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Seasonal Variation in Physicochemical Parameters and Heavy Metals in Water of Upper Lake of Bhopal

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Abstract Heavy metal pollution of fresh water is the single most important environmental threat to the future. Upper Lake is a freshwater lake, which is the major source of drinking water in the city of Bhopal, the capital city of M.P., the central province of India, but due to anthropogenic activities this lake is being polluted. During the investigation heavy metals and physicochemical parameters were analyzed to determine the water quality seasonally in the year of 2006 and 2007. All the physicochemical parameters except DO (6.50–6.97 mg l^{-1}), Free CO_2 (0.8–1.6 mg l^{-1}) and BOD (5.47–6.85 mg l^{-1}) were below the prescribed limit as recommended by Bureau of Indian Standards (BIS) for drinking water standards. In case of heavy metals, Ni (0.173–0.253 mg l^{-1}) and Cr (0.047–0.087 mg l^{-1}) were found beyond the prescribed limits (0.02 and 0.05 mg l^{-1}, respectively), whereas Pb (0.057–0.087 mg l^{-1}), Cu (0.016–0.020 mg l^{-1}) and Hg (0.0006–0.0011 mg l^{-1}) were within the safe limit. This study reveals that water of upper lake is partially polluted with heavy metals. It is recommended that strict vigilance and constant monitoring are needed to maintain water quality of the lake, which is a major source of potable water for the Bhopal city.

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Water has a unique place among all the planet's renewable resources (Kumar et al. 2005). It is the most precious natural resource (Nalina and Puttaiah 2006), needed for all living beings for their existence (Ekhaisi and Anayasi 2005). It is beneficial for the development and maintenance of the dynamics of every ramification of society (Asonye et al. 2007). But due to man's activities water pollution is increasing and water quality of several water bodies has deteriorated. In last decade, due to increased environmental pollution the importance of monitoring the build-up of some heavy metals is becoming increasingly important (Dundar and Altundag 2007). Heavy metals are common pollutants which are distributed in aquatic environment. There are some sources from which water bodies are getting polluted through heavy metals. They may occur due to industrial wastes (Kambole 2002; Jindal and Kaur 2000) anthropogenic wastes (Sambyal et al. 2004; Wepener et al. 2001) and agricultural wastes (Shrivastava et al. 2001). Physico-chemical parameters play an important role to determine the water quality. Physico-chemical parameters show the relation with heavy metals like higher amount of heavy metals is associated with depletion of oxygen demand in water. Heavy metals are one of the most toxic forms of aquatic pollution (Laws 2000). Some of these are essential for living organisms, such as Cu and Zn, however, some others like Pb, Cd, Al, etc. are toxic to living organisms (Fatoki et al. 2002). Heavy metals are integral components of drinking water standards in ascertaining the quality of water for drinking purpose (Waqar and Hasan 2006).

Upper Lake is one of the largest fresh water lakes of India. Upper lake is a shallow tropical lake located between Longitude 77° 18′ to 77° 23′E and Latitude 23° 12′ to 23° 16′N at the heart of Bhopal, the capital city of Madhya Pradesh, a central province of India. This city has a sub-tropical moderate climate where the temperature ranges 07° to 45°C. Its catchments area is 361 km^2 and water spread area is 31 km^2 (Magarade et al. 2006; Dixit et al. 2005). Its water is used for recreation and fisheries and also used as potable water, which is supplied to 40% population of Bhopal city. This lake is anthropogenically polluted through some sources like flow of untreated sewage, dumping of municipal wastes, addition of organic and inorganic material through idol and tazzia immersion, addition of detergents used by washermen and hospital waste discharge. In view of this, the study was undertaken to monitor the physico-chemical parameters and heavy metals in water of the Upper lake of Bhopal during 2006 and 2007.

