ORIGINAL ARTICLE

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Assessment of rain water chemistry in the Lucknow metropolitan city

Purnima Sharma[1] · Vibhuti Rai[1]

Abstract

Lucknow metropolitan city is one of the most populated cities of India, which have been facing many problems such as chaotic urbanization, overpopulation, water scarcity, waterlogging, etc., among these water scarcity is one of the important problem. Rain water harvesting is a futuristic tool for mitigation of water scarcity problem through conservation and storage of rain water. This rain water can be used for all purposes by human beings, thus it is necessary to check the chemistry of rain water. The rain water samples were collected from the five zones of Lucknow city. For the comparative study, water samples have been collected from two different dates first from first rainfall and second after 3 days of interval in the second rainfall. The heavy metal concentrations were found in both first and second rainfall water samples in all zones of Lucknow city. The concentration of chromium, cadmium and lead were found to be sufficiently high in several samples. These heavy metals show the concentration above the permissible limit as set by WHO, which can cause various adverse health impacts.

Keywords Water scarcity · Rain water harvesting · Heavy metals

Introduction

Rainwater is an important source of fresh water on earth. It is the purest form of naturally occurring water. It is considered, therefore, to be produced by a kind of natural distillation. However, it contains dissolved gases such as carbon dioxide, sulphur dioxide, nitrogen dioxide, ammonia, fine particulate materials or aerosols, etc., from the atmosphere (Asthana and Asthana 2003).Industrial processes, fossil fuel combustion, mining, waste incineration, motor vehicles and other human activities emit large amounts of atmospheric pollutants. One of the most important groups of the atmospheric pollutants is heavy metals. Heavy metals are toxic to living organisms and some of them such as lead and cadmium are toxic at low levels (Itoh et al. 2006; Kalantari and Ghaffari 2008; Vinodhini and Narayanan 2009).

The origins of emission of some heavy metals such as Sn, Cu, Cd, Zn, As, Pb and Se are mostly anthropogenic and the origins of the others are lithogenic such as Al, Mn and Fe (Jeferies and Snyder 1981). Wet and dry atmospheric depositions are the major pathway of accumulation of heavy metals

in aquatic ecosystems (Öztürk et al. 2009). Concentrations of heavy metals in rain water depend on different factors such as vicinity of sources, the amount of precipitation and direction of air masses (Koulousaris et al. 2009).

Chemical composition and concentration of heavy metals in atmospheric precipitation have been studied in many regions such as: Central Ontario in Canada (Jeferies and Snyder 1981), four sites in Bangladesh (Hadi et al. 1999), Cartagena in Spain (Moreno-Grau et al. 2002), Gulf of Iskenderun (Örnektekin and Cakmakli 2003), Knot in Japan (Itoh et al. 2006), Xanthi in Greece (Melidis et al. 2006), North-Eastern Mediterranean region (Özsoy et al. 2008), India (Singh and Mondal 2008), northern Aegean Sea (Koulousaris et al. 2009), Opme in France (Bertrand et al. 2008) and in many other countries and regions. Atmospheric pollutants may be removed from the atmosphere in two ways: one way is the rain out in condensation process within the clouds and the other way is the impaction with falling rain drops and washout.

Although the rain water removes the heavy metals and other pollutants yet deposition of heavy metals in the form of rain would be harmful for the ecosystem. Therefore, it is mandatory to monitor and accurate determination of these pollutants because some trace elements which are nutrients, can also acts as a toxin if they are present above permissible limits. A number of study have been conducted around the

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world for demonstration of heavy metal concentration in the rain water but there is no documented report about the concentration of heavy metals in the atmospheric precipitation in the Lucknow City.

In the Lucknow city, the rainfall occurs mainly during the monsoon season which runs from July to September. For the evaluation of heavy metal concentration, the samples were collected from different location in the city. For the comparative study, water samples have been collected from two different dates first from first rainfall and in the second rainfall. The six heavy metals i.e., *zinc* (*Zn*), *chromium* (*Cr*), *cobalt* (*Co*), *manganese* (*Mn*), *cadmium* (*Cd*), *copper* (*Cu*) *and lead* (*Pb*) were analyzed in the samples.

Study area

Lucknow is one of the most populated cities of India with many distinctive characteristics. It is the capital of the state of Uttar Pradesh, which is the highest populated state of the country having a population of 166,197,921 people as per the Census Data 2011. Lucknow being an urban agglomeration with a population of over 1 million can rightly be classified as Lucknow Metropolitan area (Anonymous, Census 2011) (Fig. 1).
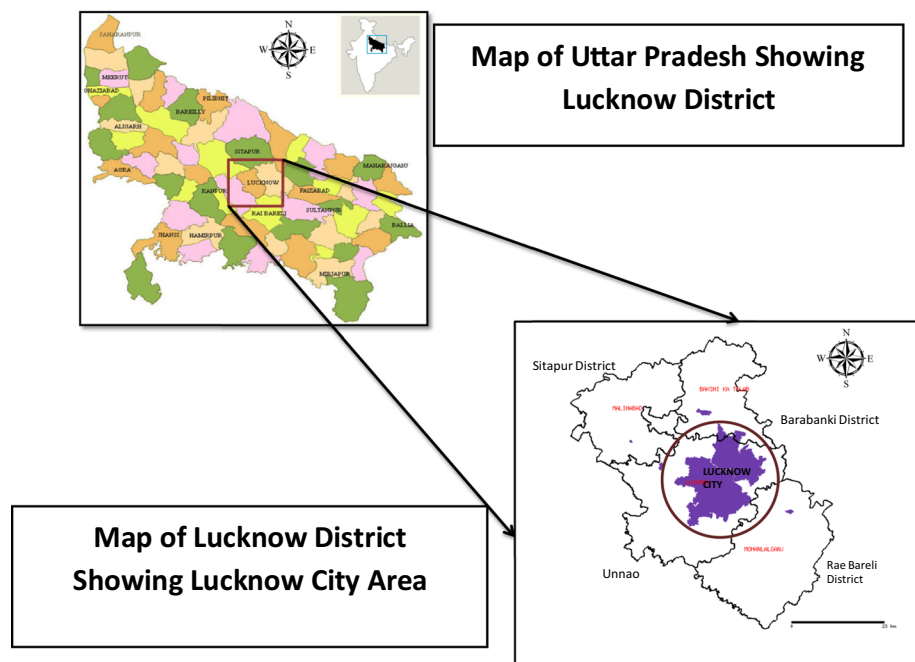
Air quality of Lucknow city

Air quality is a significant determinant of health. Ambient air quality is also known as air pollution index which measures point to know the change in level of pollutants from standard level and helps to know the effects on human health due to increase in pollution (Senthilnathan 2007). The primary sources causative to the worsening of air quality in urban areas are mainly vehicular traffic, industrial sources and power plants. Out of these three, the last two sources are stationary sources of pollutants, affecting air to a greater extent but in a limited area, while the vehicular traffic being a mobile source pollutes the atmosphere to a larger extent without limitation. Vehicles are the prime source of air pollution in urban areas and these air pollutants from vehicles received more attention than ever before with the continuous increase of vehicle demand world wide in recent decades (USEPA 1991a, b; Kenneth 1994; Larsolov 1994; Jorgensen 1996; Bradley et al. 1999; Singer and Harley 2000; Ye et al. 2000; Charron and Harrison 2003; Schifter et al. 2003). Gases and particulate emissions from automobiles add air pollution to atmosphere drastically. Lucknow has insufficient transport infrastructure. Vehicular traffic is the main source of particulate air pollution in Lucknow city. The number of different categories of vehicles registered with regional transport office (RTO) Lucknow is 14,24,478 as on 31.03.2013 which is 8.35% higher over the last year (Source: RTO, Lucknow, 2013a).

