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RESEARCH ARTICLE

FLUORIDE DISTRIBUTION IN GROUNDWATER AND PREVALENCE OF DENTAL FLUOROSIS AMONG SCHOOL CHILDREN IN VILLAGES OF JIND DISTRICT, HARYANA (INDIA)

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ABSTRACT

The present study presents the distribution and health hazards of fluoride contamination and groundwater quality parameters in 23 villages of Jind district, Haryana, India. The purpose of the study was to assess the prevalence of dental fluorosis among the school children in the age group of 5-12 years. 1428 children of different age group were examined and categorized with Dean's Fluorosis Index as recommended by WHO. The groundwater fluoride concentration was in the range 0.2-2.0 mg/l. The villages were categorized as high fluoride level (1.5-2.0 mg/l) and low/ normal fluoride level villages (0.9-1.3mg/l) for comparison. The Community Fluorosis Index (CFI) in high fluoride villages ranged between 0.22-0.29 whereas low/normal fluoride level villages ranged between 0.09-0.21. In both the cases the value of CFI being lower than 0.4 as prescribed by DEAN Index. The prevalence of dental fluorosis varied from 17.10%-25% in the high fluoride level villages and 6.58%-16.38% in the low/normal fluoride level villages. Higher Fluorosis prevalence was found in high age group of 11-12 years and decreased in lower age groups. The findings showed the presence of dental fluorosis in the studied villages and also a proportional increase in prevalence of dental fluorosis with respect to increase in fluoride level in the potable water sources. However, the CFI was on the lower site in all villages.

INTRODUCTION

Fluoride (F^-) is an important aspect of hydro-geochemistry because of its impact on human health, when ingested at specific doses. Fluoride is beneficial for both bone and dental development in human beings. Excessive ingestion of fluoride during the early childhood years may damage tooth-forming cells, leading to a defect in the enamel known as dental fluorosis. Fluoride ion replaces the hydroxyl ions in the apatite structure of enamel, thereby converting it to fluoroapatite, which makes teeth brittle and discolored (Singh *et al*., 2000). It is estimated that around 200 million people from 25 nations in the world, are under the dreadful fate of fluorosis. There are more than 20 developed and developing nations that are endemic for dental fluorosis. India and China are among the worst affected country in the world (Hussain *et al*., 2007). India lies in a geographical fluoride belt, which extends from Turkey up to China and Japan through Iraq, Iran and Afghanistan**.** 85 million tons of fluoride is present on the earth crust and approximately 12 million tons is found in India (Mollert, 1993; WHO, 1994). Recent studies show approximately 62 million people including 6 million children suffer from fluorosis because of consumption of fluoride concentrated water. It is already estimated that 65% of Indian villages are exposed to fluoride risk (UNICEF, 1999). The fluorosis problem was found pronounced in Andhra Pradesh, Punjab, Rajasthan, Haryana, Utter Pradesh and Tamil Nadu (Hussain *et al*., 2000, 2007; Ayoob and Gupta, 2006; Khaiwal and Garg, 2007).

According to WHO (1994), the fluoride concentration in drinking water should be 1.0 mg/l in the area with warm climate and in cooler climate it can increase upto 1.2 mg/l. the differentiation derives from the fact that we perspire more in hot weather and consequently drink more water. USPHS (1962) has set a range of allowable concentrations for fluoride in drinking water for a region depending on its climatic conditions, because the air temperature influences the amount of water consumed and consequently the amount of fluoride ingested. As per Table 1 the maximum allowable concentration for fluoride in drinking water in Indian conditions comes to 1.4 mg/l, whereas Indian standard is 1.5 mg/l fluoride. Haryana is one of the Indian states where endemic fluorosis has been reported as an alarming health problem. Groundwater is the major drinking water source in villages of Haryana. High fluorosis prevalence of 92.7 % was recorded among primary school children of Juai Kalan village Bhiwani District of Haryana (Dahiya *et al*., 2000). The quality of groundwater has been investigated in some other parts of Haryana including Hisar, Jind region, Faridabad and Rohtak. Khaiwal and Garg (2006) reported relatively high ranges of fluoride concentration i.e. 0.03-16.6 mg/l in groundwater of Hisar region of Haryana. The present study was undertaken in 23 villages of Jind district where no study has been done. The study presents the fluoride concentration in the drinking water, CFI (Community Fluorosis Index) and prevalence of dental fluorosis among school children in study area.