Materials and Methods

Water samples were collected seasonally (summer, rainy and winter) during 2006 and 2007 from Upper Lake of Bhopal. Five sampling stations were selected for sample collection depending on the importance of the extent of anthropogenic interference. For dissolved oxygen estimation, samples were taken by DO bottles, and for heavy metals, samples were taken with the help of rottener sampler. All samples were kept in plastic bottles which were rinsed with 5% nitric acid and distilled water and then washed with lake water before sampling. Parameters like pH was analyzed by pH meter, total hardness were analyzed by standard EDTA titration method, chlorides by using H_2SO_4 titration method and Free CO_2 by using phenolphthalein titration method, while DO and BOD were analyzed with Winkler's method in the laboratory. For heavy metal analysis, all samples were collected and preserved according to standards of APHA (1998). Water samples were digested with 5 ml of diacid mixture (HNO_3 : $HCLO_4$ :: 9:4) on a hot plate and filtered by Whatman no. 42 filter paper and made up volume to 50 ml by double distilled water for analysis of five heavy metal, namely, Pb, Ni, Cu, Cr and Hg using atomic absorption spectrophotometer (Perkin Elmer 2380; Perkin Elmer corporation, Norwalk, USA).

The location of the five stations along with the lake is shown in Fig. 1. These sampling stations were chosen based on the human activities, which affect the water quality of lake. In the present study these stations were selected for taking water samples seasonally during the year 2006 and 2007. Station 1 is Betagaon, which is situated near Bairagarh and polluted by domestic and sewage waste; Station 2 is Halalpura, which is polluted seasonally by Durga and Ganesh idol immersion; Station 3 is Khanugaon which is polluted by motor parts waste, tazzia immersion, hospital waste and sewage waste; Station 4 is opposite to Kamla Park which is polluted by pilgrim and

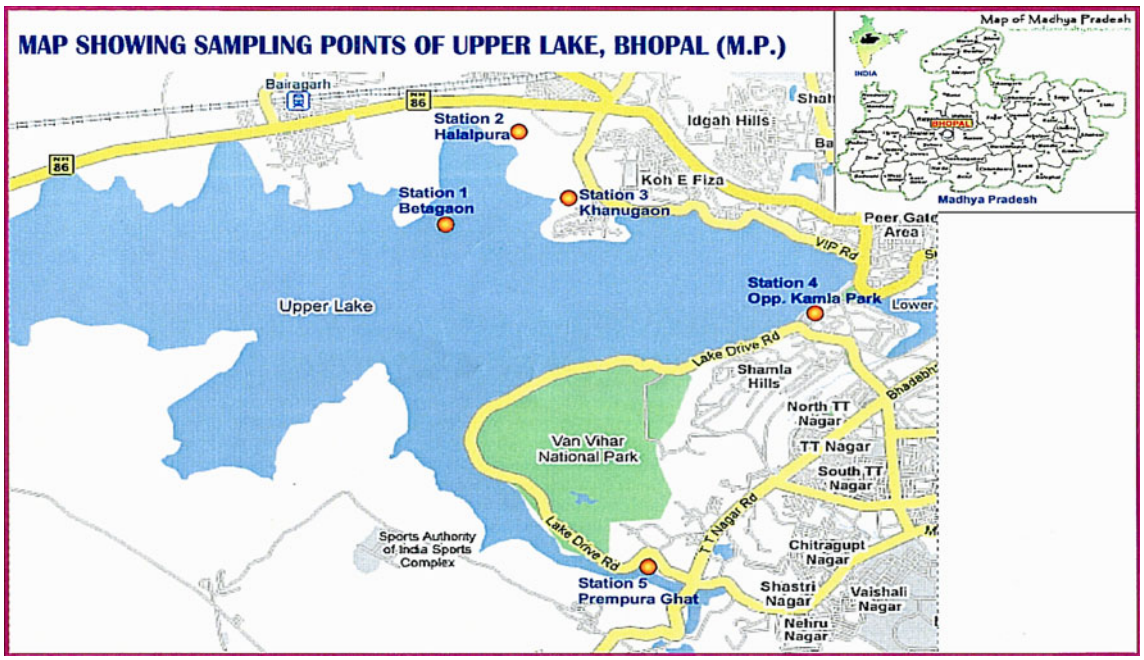

Fig. 1 Showing map of upper lake

human activities like washing and bathing, and the last station is Prempura ghat, which is also polluted by idol immersion of Godess Durga and Lord Ganesha.