According to the study carried out by Anonymous, Indian Institute of Toxicology Research (IITR) in the months of March–May, 2012 to see the status of air quality by monitoring and assessment of some selected air pollutants, namely respirable particulate matter (RSPM or PM10), fine particulates (PM2.5), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and trace metals—iron (Fe), nickel (Ni), chromium (Cr), zinc (Zn), lead (Pb), manganese (Mn) and cobalt (Co)

Fig. 1 Location map of study area

Map of Uttar Pradesh Showing Lucknow District

Map of Lucknow District Showing Lucknow City Area

level at 9 representative locations, categorized as residential (four), commercial (four) and industrial (one) areas in Lucknow city.

The results revealed the 24 h concentration of PM10 in the range of 113.0– 396.2 µg/m$_3$ with an average of 231.9 µg/m$_3$. The corresponding 24-h values of PM2.5 ranged between 59.8 and 175.4 µg/m$_3$ with an average of 89.3 µg/m$_3$. The average values of PM10 and PM2.5 irrespective of locations were found to be above the permissible limit (PM10 = 100 µg/m$_3$ and PM2.5 = 60 µg/m$_3$) prescribed by MoEF. 24-h concentration of SO$_2$ and NOx were found in the range of 9.8–24.9 and 21.6–61.5 µg/m$_3$ with an average concentration of 17.5–37.3 µg/m$_3$, respectively, and all the values were below the permissible limits (80 µg/m$_3$). The mean level of trace metals were found Fe = 1502.92, Ni = 14.00, Cr = 39.39, Pb = 34.45, Zn = 150.11, Mn = 113.34 and Co = 4.15 ng/m$_3$.

The study revealed that trace elements present in the atmosphere in different concentrations which might come down with the precipitation. Thus, the study evaluates the concentration of heavy metals in the rainfall water, which can be further used for potable or non-potable water source.

Table 1 Average rainfall trend in monsoon period (July–September) since 2006 to 2013 of Lucknow city (Anonymous, Hydromet Division of India Meteorological Department, Lucknow 2013b)

Year	July	August	September	Average rainfall in mm
2006	342	151.1	32.9	175
2007	246.7	197.1	118	187
2008	444.3	377.5	330.6	384
2009	166.1	256.5	229.9	217
2010	342.2	199.9	144.2	228
2011	246.3	323.6	109.6	226
2012	288	210.1	194.9	231
2013	223.3	192.3	30.5	148
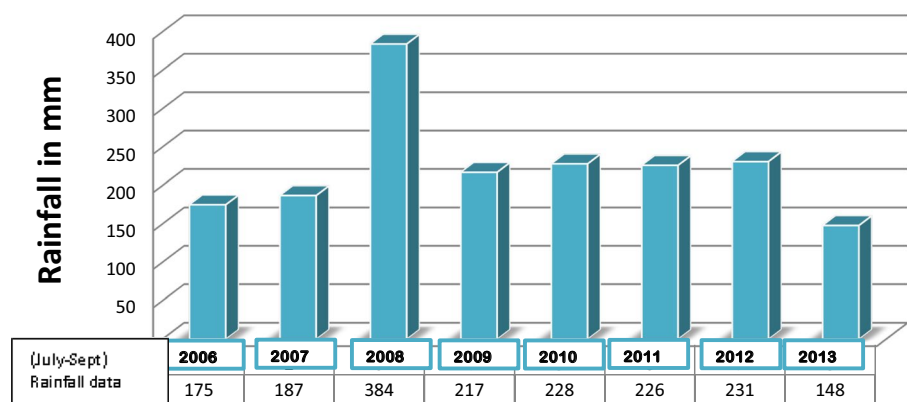
Rainfall statistics in the monsoon period of Lucknow

Rainfall data collected from Indian Meteorological Department (IMD) for the last 7 years and for 2013 shows that the average rainfall trend throughout the monsoon period (July–September), are 175, 187, 384, 217, 228, 226, 231 and 148 mm for the year 2006, 2007, 2008, 2009, 2010, 2011, 2012 and 2013, respectively (Table 1; Fig. 2)

Collection of samples

Gomati River divides the Lucknow city into two parts i.e., *Cis*-Gomati and *Trans*-Gomati area. For the collection of rain water, we further divided the city area into five different zones as follows.

Zone 1

Zone 1 is a mix up of residential and commercial areas situated in the Trans-Gomati area having some important government/public sector and private sector offices like the Reserve Bank of India, passport office, etc., are located in this area. In addition, the new premise of U.P. High Court-Lucknow Bench is under construction in this area. The main localities in Zone 1 are Gomti Nagar, Indira Nagar, Kamta, Chinhat, Faizabad Road, Rabindra Palli, Sanjay Gandhi Puram, Maruti Puram and New Gulistan Colony.

Zone 2

Zone 2 is illustrated as semi-commercial areas situated in the Trans-Gomati area, consist localities of Aliganj, Vikas nagar, Mahangar, Daliganj, Triveni Nagar, Kalyanpur, Kursi Road, Engineering College.

Fig. 2 Average rainfall trend in Monsoon period (July–September) since 2006 to 2013 of Lucknow City (Anonymous, Hydromet Division of India Meteorological Department, Lucknow, 2013b)

(July-Sept) Rainfall data	2006	2007	2008	2009	2010	2011	2012	2013
	175	187	384	217	228	226	231	148

Zone 3

Zone 3 is mainly demarcated as residential areas of Cis-Gomati, constitutes the Chowk, Thakurganj, Rajajipuram, and localities near Hardoi Road.

Zone 4

Zone 4 constitutes the cantonment and industrial areas of Cis-Gomati. The localities near Kanpur road, LDA colony, Alambagh, Hindnagar, Sarojini nagar, and Telibagh exists in this zone.

Zone 5

Zone 5 is the hub of commercial areas of the city. This zone also termed as Central Lucknow as it constitutes the prime commercial areas of Hazratganj, Aminabad, Nishatganj, Dalibagh, and Kaiserbagh, New Hyderabad, and Mall Avenue.