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MATERIALS AND METHODS

Study Area

Jind district (29°03', 29°51' N and 75°53', 76°47' E) lies in tropical steppe, semi-arid and hot zone of Haryana (India). The average rainfall over the district as a whole is 515mm, but in monsoon season it goes up to 70cm. The rainfall is mainly concentrated during the rainy season, which is inadequate and uncertain. The mean maximum temperature is 41°C in May and June and minimum temperature is 6°C in the month of January (Gupta, 2007). The depth of water level ranges from 3.04 to 21.30 m bgl in Jind district. Due to high temperature during warm season and low rainfall, the consumption of water and consequently the amount of fluoride ingested is very high in the study area. So the maximum allowable fluoride concentration decrease and the chances of Fluorosis increase in the region.

Sample Collection

Different groundwater samples were collected from 23 villages of Jind, Julana and Pillukhera blocks in August 2009 from tube wells and hand pumps. The samples were collected in clean plastic bottles of two liters, properly labeled and brought to the laboratory for further chemical analysis. The collected samples were analyzed for different quality parameters like pH, total hardness, calcium hardness, magnesium hardness, Chloride, Alkalinity, acidity etc. following the standard method given by APHA (1995). pH of the samples was note at the sampling time and remaining parameters were analyzed in laboratory. Fluoride analysis was done by SPANDS method.

Clinical Examination

For collection of data pertaining to evidence, prevalence and severity of dental fluorosis, a survey was conducted with the help of a dentist. Teeth of different children were carefully examined in proper daylight for the examination of dental fluorosis. Following indexes and classification were used in survey to measure the presence and severity of dental fluorosis.

Dean's Fluorosis Index

It was developed in the 1930s by H.T. Dean to assess the prevalence and severity of dental fluorosis. In 1942 Dean introduced the revised version of this fluorosis index. Major criteria for each category are listed below:

Questionable: Slight aberrations in translucency, ranging from a few white flecks to occasional white spots (statistical weight- 0.5).

Very mild: Small opaque paper white areas scattered irregularly or streaked over the tooth surface; involves less than 25 per cent of tooth surface; frequently included in this classification are teeth showing no more than about 1-2 mm of white opacity at tip of summit of cusps, bicusps or second molars (statistical weight- 1).

Mild: White opaque areas more extensive but do not involve as much as 50 per cent of tooth (statistical weight- 2).

Moderate: All enamel surfaces of the teeth affected; surfaces subject to attrition show marked wear; brown stain frequently a disfiguring feature (statistical weight- 3).

Severe: All enamel surfaces affected and hypoplasia so marked that general form of tooth may be affected; major diagnostic sign of this classification is the discrete or confluent pitting; brown stains are widespread; teeth often present a corroded-like appearance (statistical weight- 4).

Community Fluorosis Index (CFI)

This is a method proposed by T.H. Dean in 1935 to calculate the prevalence and severity of dental fluorosis in a group or community. The score assign to n individual is the one which corresponds to the two most severely affected teeth in the month. CFI (Community Fluorosis Index) can be calculated by summing up the scores of individual grades of dental fluorosis as described by Dean and dividing the sum by total sample size.

$$CFI = \frac{\text{Sum of (number of individuals x statistical weight)}}{\text{Number of Individuals examined}}$$

The public health significance is analyzed on the basis of CFI value. The public health significance of CFI value is given below:

CFI value Range	Public health significance
0.0-0.4	Negative
0.4-0.6	Borderline
0.6-1.0	Slight
1.0-2.0	Medium
2.0-3.0	Marked
3.0-4.0	Very Marked