Results and Discussion

Spatial distribution of pH, chlorides, total hardness, DO, BOD and free CO_2 were analyzed in water of upper Lake of Bhopal and the average of seasonal data of these parameters of the year 2006 and 2007 are given in the (Table 1 and Fig. 2a–f). pH indicates the acidic and alkaline status of water (Alam et al. 2007). In this investigation it was observed that the mean value of pH ranged from 7.1 ± 0.4 to 7.8 ± 0.6 (Table 1). These values are close to those reported by Ayoade et al. (2006) in two lakes of Nigeria and fluctuation in pH was reported by Rim-Rukeh et al. (2006). Standard BIS (1991) value for pH for drinking purpose is 6.5–8.5 and in the respect, pH was found under the permissible limit. Highest pH has recoded in winter during the study period of 2006 and 2007 with the comparison of other seasons (Fig. 2a) slightly basic nature of water was due to the presence of alkaline salt in sewage being drained into the lake.

Chloride content of water fluctuated at the different stations of the lake. Mean values of chlorides were between 42.6 ± 15.5 and 49.5 ± 20.6 (Table 1). Seasonal data (Fig 2b) shows that during the study period the chloride content was high in summer at station 1 which was probably due to the sewage waste. Standard limit of chlorides for drinking purpose is 250 mg l^{-1} given by BIS (1991). Chlorides were much below in this study which was similar to the result reported by Rai and Shrivastava (2006), but Chaturvedi and Pandey (2006) reported high chlorides. In this study mean values of total hardness ranged between 93.9 ± 15.1 and 123.8 ± 48.8 mg l^{-1} at the different stations (Table 1). As per BIS (1991), prescribed standard limit for total hardness is 300 mg l^{-1} and hence it was within permissible limit. Almost similar kind of results was obtained by Vyas et al. (2006) in upper lake, but Mishra et al. (2008) reported significant increase of total hardness in aquaculture ponds in Orissa. The highest level of total hardness in upper lake was in rainy season at station 3 (Fig. 2c) which may be due the mechanical engineering waste, hospital waste, sewage waste and tazzia immersion. Dissolved oxygen indicates the pollution level of the water. In this analysis mean value of dissolved oxygen ranged between 5.9 ± 0.9 and 6.8 ± 1.6 mg l^{-1} (Table 1). BIS (1991) standard value for dissolved oxygen for drinking purpose is 6 mg l^{-1}. Lower values of dissolved oxygen were found in station 3 and 5. This indicates higher pollution level due to the idol immersion and organic matter. Figure 2d shows the high value of DO at

Table 1 Physico-chemical parameters (mg l^{-1}) of water in 2005 and 2006

Sta.	Parameters											
	PH		Cl		TH		DO		BOD		Free Co2	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
U1	7.4–8.4	7.8 ± 0.435	26.5–58.5	48.51 ± 15.581	77–124	103.91 ± 17.06	5.1–8.9	6.97 ± 1.342	3.5–8.4	5.983 ± 1.673	0–2.8	1.0 ± 1.242
U2	7.1–8.7	7.8 ± 0.625	20.2–72.5	44.2 ± 17.675	87–122	106.75 ± 15.184	3.5–8.4	5.98 ± 1.673	3.0–7.3	5.466 ± 1.419	0–2.2	1.2 ± 0.801
U3	7.1–8.3	7.8 ± 0.495	25.5–80.2	48.116 ± 20.63	20.5–160	93.98 ± 56.51	4.4–8.5	6.83 ± 1.521	4.9–8.4	6.483 ± 1.525	0–2.8	1.6 ± 1.275
U4	7.2–8.2	7.7 ± 0409	27.0–70.0	49.53 ± 16.19	60–150	123.8 ± 34.90	4.3–8.1	6.50 ± 1.401	5.4–8.4	6.85 ± 1.294	0–2.0	0.8 ± 0.769
U5	7.2–8.0	7.7 ± 0.403	21–64.4	42.63 ± 17.57	95–132.5	103.2 ± 48.81	5.5–8.0	6.88 ± 0.996	4.5–9.3	6.76 ± 1.9200	0–2.6	1.2 ± 1.083