The rain water samples were collected from all the five zones (Fig. 3). Plastic buckets that have been previously washed and leached with 10% HNO_3 and 1:1 HCl for 48 h were used to collect rainwater samples in an open place with a stand of about twenty feet above the ground. Then, this water was stored into pre-distilled sampling water bottles. For the comparative study, water samples have been

Fig. 3 Location of rainwater sample in Lucknow city plotted with the help of GPS
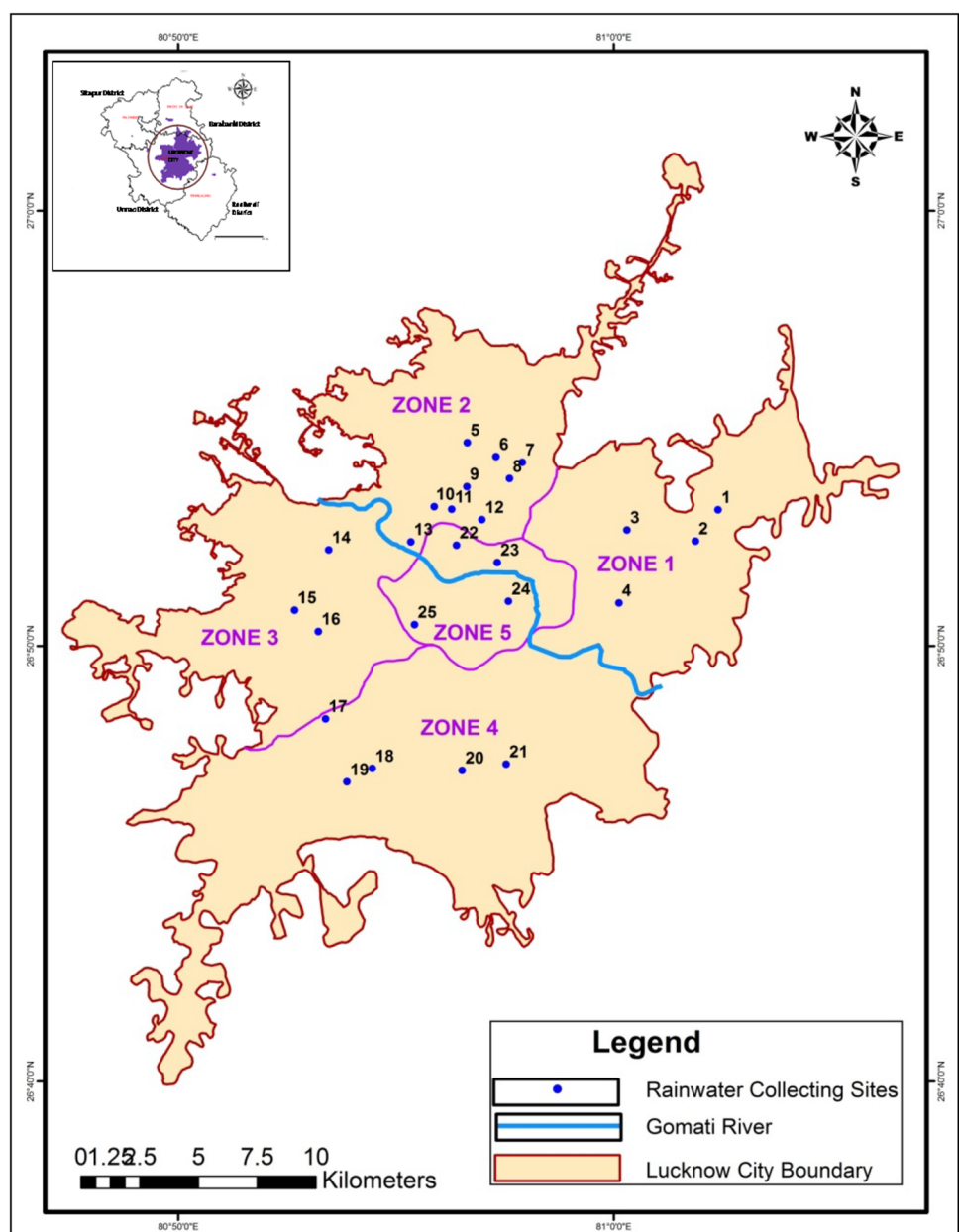
collected from two different dates first from first rainfall (5th July, 2012) and second after 3 days of interval (9th July, 2012) in the second rainfall.

The samples were preserved by acidifying and keeping them in refrigerator at low temperature. The heavy metals were determined through atomic absorption spectrometer.

Measurement of trace elements

The present work focuses on exposure to the seven "heavy" metals, namely—zinc (Zn), chromium (Cr), cobalt (Co), manganese (Mn), cadmium (Cd), copper (Cu), lead (Pb), as they are arguably the most important metal toxins from a global perspective.

Sample preparation

The water sample was digested to solubilise the solid matter and to remove the organics by oxidation and volatilization. The open digestion method was used for the digestion of samples.

Open digestion method

Two hundred ml of water samples is taken in a 250 ml conical flask, water sample is boiled over hot plate until the volume reduced to half and then digested using diacid HNO_3 (nitric acid) and $HClO_4$ (perchloric acid) in a 5: 1 ratio by adding 10 ml of concentrated acid mixture till the white fume appears, the digested water samples are filtered and diluted to 50 ml with 0.1 N of HNO_3 solution (Anonymous, APHA 2005).

Analysis

Analysis is performed by atomic absorption spectrometer (AAS: Perkin Elmer Analyst 700). Atomic absorption spectrometer is an analytical tool for determination of the presence and concentrations of trace amounts of metals in liquid samples. It can determine more than 70 elements such as iron (Fe), copper (Cu), aluminium (Al), lead (Pb), calcium (Ca), zinc (Zn), cadmium (Cd), manganese (Mn), nickel (Ni), etc. In atomic absorption spectrometer, light of a specific wavelength is passed through the atomic vapour of an element of interest, and measurement is made of the attenuation of the intensity of the light as a result of absorption.

Results

The results obtained from analysis of rainwater sample from different places of Lucknow city are given in Table 2. This table shows the comparison between concentration of heavy metals between first and second rainwater. After the analysis of all heavy metals, the values are compared with the standard range for drinking water described by the Anonymous, World Health Organisation, 2006 (WHO) (Table 3).

Zinc (Zn)

Zinc is a very common substance that occurs naturally. Many foodstuffs contain certain concentrations of zinc. Drinking water also contains certain amounts of zinc. It is very important and essential micronutrient for human health. It is a necessary element for physical and neurobiological growth of infants, children and adults. It also influences the activity of various enzymes and hormones. According to WHO (World Health Organization), the recommended dietary dose of zinc for an adult male is 9.4 and 6.5 mg/day for female and the permissible limit of zinc in water is not more than 5 mg/l. Both deficiency and excess amount of zinc causes various health-related problems in human beings. Zinc deficiency is characterized by growth retardation, loss of appetite, and impaired immune function. In more severe cases, zinc deficiency causes hair loss, diarrhoea, delayed sexual maturation, impotence, hypogonadism in males, and eye and skin lesions. Zinc toxicity can occur in both acute and chronic forms. Acute adverse effects of high zinc intake include nausea, vomiting, loss of appetite, abdominal cramps, diarrhoea, and headaches (anonymous, dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc 2001).

