</i> = 2)	19.31	BDL	BDL	BDL
Permissible limits	EU	0.2	2.3	0.3	0.2
	IS	20	2.5	1.5	20

soil samples exceeding the permissible limits for Ni content.

None of the soil samples collected from sites irrigated with water from Margondanahalli, YMS, Hoskote, Varthur, Byramangala and Jigani lakes, exceeded EU and IS limits for soil Pb, though few of the samples showed presence of lead with lake water irrigation. In urban areas, the principal source of Pb in wetlands is from gasoline additives, metal plating, e-waste and battery cells, electrical equipment, textile mills, dyes and pigments, paper mills, chemical and fertilizer industries and ghee-manufacturing industries<sup>11</sup>.

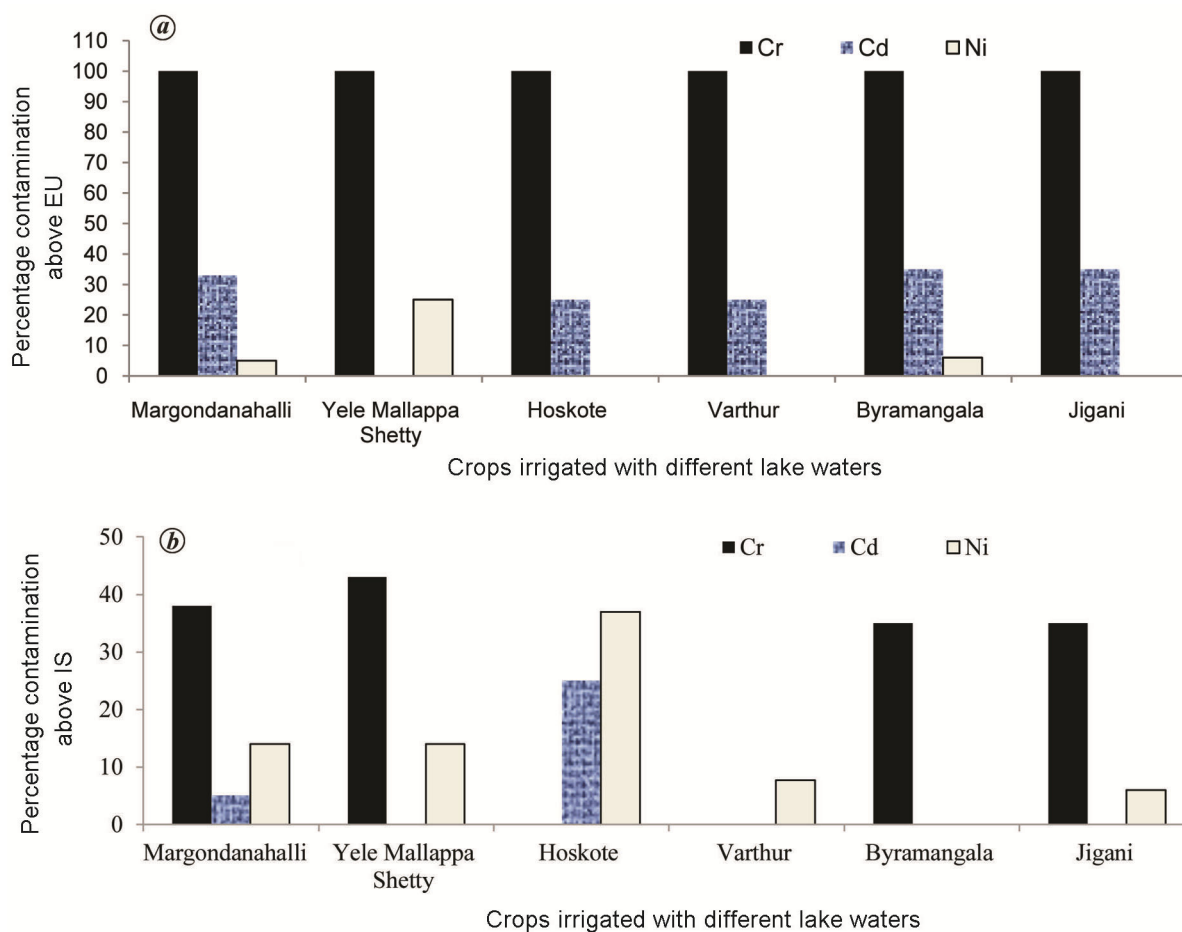
The concentration of heavy metals in soils irrigated with lake water did not show a common trend for the crops under cultivation. A wide variation in accumulation of heavy metals in soils was observed irrespective of the crops grown. Vegetables being short-duration crops, farmers change crops frequently in these locations, adopt different management practices such as fertilizers, frequency of irrigation, etc. Hence the type of crop under cultivation is not being focused here.

Irrespective of the sites and crops being grown, concentration of heavy metals was found in the order of Cr > Ni > Pb > Cd in soils irrigated with water from Margondanahalli, Hoskote and Byramangala lakes,

whereas the order was Cr > Ni > Cd > Pb in soils irrigated with water from other lakes (Table 1). Similarly, the concentration of heavy metals in soils was in the order of Ni > Cr > Pb<sup>12</sup>. However, in soils receiving water from River Cauvery through channels in Tamil Nadu, it was in the order Pb > Cr > Cd<sup>13,14</sup>.