RESULT AND DISCUSSION

Water quality parameters analyzed during the study are summarized in Table 2. All parameters were found in standard range when compared with Indian standards. But dissolved solids, pH and DO were not found in standard range in some villages. pH was found to range from 6.77-7.88. Highest pH was found in Karsola (7.88) and minimum in Pindara (6.77). DO was observed to range between 0.8-3.6 mg/l which is below the permissible range. Minimum dissolved oxygen was found in Amarhedi (0.8 mg/l). Total hardness ranged between 56-960 mg/l above the permissible limit (300mg/l, BIS). Maximum total hardness (967 mg/l) was found in Radhana village and minimum (56 mg/l) in Gatoly village of Julana Block. Calcium concentration was notably low, ranged from 2.4-13.8 mg/l and maximum (13.8 mg/l) was found in Nidana while minimum (2.4 mg/l) in Ludana village of Pillukhera block. Alkalinity expressed as HCO^-_3 was found to range between 142-400 mg/l exceeding permissible limit (200 mg/l, BIS) in some villages. Highest total alkalinity (400 mg/l) was found in Ludana village and minimum (142 mg/l) in Nidani. Chloride concentration was found above permissible limit in some villages viz. Aasan, Gatoly, Radhana, Pindara and Nidana and ranged between 15.23-440.4 mg/l. Minimum chloride concentration was found in Kilazafargarh (15.62 mg/l) and maximum (440.2 mg/l) in Radhana village.

A total dissolved solid was estimated to be 302-2532 mg/l. TDS was found out of permissible limit (500 mg/l, BIS) in all villages except Jaijavanti, Jind City, Karsola, Kilazafargarh and Padana. Highest TDS was found in Pindara (2532 mg/l) and lowest in Karsola (302 mg/l). Nitrate was found in permissible range from 5-40 mg/l. Fluoride concentration was found to range between 0.2-2 mg/l exceeding permissible limit (1.0 mg/l, BIS) in Chabri, Dhigana, Gatoly, Ludana, Nidana, Sadipur, Aasan, Jaijawanti, kilazafargarh, Ramkali, Sindhvi kheda and Taloda villages. All the water quality parameters were found to have positive correlated with fluoride except nitrate and total hardness viz. pH (r= 0.476, P= 0.01), DO (r= 0.154), calcium hardness (r= 257), total alkalinity (r= 0.290), chloride (r= 0.257) and TDS (r= 0.379) as shown in Table 3. Table 4 shows the prevalence of dental fluorosis in children of different age group in high fluoride level villages i.e. Chabri, Dhigana, Gatoly, Ludana, Nidana and Sadipur. A total of 758 school children were screened with Dean's Index for dental fluorosis from these six villages. Dental fluorosis was evidenced in 154 (prevalence= 20.32%) children. Highest prevalence of dental fluorosis (prevalence=25%) was found in higher age group (11-12 years) and found to decrease from higher to lower age group (prevalence= 17% in 5-6 years age group). This indicates that regular and excess intake of fluoride concentrated water and residence for a long time in that area increase the chances of dental fluorosis.

Prevalence of dental fluorosis and community fluorosis index (CFI) values in high fluoride level villages are shown in Table 5. Higher prevalence of dental fluorosis was observed in Dhigana (prevalence= 23.74%) with 2 mg/l fluoride concentration and minimum (prevalence= 18.44%) in Gatoly with 1.6 mg/l fluoride concentration in drinking water. The CFI values of Chabri, Dhigana, Gatoly, Ludana, Nidana and Sadipur (0.23, 0.29, 0.22, 0.22, 0.24 and 0.25 respectively) indicates a 'negative' (CFI scores less than 0.4) public health significance as per Dean's (1946) classification. Statistical analysis showed that there is a positive correlation between fluoride concentration in water and dental fluorosis (r = 0.695) with a fluoride level more than 1.5 mg/l. Table 6 shows the prevalence of dental fluorosis in children of different age group of low/normal fluoride level villages i.e. Aasan, Jaijawanti, kilazafargarh, Ramkali, Sindhvi kheda and Taloda. 670 children were screened for dental fluorosis prevalence from these villages, out of which 71 (prevalence 10.60%) showed evidence of fluorosis. Higher prevalence of dental fluorosis (prevalence= 16.38%) was found in age group of 11-12 years and decrease as the age of the children decrease (prevalence= 6.58% in 5-6 age group). Prevalence of dental fluorosis and

Table 1. USPHS recommendations for maximum allowable fluoride in drinking water

Annual average of maximum daily air temperature (°C)	Recommended fluoride concentration (mg/l)			Maximum allowable fluoride concentration (mg/l)
	Lower	Optimum	Upper	
10-12	0.9	1.2	1.7	2.4
12.1-14.6	0.8	1.1	1.5	2.2
14.7-17.7	0.8	1.0	1.3	2.0
17.8-21.4	0.7	0.9	1.2	1.8
21.5-26.2	0.7	0.8	1.0	1.6
26.3-32.5	0.6	0.7	0.8	1.4