In first rainfall, water samples zinc was found in all samples, values ranges between 0.04 and 0.18 ppm. While in second rainfall, water samples the value of zinc slightly decreased than first rainwater values. The values range from 0.03 to 0.16 ppm. Although all water samples come under the permissible limit (3 ppm) described by World Health Organization standards for drinking water (WHO), yet this low to very low concentration of zinc can also adversely affect the human health (Fig. 4).

Lead (Pb)

Lead is one of the most commonly used metals in the world and like many other metals, is rarely found in its elemental form; rather, it is found in a variety of compounds, complexes and alloys. It occurs naturally in the environment. However, most lead concentrations that are found in the

Table 2 Concentration of different heavy metals of rainwater samples collected from different zones of Lucknow city during first and second rainfall (*Lat* latitude, *Long* longitude, *Zn* zinc, *Pb* lead, *Cd* cadmium, *Cr* chromium, *Cu* copper, *Mn* manganese, *Co* cobalt, ppm parts per million or mg/l, *BDL* below detection limit)

S. no.	Zone	Name of the locations	Lat. in decimal	Long. in decimal	Zn (ppm) I	Zn (ppm) II	Pb (ppm) I	Pb (ppm) II	Cd (ppm) I	Cd (ppm) II	Cr (ppm) I	Cr (ppm) II	Cu (ppm) I	Cu (ppm) II	Mn (ppm) I	Mn (ppm) II	Co (ppm) I	Co (ppm) II
1	Zone 1	Chinhat near Allahabad bank	26.8854	81.040	0.065	0.047	0.02	0.035	0.008	0.02	0.130	0.016	BDL	0.004	BDL	BDL	BDL	BDL
2		Matiyari Chauraha Chinhat	26.8734	81.031	0.096	0.086	0.04	0.048	0.007	0.01	0.107	0.014	0.001	0.001	BDL	BDL	0.002	BDL
3		Sec-8 Indiranagar	26.8777	81.005	0.119	0.051	0.03	0.064	0.017	0.08	0.206	0.031	BDL	0.006	BDL	BDL	BDL	BDL
4		Gomati Nagar	26.8498	81.002	0.097	0.093	0.04	0.065	0.007	0.07	0.144	0.009	BDL	0.012	0.01	0.022	BDL	BDL
5		Engineering College Aliganj	26.9111	80.944	0.151	0.123	0.03	0.042	0.01	0.01	0.124	0.016	BDL	0.007	0.02	BDL	BDL	BDL
6	Zone 2	Kursi Road near Sabji Mnadi	26.9058	80.955	0.114	0.108	0.03	0.057	0.008	0.04	0.143	BDL	BDL	0.012	BDL	0.022	BDL	BDL
7		Kalyanpur	26.9037	80.965	0.118	0.110	0.03	0.054	0.014	0.06	0.106	0.014	BDL	0.014	BDL	BDL	BDL	BDL
8		Vikas Nagar-Sector 3	26.8974	80.960	0.093	0.091	0.04	0.033	0.013	0.03	0.134	BDL	BDL	0.005	BDL	BDL	BDL	BDL
9		Near Purania Crossing	26.8943	80.944	0.064	0.061	0.03	0.036	0.008	0.02	0.086	0.001	BDL	0.002	BDL	0.003	BDL	BDL
10		Triveni Nagar	26.8866	80.931	0.167	0.102	0.08	0.067	0.023	0.06	0.024	0.018	0.001	0.007	BDL	BDL	BDL	BDL
11		CSIR aliganj	26.8856	80.938	0.188	0.161	0.03	0.043	0.022	0.04	0.132	0.019	BDL	0.008	0.01	BDL	BDL	BDL
12		Mandir marg Mahan-agr	26.8816	80.950	0.093	0.057	0.03	0.076	0.012	0.07	0.149	0.043	BDL	0.002	BDL	BDL	BDL	BDL
13	Zone 3	Daliganj	26.8731	80.922	0.052	0.044	0.02	0.033	0.011	0.04	0.168	BDL	0.026	0.006	BDL	BDL	BDL	BDL
14		Thakurganj	26.8701	80.891	0.134	0.087	0.02	0.046	0.013	0.04	0.120	0.014	BDL	0.019	0.01	BDL	BDL	BDL
15		Rajaji puram E-Block	26.8470	80.878	0.041	0.030	0.02	0.032	0.002	0.05	0.168	0.003	BDL	0.012	BDL	BDL	BDL	BDL

Table 2 (continued)

S. no.	Zone	Name of the locations	Lat. in decimal	Long. in decimal	Zn (ppm) I	Zn (ppm) II	Pb (ppm) I	Pb (ppm) II	Cd (ppm) I	Cd (ppm) II	Cr (ppm) I	Cr (ppm) II	Cu (ppm) I	Cu (ppm) II	Mn (ppm) I	Mn (ppm) II	Co (ppm) I	Co (ppm) II
16		Rajaji puram B-Block	26.8389	80.887	0.121	0.074	0.02	0.083	0.015	0.06	0.118	0.023	BDL	0.018	BDL	BDL	BDL	BDL
17	Zone 4	Bhola Khera Kanpur road	26.8054	80.890	0.085	0.057	0.03	0.092	0.004	0.07	0.027	0.026	BDL	0.013	BDL	BDL	BDL	BDL
18		Power house, LDA colony	26.7864	80.908	0.058	0.050	0.02	0.083	0.003	0.05	0.168	0.027	BDL	0.010	BDL	BDL	BDL	BDL
19		Hindnagar LDA Colony	26.7813	80.898	0.121	0.113	0.04	0.065	0.022	0.01	0.138	0.023	BDL	0.012	BDL	BDL	BDL	BDL
20		Subash Nagar, Telibagh	26.7857	80.942	0.099	0.089	0.04	0.084	0.001	0.06	0.057	0.016	BDL	0.015	0.01	BDL	BDL	BDL
21		Ghosiyana Telibagh	26.7881	80.959	0.134	0.109	0.02	0.088	0.011	0.05	0.107	0.021	BDL	0.014	BDL	BDL	BDL	BDL
22	Zone 5	IT crossing	26.8718	80.940	0.17	0.152	0.04	0.046	0.019	0.05	0.136	0.028	0.003	0.003	BDL	BDL	BDL	BDL
23		SCERT, Nishat-ganj	26.8652	80.955	0.097	0.095	0.04	0.057	0.005	0.04	0.102	0.02	BDL	0.015	BDL	BDL	BDL	BDL
24		Dalibagh	26.8504	80.960	0.097	0.052	0.06	0.077	0.005	0.06	0.123	0.028	BDL	0.007	BDL	BDL	BDL	BDL
25		Ganesh-ganj, Amin-abad	26.8415	80.924	0.099	0.091	0.03	0.141	0.023	0.05	0.111	0.026	BDL	0.014	BDL	0.026	BDL	BDL

Table 3 Standards of permissible limits of various parameters of rainwater (Anonymous, WHO 2006)

Heavy metals	WHO standards
Zinc (ppm)	3
Lead (ppm)	0.01
Cadmium (ppm)	0.003
Chromium (ppm)	0.05
Manganese (ppm)	0.5
Copper (ppm)	2.0
Cobalt (ppm)	0.0002

environment are a result of human activities. Due to the application of lead in gasoline, an unnatural lead cycle has taken place. In automobile engines, lead is burned, so that lead salts (chlorides, bromides, oxides) originate. These lead salts enter the environment through exhausts of automobiles. The larger particles will drop to the ground immediately and pollute soils or surface waters, the smaller particles will travel long distances through air and remain in the atmosphere. Part of this lead will fall back on earth when it is raining. Beside this, lead enters in drinking water primarily as a result of corrosion or the wearing away of materials that are in the water supply system and household plumbing. These materials can include lead-based solder, brass- and chrome-plated faucets.