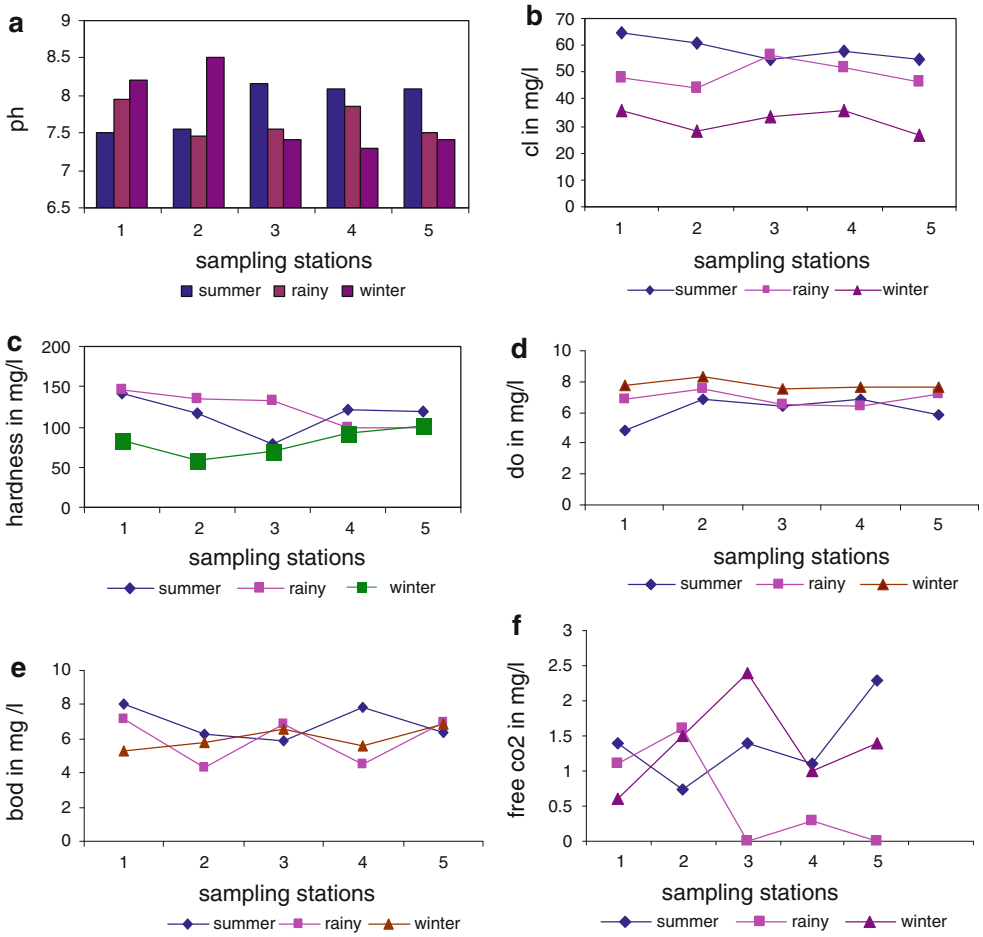

Fig. 2 Seasonal variation in physicochemical parameters at sampling stations

station 4 in summer season due to the favored growth of algae. Increased level of DO was reported by Ayoade et al. (2006); and Vyas et al. (2006) in different lakes. In the case of BOD, BIS (1991) standard for drinking purpose is 2 mg l^{-1}, which is exceeded to a great extent in this investigation. Similarly high amount of BOD was reported by Vyas et al. (2006). Mean values ranged between 5.4 ± 1.419 and 6.8 ± 1.920 mg l^{-1} (Table 1). The greater increase of BOD values in water was found at station 1 and 4 due to organic matter discharge, sewage and domestic waste and anthropogenic activities like bathing, washing, etc. Figure 2e shows that the BOD values were enhanced in summer season due to the biodegradation of organic matter. For Free CO_2, mean values ranged from 0.8 ± 0.769 to 1.2 ± 1.275 (Table 1). The prescribed limit for drinking purpose is 0 mg l^{-1}. In this study, free CO_2 exceeded the permissible limit (Fig. 2f). Similar kind of result was also reported by Rai and Shrivastava (2006). Higher values were observed in station 3 and 5, which were due to pollution caused by idol immersion, tazzia immersion and hospital wastes being dumped.