Table 2. Quality parameters and fluoride content in groundwater of different villages

Villages	Station	pH	DO mg/l	TH mg/l	CaH mg/l	TA mg/l	Cl^- mg/l	N µg/l	F mg/l	TDS mg/l
Aasan	S1	7.55	2	660	9.7	230	346.48	5	1.2	1864
	S2	7.12	2	645	9.4	215	346.15	5	1.4	1916
Amarhedi	S1	6.95	0.8	320	5	220	35.5	20	0.8	534
	S2	6.78	0.8	338	5	182	35.5	20	0.6	548
Chabri	S1	7.82	2.4	400	6	270	123.54	5	2	1494
	S2	7.68	2.6	423	6.8	241	125.1	10	2	1435
Dhighana	S1	7.87	2.4	380	5	230	133.7	5	2	1010
	S2	7.81	2.4	380	5.2	212	134.1	5	2	1341
Gatoly	S1	7.67	2.8	56	7.6	246	293.94	40	1.6	1806
	S2	7.46	2.4	110	8.3	243	283	40	1.6	1869
Jaijavanti	S1	7.63	2.4	328	6	194	34.08	40	1.2	426
	S2	7.63	2.4	345	6.4	189	34.64	40	1.2	461
Jind City	S1	6.77	1.6	340	2.8	230	28.4	40	0.2	476
	S2	7	1.8	322	4.5	245	28	40	0.6	506
Karsola	S1	7.88	2.8	300	5.2	274	17.04	5	0.8	302
	S2	7.46	2.8	316	4.8	246	19.4	5	0.6	346
Kharak Ramji	S1	7.12	1.6	404	7	200	62.48	5	0.8	834
	S2	7.2	1.8	440	8.2	224	71.23	10	0.8	857
Kilazafargarh	S1	7.58	3	168	3.6	180	15.62	10	1.2	336
	S2	7.58	3.2	187	4.2	176	15.23	10	1.2	330
Ludana	S1	7.66	1	300	2.4	400	163.4	40	1.6	1620
	S2	7.52	1	312	4.5	400	149.2	40	1.6	1579
Manoharpur	S1	7.2	2.8	820	10	318	184.6	40	0.4	1350
	S2	7.42	2.4	856	8.9	346	184.4	20	0.8	1289
Nidana	S1	7.54	2	540	13.8	260	269.8	5	2	2092
	S2	7.46	2	519	13.4	246	264.5	5	2	2164
Nidani	S1	7.01	2	316	7	142	71	20	0.8	848
	S2	7.1	2	334	8.5	148	59	20	0.8	879
Nirjan	S1	7.66	3.2	380	5.2	180	55.38	40	0.2	832
	S2	7.41	2.4	389	5.7	146	55.43	20	0.4	845
Padana	S1	7.05	1	304	5.8	150	39.76	20	0.8	466
	S2	7.09	1	315	5.3	150	39.57	20	0.8	482
Pillukheda	S1	7.6	1.6	340	5.4	158	99.4	5	0.4	882
	S2	7.46	1.6	352	5.7	146	98.46	5	0.4	891
Pindara	S1	6.88	1.2	520	7.8	240	340	40	0.8	2532
	S2	6.67	1.2	512	7	231	345	20	0.8	2435
Radhana	S1	7.06	2	960	10.6	240	440.2	10	0.8	2322
	S2	7.1	2	967	11	240	424	10	0.6	2278
Ramkali	S1	7.1	2.4	420	9.8	240	113.6	5	0.8	888
	S2	7.16	2.4	435	9.1	246	113.6	5	1	819
Saadipur	S1	7.46	2.8	800	11	196	153.36	40	1.6	1302
	S2	7.54	2.8	824	11	193	153.43	40	1.6	1346
Sindhvi Kheda	S1	6.95	1.2	280	5.6	180	17.04	10	1.2	560
	S2	6.97	1.2	258	5.6	178	17.1	10	1	545
Taloda	S1	7.8	3.6	320	3.2	220	46.86	40	0.8	692
	S2	7.59	2.8	346	4.2	212	46.23	40	1	678
Standard Deviation		0.33	0.71	208.94	2.71	58.22	120.8	14.87	0.52	651.93
Maximum		7.88	3.6	967	13.8	400	440.2	40	2	2532
Minimum		6.67	0.8	56	2.4	142	15.23	5	0.2	302