Lead fulfils no essential function in the human body; it can prove to be a serious health hazard if taken through food, air or water. It can cause several unwanted effects, such as disruption of the biosynthesis of haemoglobin and anaemia, a rise in blood pressure, kidney damage, miscarriages and subtle abortions, disruption of nervous systems, brain damage, declined fertility of men through sperm damage,

diminished learning abilities of children and behavioural disruptions of children, such as aggression, impulsive behaviour and hyperactivity. Lead can enter a foetus through the placenta of the mother. Because of these issues, it can cause serious damage to the nervous system and the brains of unborn children (www.lenntech.com).

In the water sample of first rainfall, Lead was found in all samples. The values range from 0.017 to 0.078 ppm. Comparatively, in second rainfall water samples, the value of lead slightly increased than first rainwater values. The values range between 0.03 and 0.14 ppm. All the samples show the values more than a permissible limit (0.01 ppm) define by WHO, which can be harmful for human health (Fig. 5).

Cadmium (Cd)

A limited concentration of cadmium is found in water bodies naturally through weathering of rocks and the rest of the cadmium is released through human activities, such as manufacturing plants and industries. Another important source of cadmium emission is during the production of artificial phosphate fertilizers. Part of the cadmium ends up in the soil after the fertilizer is applied on farmland and the rest of the cadmium ends up in surface waters due to waste from fertilizer production plants (www.lenntech.com). It is a by-product of zinc production plant and one of the most toxic elements to which man can be exposed through inhalation, contaminated food and water. Once absorbed, Cd is efficiently retained in the human body, in which it gets accumulated for life. Cd is primarily toxic to the kidney, especially to the proximal tubular cells which is the main site for accumulation. Cd can also cause bone demineralization, either through direct bone damage or indirectly as a result of renal dysfunction (Bertrand et al. 2008).
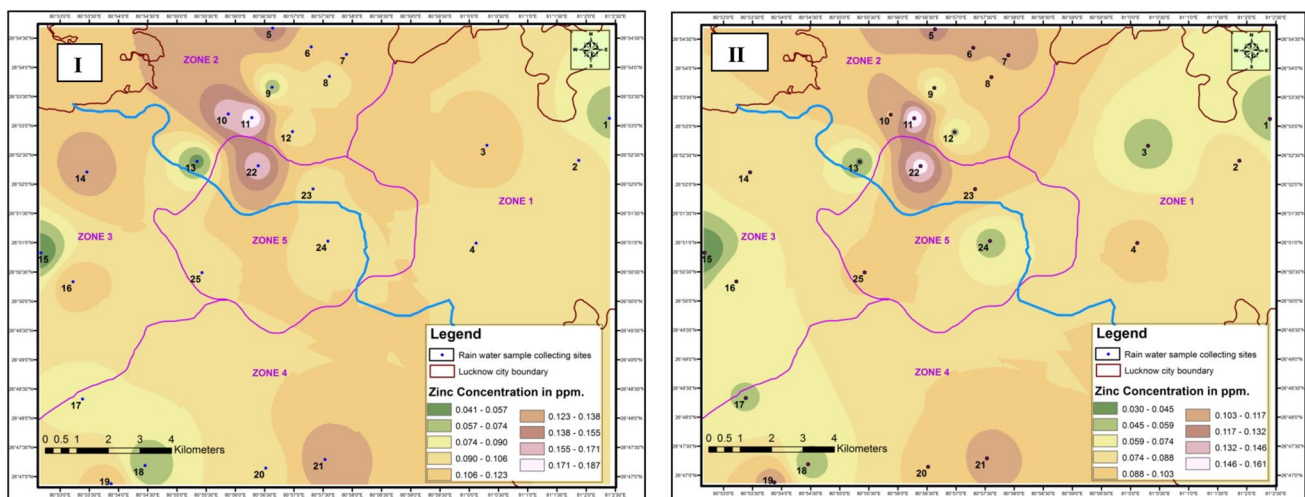
Fig. 4 Contour map of zinc values at five zones of Lucknow city during first (I) rainfall and second(II) rainfall
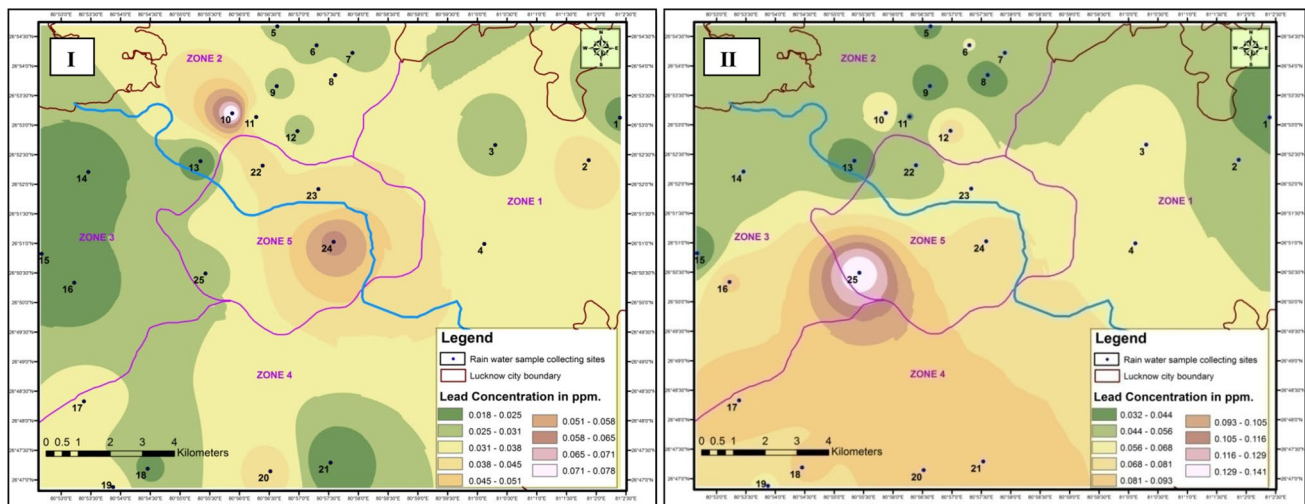
Fig. 5 Contour Map of lead values at five zones of Lucknow city during first (I) and second (II) rainfall

In the water sample of first rainfall, Cadmium was found in all samples, value ranges between 0.001 and 0.022 ppm. Comparatively, in second rainfall water samples, the value of cadmium shows slight enhancement than first rainwater values. The value varying from 0.07 to 0.01 ppm. According to WHO specification, all the water samples show a higher concentration beyond the permissible limit (0.003 ppm). This value can be harmful for human health (Fig. 6).