Heavy metals were found in the water samples of lake, which may be due to such factors as idol immersion, sewage waste, tazzia immersion, hospital wastes, etc. (Table 2). Pb is potentially hazardous to different form of life due to toxicity (Fatoki et al. 2002). The mean concentration of Pb was 0.057 ± 0.03–0.184 ± 0.06 mg l^{-1} (Table 2). According to the BIS (1991), standard value of Pb 0.1 mg l^{-1} and this element was within the permissible limit in this lake. Quite opposite results were reported by Ali and Fisher (2005) and Dumen et al. (2007). High Pb value was recorded in upper lake in winter season at the station 5 (Fig. 3a). This might be due to the idol immersion of Goddess Durga and Lord Ganesha and wastewater drainage of wastes from automobile and other metal industries. Copper is the essential element amongst heavy metals in trace quantities, but in the excess amount it becomes toxic for aquatic life as well as human beings. In the present study, mean values of Cu concentration in upper lake ranged between 0.021 ± 0.005 and 0.038 ± 0.013 mg l^{-1} (Table 2). The higher values of Cu were found in summer season at station 3 (Fig. 3b). It may be due the hospital waste, tazzia immersion, and sewage waste. According to the BIS (1991) standard threshold value of Cu is 0.05 mg l^{-1}, and in this study Cu content was found below the permissible limit. But high Cu

Table 2 Heavy metals (mg l^{-1}) in water in 2005 and 2006

Sta.	Parameters									
	Pb		Cu		Ni		Cr		Hg	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
U1	0.006–0.146	0.076 ± 0.052	0.011–0.030	0.016 ± 0.007	0.162–0.345	0.238 ± 0.072	0.040–0.053	0.047 ± 0.005	0.0004–0.0009	0.0006 ± 0.0002
U2	0.006–0.121	0.057 ± 0.050	0.008–0.027	0.016 ± 0.007	0.101–0.255	0.173 ± 0.056	0.022–0.136	0.087 ± 0.038	0.0012–0.0019	0.0010 ± 0.0003
U3	0.002–0.164	0.087 ± 0.061	0.011–0.035	0.019 ± 0.009	0.141–0.476	0.253 ± 0.116	0.071–0.151	0 .08 ± 0.039	0.0011–0.0015	0.0013 ± 0.0001
U4	0.004–0.094	0.068 ± 0.0.33	0.006–0.053	0.020 ± 0.016	0.121–0.291	0.212 ± 0.071	0.021–0.125	0.070 ± 0.041	0.0004–0.0009	0.0006 ± 0.0002
U5	0.003–0.184	0.084 ± 0.066	0.004–0.041	0.020 ± 0.012	0.160–0.225	0.199 ± 0.024	0.005–0.095	0.047 ± 0.033	0.0010–0.0014	0.0011 ± 0.0001

contents were reported by Mazhar and Dawood (2005) and Dumen et al. (2007). The mean concentration of Ni ranged from 0.173 ± 0.024 to 0.253 ± 0.116 in the present study (Table 2). Relatively higher concentration of Ni was observed in station 3 (Fig. 3c), which may be due to the pollution by motor parts waste, tazzia immersion, sewage waste and domestic waste at this station. The highest level of Ni in summer season might be due to the evaporation effect of water. Ni concentration was above the permissible limit given by BIS (1991). The result was contrary to that reported by Yayintas et al. (2007) and Shrivastava et al. (2001). Cr is found in the two forms, Cr III and VI. But Cr (VI) is toxic due to its highly oxidizing effect; that's why it is considered to be a carcinogenic agent. In this investigation, mean concentrations of Cr was recorded between 0.047 ± 0.005 and 0.087 ± 0.041 mg l^{-1} (Table 2). The highest level of Cr was found in winter season at the station 2 and 5 due to the idol immersion in this season. The BIS (1991) prescribed limit of Cr is 0.05 mg l^{-1} and accordingly Cr was observed above the permissible limit. Similar results were reported by Akubugwowu et al. (2007) in Uburu Salt Lake, Nigeria, whereas contrary results were reported by Lokeshwari and Chandrappa (2006). Hg is a highly toxic metal amongst all heavy metals. In this investigation it was found that mean concentration of Hg ranged between 0.0006 ± 0.0001 and 0.0013 ± 0.0003 mg l^{-1} (Table 2). Figure 3e shows maximum concentration of Hg in winter at the station 2, 3 and 5, which were due to the anthropogenic activities like sewage waste, domestic waste, hospital waste and idol and tazzia immersion. Permissible limit of Hg, which is given by BIS (1991), is 0.001 mg l^{-1} and in this study level of Hg was found within the permissible limit. High amount of Hg was reported by Reddy and Kumar (2001) in Husain Sagar Lake. They observed the mean concentration of Hg 0.689 mg l^{-1} in water samples which was beyond the permissible limit.