Note: DO- Dissolved Oxygen, TH- Total Hardness, CaH- Calcium Hardness, TA- Total Alkalinity, Cl^- - Chloride, N- Nitrate, F- Fluoride and TDS- Total Dissolved Solids. Note: S1 and S2 are two different stations from a village.

Table 3. Correlation between different water quality parameters with fluoride

Parameters	DO	TH	CaH	TA	Cl^-	N	F	TDS
pH	0.662**	-0.172	-0.189	0.163	-0.13	0.02	0.476*	-0.089
DO		0.075	0.105	-0.039	-0.064	0.071	0.154	-0.11
TH			0.678**	0.225	0.593**	-0.072	-0.045	0.528**
CaH				0.073	0.657**	-0.225	0.257	0.625**
TA					0.344	0.203	0.29	0.417*
Cl^-						-0.061	0.257	0.950**
N							-0.101	-0.005
F								0.379

** Correlation is significant at the 0.01 level * Correlation is significant at the 0.05 level

Table 4. Prevalence of dental fluorosis in villages with high level of fluorosis (above 1.5 mg/l) according to age group

Age Group	No. of examined student	No. of effected student	Prevalence (%)
5-6	169	30	17.75
6-7	152	26	17.10
7-8	160	30	18.75
9-10	141	34	24.11
11-12	136	34	25.00
Total	758	154	20.32

Table 5. Prevalence of dental fluorosis and community fluorosis index in villages with high level of fluoride (above 1.5 mg/l)

Villages	Fluoride Conc. mg/l	Total Students Examined	Students effected by Fluorosis	Prevalence (%)	Normal	Questionable	Very mild	Mild	Moderate	Severe	CFI
Chabri	2.0	97	20	20.62	77	8	5	5	2	-	0.23
Dhighana	2.0	139	33	23.74	106	15	8	6	3	1	0.29
Gatoly	1.6	141	26	18.44	115	15	4	3	2	2	0.22
Ludana	1.6	158	32	20.25	126	17	8	4	2	1	0.22
Nidana	2.0	74	15	20.27	59	8	3	1	3	-	0.24
Saadipur	1.6	149	28	18.79	121	16	3	3	4	2	0.25

Table 6. Prevalence of dental fluorosis in villages with normal level of fluorosis (0.9-1.3 mg/l) according to age group

Age Group	No. of examined student	No. of effected student	Prevalence (%)
5-6	152	10	06.58
6-7	144	12	08.33
7-8	125	14	11.20
9-10	133	16	12.03
11-12	116	19	16.38
Total	670	71	10.60

Table 7. Prevalence of dental fluorosis and community fluorosis index in villages with normal level of fluoride (0.9-1.3 mg/l).

Villages	Fluoride Conc. mg/l	Total Students Examined	Students effected by Fluorosis	Prevalence (%)	Normal	Questionable	Very mild	Mild	Moderate	Severe	CFI
Aasan	1.3	82	12	14.63	70	4	3	3	2	1	0.21
Jaijawanti	1.2	90	11	12.22	79	5	2	2	2	-	0.16
Kilazafarfarh	1.2	163	20	12.27	143	10	3	4	3	-	0.15
Ramkali	0.9	110	08	07.27	102	3	2	2	1	-	0.09
Sindhvi Kheda	1.1	126	12	09.52	114	4	3	3	2	-	0.13
Taloda	0.9	99	08	08.08	91	3	3	1	1	-	0.09