Chromium (Cr)

Chromium compounds are present in water samples only in trace amounts. Chromium is found in two forms either in anionic trivalent or hexavalent. Chromium has a large influence upon drinking water quality. It cannot normally be found in groundwater and surface water in considerable concentrations. The concentration increases due to discharge of waste water into the surface water bodies and over ground through various industries. The estimated safe and adequate daily dietary intake range for chromium varies from 50 to 200 micrograms (Anonymous, National Research Council, Food and Nutrition Board, Recommended Dietary Allowances, 1989). Among the two form of chromium, the trivalent form is non-toxic but hexavalent form is very toxic for human health. Trivalent chromium is an essential trace element for humans. Together with insulin, it removes glucose from blood, and it also plays a vital role in fat metabolism. Chromium deficits may enhance diabetes symptoms. Chromium can also be found in RNA.
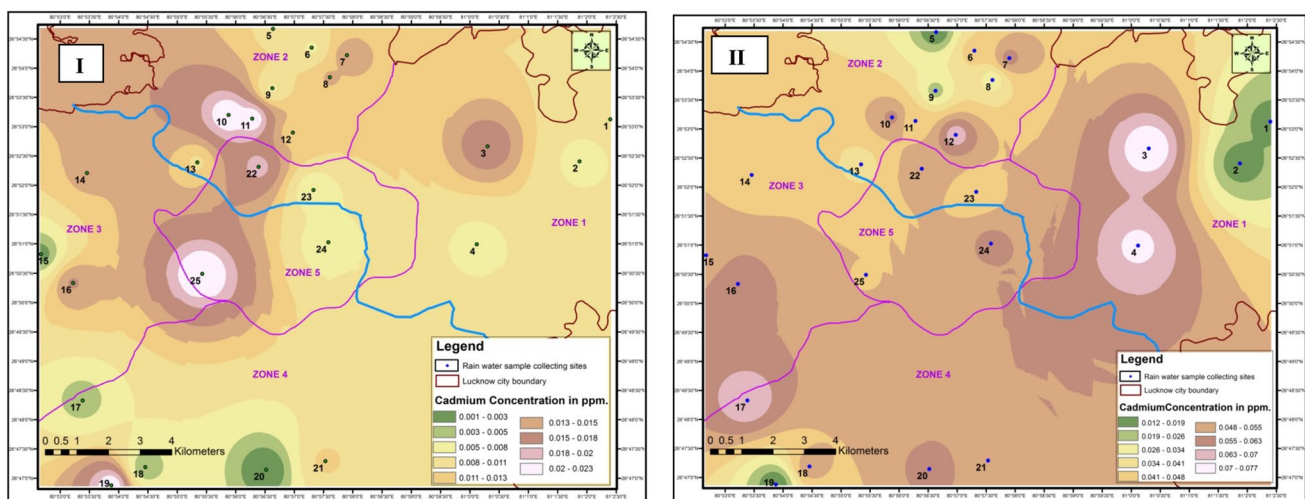

Fig. 6 Contour map of cadmium values at five zones of Lucknow city during first (I) rainfall and second(II) rainfall

Trivalent chromium (III) toxicity is unlikely at least when it is taken up through food and drinking water. It may even improve health and cure neuropathy and encephalopathy. Hexavalent chromium (VI) is known for its negative health and environmental impact, and its extreme toxicity. It causes allergic and asthmatic reactions, is carcinogenic and is 1000 times as toxic as trivalent chromium. Health effects related to hexavalent chromium exposure include diarrhoea, stomach and intestinal bleedings, cramps, and liver and kidney damage. Hexavalent chromium is mutagenic. Toxic effects may be passed on to children through the placenta (www. lenntech.com).

In the water sample of first rainfall, chromium was found in all samples with the value ranging from 0.02 to 0.2 ppm. Comparatively, in second rainfall water samples, the chromium was found in 22 samples out of 25 samples. The value ranges between 0.0009 and 0.04 ppm. It indicates that the concentration of chromium in first rainfall water, except one sample, is high than permissible limit defined by WHO, that values can be harmful for human health. While the second rainfall values come under the permissible limit (Fig. 7).

Copper (Cu)

Copper is a very common substance that occurs naturally in the environment and spreads through the environment in a natural way. On account of human activities such as disposal of waste water that is contaminated with copper to the water bodies such as ponds, bawori, canals, etc. there would be increased concentration of copper. Although copper is a toxic heavy metal, yet it is essential for good health. The recommended daily dose of copper is 1.5–2.5 mg per day by WHO. Copper is incorporated into a variety of proteins and metallo-enzymes which perform essential metabolic functions; the micronutrient is necessary for the proper growth, development and maintenance of bone, connective tissue, brain, heart and many other body organs. Copper is involved in the formation of red blood cells, the absorption and utilization of iron, the metabolism of cholesterol and glucose, release of life sustaining proteins and enzymes. These enzymes in turn produce cellular energy and regulate nerve transmission, blood clotting and oxygen transport. However, exposure to higher doses can be harmful. Long-term exposure to copper dust can irritate our nose, mouth and eyes, and causes headaches, dizziness, nausea, and diarrhoea (Anonymous, Agency for Toxic Substances and Disease Registry, 2004).

In the water sample of first rainfall, copper was found only in 4 samples out of 25 samples, values range between 0.0006 and 0.0268 ppm. Comparatively, in second rainfall water samples, the copper was found in all samples. It is observed that, the value of copper has increased than first rainwater values. The values range from 0.0008 to 0.0194 ppm. This result shows that all the values come under prescribed standards by WHO, but the values are too low, therefore, all the samples are deficient in copper, which can be harmful for human health (Fig. 8).

Manganese (Mn)