The study clearly indicates that some of the physicochemical and heavy metal parameters undertaken to assess the water quality of upper lake were found below the prescribed limit, while some were found above the prescribed limit. During the investigation period of 2006 and 2007 results reveal that upper lake is partially polluted. All physicochemical parameters were below the permissible limit except DO and BOD, while in the case of heavy metals all were within permissible limit except Ni and Cr. On the basis of BIS limit sequence order for the physicochemical parameters was BOD>FreeCO2>DO>TH>Cl> pH and for heavy metals Cr>Ni>Pb>Cu>Hg was found during the investigation. This study reveals that water of lake is partially polluted with some heavy metals. So it is recommended that strict vigilance and constant monitoring are needed to maintain water quality.

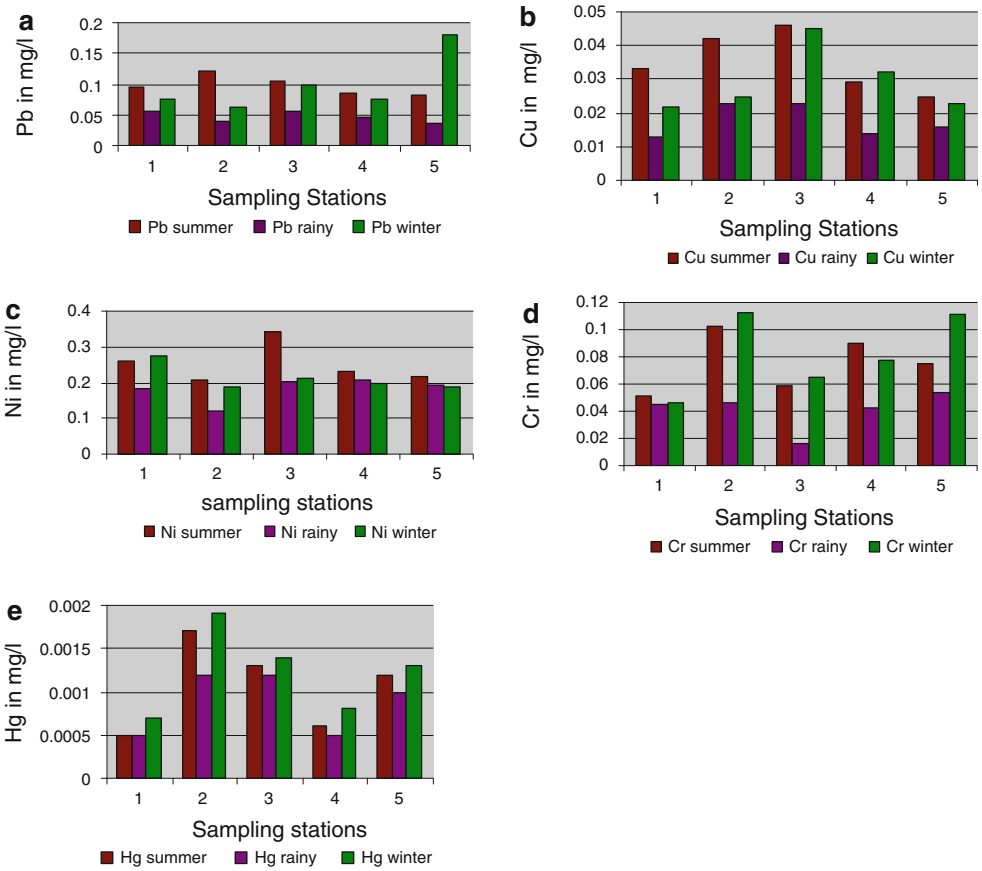

Fig. 3 Seasonal variation of heavy metals in water of upper lake

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