DTPA extractable heavy metal content in soils irrigated with water from different lakes was found to be below detectable limit in the present study and DTPA-extractable heavy metal content does not indicate the plant available fraction of heavy metal in soils. Hence, it is not being mentioned here. The results are similarly reported as the DTPA-extractable heavy metals in the soils irrigated with Vrishabhavathi water were found to be negligible<sup>15</sup>.

Concentration of Cr in vegetable crop samples ranged from 7.93 to 56.15 mg kg<sup>-1</sup> (Table 2). All the plant samples collected from the fields irrigated with Margondanahalli lake water were above EU limits (0.3 mg kg<sup>-1</sup>) for Cr, nearly 33% for Cd and 5% for Ni. None of the samples was above permissible limits of EU (0.3 mg kg<sup>-1</sup>) for Pb (Figure 4). Average concentration of Cd and Ni in plant samples was 0.001 and 1.5 mg kg<sup>-1</sup> respectively, and Pb was below detection limits in plants irrigated with YMS lake water.



**Figure 4.** Percentage of samples above permissible limits for heavy metals according to (a) EU standards and (b) IS in plants irrigated with water from different lakes.

Among the leafy vegetables, coriander followed by spinach are known to accumulate heavy metals, but our results also revealed accumulation of heavy metals in knol khol samples. The trace metal content in spinach and coriander crops irrigated with Bellandur lake water was higher than the IS and World Health Organization (WHO) limits for Pb (2.5 and 5.0 mg kg<sup>-1</sup> respectively) and IS for Cr (20.0 mg kg<sup>-1</sup>)<sup>4</sup>.

All the plant samples recorded Cr content above EU permissible limits, whereas 25% of the samples were above the limits for Cd and none of the samples exceeded EU limits for Ni and Pb irrigated with Varthur lake water. Out of 17 plant samples collected from the fields irrigated with Byramangala lake water, it was found that all were above permissible limits of EU standards for Cr, 35% for Cd, 6% for Pb and none for Ni (Figure 4).

In general, green leafy vegetables such as amaranthus, coriander and spinach accumulate higher amounts of heavy metals. This may be attributed to high translocation and transpiration rate of leafy vegetables in which transfer of metals from root to stem and leaves was higher and was lower to fruits, which results in lower accu-

mulation in crops other than leafy vegetables. In addition, due to their large surface area exposed to environmental pollution, leafy vegetables accumulate more heavy metals<sup>16</sup>. Similar observations were made in vegetables grown with contaminated water in Pakistan<sup>17</sup>. The order of toxic heavy metal contamination in vegetables found in the present study was as follows: spinach > amaranthus > coriander > radish > beetroot > beans (Table 2). Whereas, the order was spinach > radish > brinjal > beans in case of other findings<sup>18</sup>.

Irrespective of the crop, type of soil under cultivation and lake water being used for irrigation, the order of heavy metals accumulation in plant samples was found to be Cr > Ni > Cd > Pb (Figure 4).

Variation in the concentration of heavy metals in vegetables observed during the present study may be ascribed to the physical and chemical properties of soils (production sites), absorption capacities of heavy metals by vegetables, atmospheric deposition of heavy metals, which may be influenced by several environmental factors such as temperature, moisture and wind velocity, and the nature of the vegetables, i.e. leafy, root, fruit,



exposed surface area, and hairy or smooth exposed parts<sup>19,20</sup>.

A survey was conducted in and around the peri urban Bengaluru for crop fields being irrigated with water from different lakes. The soil and crop samples were analysed for heavy metal content and characterized based on standard permissible limits. Higher concentration of Cr was observed in soils irrigated with Byramangala lake water than other lakes, Cd in Jigani, Ni and Pb in Hoskote and Margonadanahalli respectively. The concentration of heavy metals in soils irrigated with lake water did not have a common trend for the type of crop under cultivation. A wide variation in concentration was observed irrespective of the crop grown. Irrespective of the sites and crops being grown, concentration of heavy metal was found in the order of Cr > Ni > Pb > Cd in soils irrigated with Margondanahalli, Hoskote and Byramangala lakes, whereas the order was Cr > Ni > Cd > Pb in soils irrigated with water from other lakes. Irrigating the crop fields with lake water has not only resulted in accumulation of heavy metals in the soil, but plant samples also showed the presence of heavy metals. The average values in different crops indicate higher Cr content in coriander leaves followed by spinach, radish, amaranthus and knol khol. Among the leafy vegetables, coriander followed by spinach is known to accumulate heavy metals. Irrespective of the plant type, soil under cultivation and lake water being used for irrigation, the order of accumulation in plant samples was found to be Cr > Ni > Cd > Pb. From this study, we can conclude that the use of lake water in and around Bengaluru for irrigation leads to accumulation of heavy metals above permissible limits for soils and crops. This makes the crops unfit for consumption and if consumed may lead to various health hazards.

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