Manganese compounds exist naturally in the environment as solid compounds in the soil and as dissolved particles in the water. Humans enhance manganese concentrations in the air by industrial activities and through burning fossil fuels. Manganese that derives from human sources can also enter surface water, groundwater and sewage water. Manganese is an essential nutrient involved in the formation of bone besides its active role in amino acid, cholesterol, and
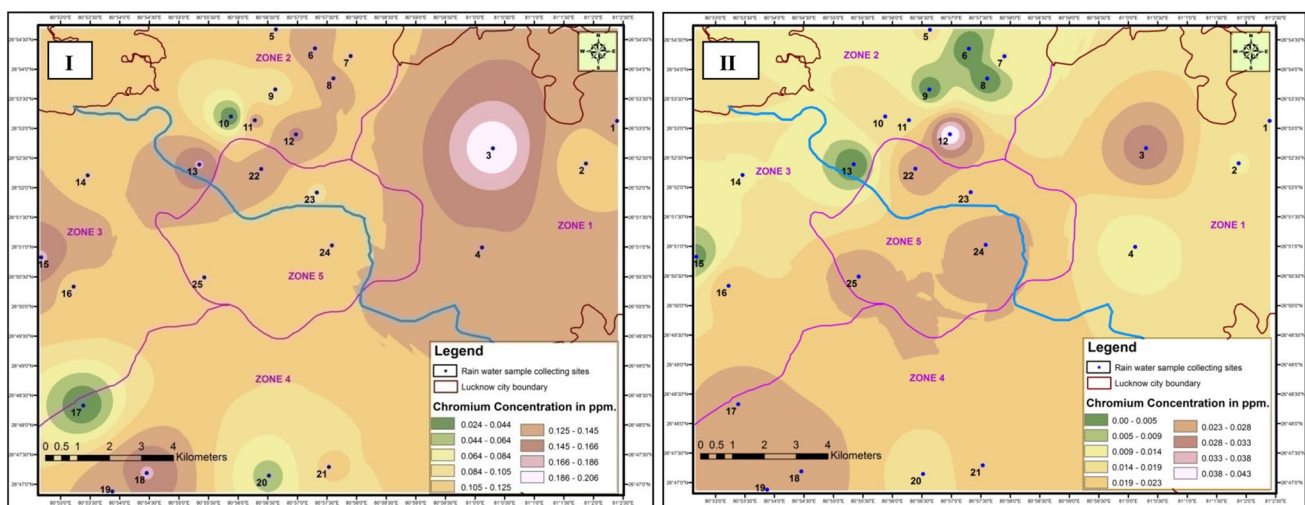

Fig. 7 Contour Map of chromium values at five zones of Lucknow city during first (I) and second (II) rainfall
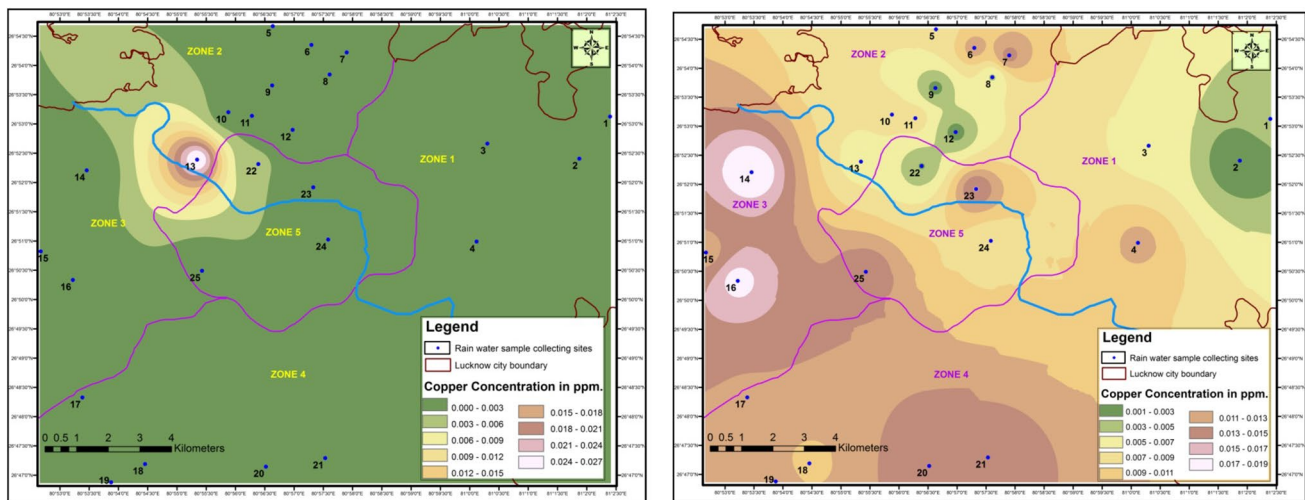
Fig. 8 Contour map of copper values at five zones of Lucknow city during first (I) rainfall and second(II) rainfall

carbohydrate metabolism. The recommended daily intake dose of manganese is 5 mg/day. The deficiency of manganese can also cause adverse health effects such as skin problems, changes of hair colour, glucose intolerance, neurological symptoms, etc.

On the other hand, the overdose of manganese severely affects the respiratory tract and brain. Symptoms of manganese poisoning are hallucinations, forgetfulness and nerve damage. Manganese can also cause Parkinson, lung embolism and bronchitis. When men are exposed to manganese for a longer period of time they may become impotent. A syndrome that is caused by Manganese has symptoms such as schizophrenia, dullness, weak muscles, headaches and insomnia (www.lenntech.com).

In the water sample of first rainfall, manganese was found only in 6 samples out of 25 samples. The concentration varies from 0.001 to 0.02 ppm. Comparatively, in second rainfall water samples, the manganese was found in only four samples. It is observed that the value of manganese has slightly increased than first rainwater values. The concentration ranges between 0.003 and 0.025 ppm. According to WHO specification, all the water samples show the concentration below permissible limit (0.5 ppm). The result shows that there is deficiency of manganese in the samples, which can be harmful for human health (Fig. 9).
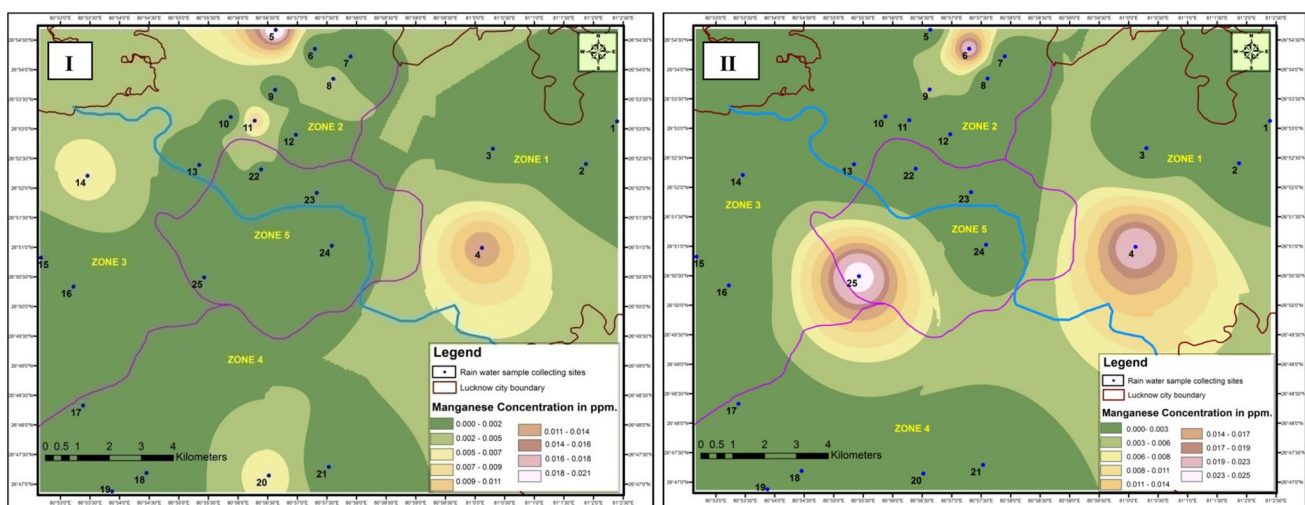