community fluorosis index (CFI) values in low/normal fluoride level villages are shown in Table 7. Highest prevalence of dental fluorosis (prevalence= 14.63%) was found in Aasan village with 1.3 mg/l and minimum (prevalence= 7.27%) in Ramkali with 0.9 mg/l fluoride in drinking water. Prevalence was found to be increased with increase in fluoride concentration. The CFI values are 0.21, 0.16, 0.15, 0.09, 0.13 and 0.09 in Aasan, Jaijawanti, kilazafargarh, Ramkali, Sindhvi kheda and Taloda villages respectively indicate a 'negative' (CFI scores less than 0.4) public health significance. Statistical analysis showed that there is a positive correlation between fluoride concentration in water and dental fluorosis (r = 0.971) with 0.9-1.3 mg/l fluoride concentration in drinking water. The prevalence of dental fluorosis and community fluorosis index (CFI) was found to range between 18.44%-23.74% prevalence and 0.22-0.29 CFI in high fluoride level villages and 7.27%-14.63% prevalence and 0.09-0.21 CFI in low/normal fluoride level villages. This shows that the chances for dental fluorosis increase with increase in the concentration of fluoride in drinking water. During the present investigation, it has been observed that the prevalence of dental fluorosis has a linear relationship with the increasing age. Similar finding were also recorded in school children of rural school in Haryana (Dahiya *et al.*, 2000). The reason of such trend in prevalence of dental fluorosis is the placental barrier to transfer fluoride to the developing primary teeth where most of the teeth are deciduous in the age group of 5 years and most of the mineralization takes place in the intrauterine phase. This can also be explained by the reason that the period of enamel formation for primary teeth is shorter and hence the exposure to fluoride is shorter, the enamel of primary teeth is thinner than that of permanent teeth and the rapidly growing skeleton of foetus may absorb fluoride at more rapid rate since fluoride is a hard-tissue seeker and is thus less available for primary teeth. On the contrary

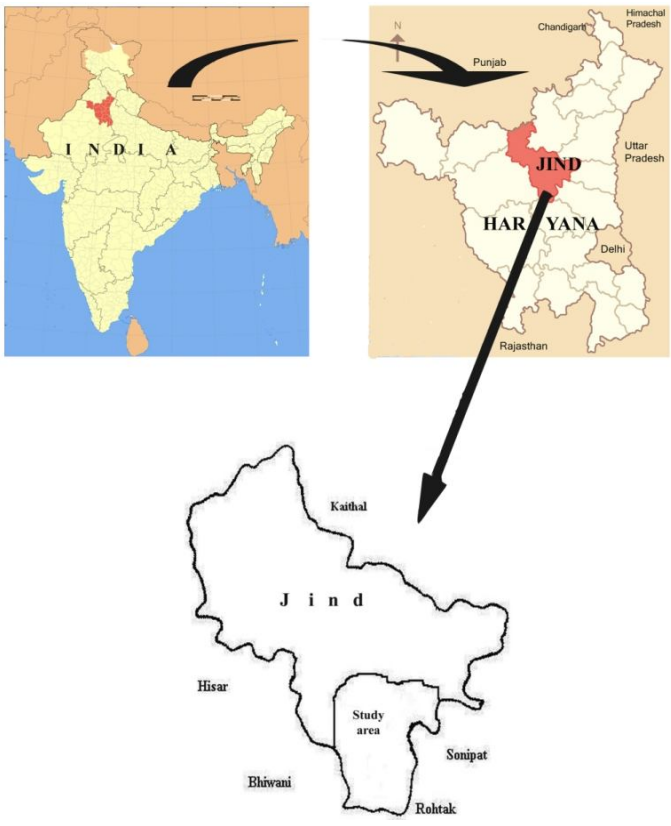

Fig. 1. Sampling location in jind district

greater physical size and activity and kind of nutrient intake lead to higher intake of water, hence a higher prevalence in older age groups (Chauhan *et al.*, 2012).

Conclusion

The study establishes relationship between the water fluoride level in drinking water and prevalence of dental fluorosis and revals that though the prevalence is low but dental fluorosis is public health problem in rural area of Jind District, Haryana. The prevalence varied between 18.44%-23.74% high fluoride level villages and 7.27%-14.63% prevalence in low/normal fluoride level villages. Fluoride was found nearly higher than that of recommended upper limit by WHO and ICMR in some villages. Low cause awareness, poor knowledge about appropriate preventive measures and poor access to safe drinking water could be some factor implicated for this. Thus in this region, there is an instant need to warn the people against the risk of dental fluorosis, and people are advised to adopt some techniques of defluoridation of groundwater before using it for drinking purpose.

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