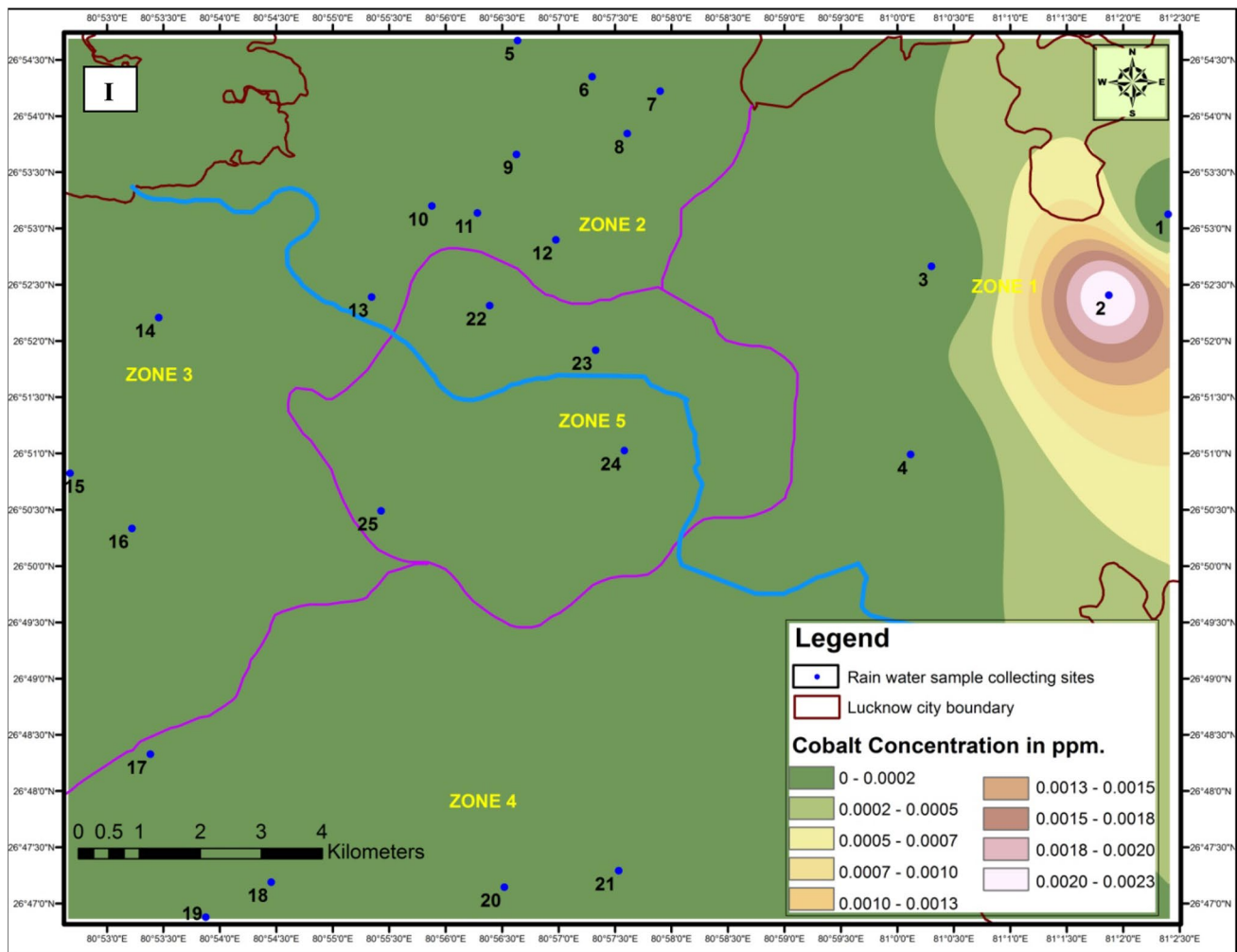**Fig. 9** Contour Map of manganese values at five zones of Lucknow city during first (I) and second (II) rainfall

Fig. 10 Contour map of cobalt values at five zones of Lucknow city during first (I) rainfall

Cobalt (Co)

Cobalt may enter the environment from both natural sources and human activities. Cobalt occurs naturally in soil, rock, air, water, plants, and animals. It may enter air and water, and settle on land from windblown dust, seawater spray, volcanic eruptions and forest fires and may additionally get into surface water from runoff and leaching when rainwater washes through soil and rock containing cobalt. Cobalt has both beneficial and harmful effects on human health. Cobalt is beneficial for humans because it is part of vitamin B_{12} which is essential to maintain human health. Cobalt (0.16–1.0 mg/kg of body weight) has also been used as a treatment for anaemia (less than normal number of red blood cells), including in pregnant women because it causes red blood cells to be produced. Cobalt also increases red blood cell production in healthy people, but only at very high exposure levels. Exposure of humans and animals to average levels of cobalt normally found in the environment is not harmful. When too much cobalt is taken into body, however, harmful health effects can occur. Serious effects on the lungs, including asthma, pneumonia and wheezing have been found in people exposed to 0.005 mg/m$_3$. Nonradioactive cobalt has not been found to cause cancer in humans or in animals following exposure in the food or water. Cancer has been shown to occur in animals who breathed cobalt or when cobalt was placed directly into the muscle or under the skin (Anonymous, Agency for Toxic Substances and Disease Registry, 2004).

In the water sample of first rainfall, cobalt was found only in 1 sample out of 25 samples, value is 0.02 ppm, which is beyond the permissible limit (0.0002 ppm). Comparatively, in second rainfall water, none of the samples show the cobalt concentration (Fig. 10).

Table 4 Mean values of different heavy metals of rainwater samples collected from five zones of Lucknow city (*ppm* parts per million or mg/l, *BDL* below detection limit)

S. no.	Parameters	Mean values of first rainwater (5th July, 2012)	Mean values of second rainwater (9th July, 2012)	Standard values (ppm)
1	Zinc	0.122	0.085	3
2	Lead	0.033	0.062	0.01
3	Cadmium	0.011	0.046	0.003
4	Chromium	0.121	0.017	0.05
5	Copper	0.001	0.01	2.0
6	Cobalt	0.0001	BDL	0.0002
7	Manganese	0.002	0.003	0.5

Conclusions

The present study reveals the concentration of heavy metals in the rainwater sample of the Lucknow city. The mean values of different parameters are generally within the permissible limits (Table 4).

The heavy metal concentrations were found in both first and second rainfall water samples in all zones of Lucknow city. The concentration of chromium, cadmium and lead were found to be sufficiently high in several samples. These heavy metals show the concentration above the permissible limit as set by WHO, which can cause various adverse health impacts. However, some parameters like zinc, copper, cobalt and manganese are present in very low concentrations, which can also create health problems as these heavy metals are essential for the proper development and metabolism of the human body.

It is, therefore, concluded that the rain water can be an important natural resource of fresh water, but as the result reveals that some parameters deviates from the standards for drinking water. Therefore, it is recommended to treat the rainwater before using it for potable purposes. Whether it is removal of certain toxic elements or addition of essential elements, both should be taken care of.

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